UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

HP INC., MICROSOFT CORPORATION, DELL INC.,
DELL PRODUCTS LP, LENOVO (UNITED STATES) INC., MOTOROLA MOBILITY LLC
Petitioner

v.

NEODRON LTD.
Patent Owner

Case IPR2020-00459
Patent No. 8,946,574

**DECLARATION OF VIVEK SUBRAMANIAN, PH.D.
IN SUPPORT OF PETITION FOR
INTER PARTES REVIEW OF U.S. PATENT NO. 8,946,574**

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I, Vivek Subramanian, hereby declare as follows:

I. INTRODUCTION

1. I have been retained as an expert witness on behalf of HP Inc., Microsoft Corporation, Dell Inc., Dell Products LP, , Lenovo (United States) Inc., and Motorola Mobility LLC for the above-captioned Petition for *Inter Partes* Review ("IPR") of claims 1-4, 6-11, and 13-15 (the "challenged claims) of U.S. Patent No. 8,946,574 ("the '574 patent"). I am being compensated for my time in connection with this IPR at my standard consulting rate of $650 per hour. My compensation is in no way dependent on the outcome of this matter.

2. I have been asked to provide my opinions regarding whether the challenged claims of the '574 patent are invalid as obvious. In preparing this declaration, I have reviewed the '574 patent, the file history of the '574 patent, and the documents identified in the Petition for this IPR.

3. In forming the opinions expressed in this declaration, I relied upon my education and experience in the relevant field of the art, and have considered the viewpoint of a person having ordinary skill in the relevant art, as of 2011. My opinions directed to the invalidity of the challenged claims are based, at least in part, on the publications identified in the Petition and discussed further below, which I have been instructed by Petitioner's counsel constitute prior art.

II. BACKGROUND AND QUALIFICATIONS

4. My background and expertise that qualify me as an expert in the technical issues in this case are as follows:

5. As indicated on my *Curriculum Vitae* attached as **Exhibit A**, I am currently a Professor of Electrical Engineering and Computer Sciences at the University of California, Berkeley. I am also a Professor of Microengineering at Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland. I am also a founder of Locix, Inc., of San Bruno, California, a privately-held company that develops wireless sensors for industrial and commercial applications.

6. I received a Ph.D. in electrical engineering from Stanford University in 1998. I received my MS, also in electrical engineering from Stanford in 1996, and my BS in Electrical engineering from Louisiana State University, Baton Rouge, in 1994.

7. After completing my PhD, I held multiple jobs simultaneously. First, I was a founder and member of technical staff of Matrix Semiconductor, which developed high density memories. We founded Matrix in 1997, and I maintained a full-time role through 2000, at which point I transitioned to an advisory role. Matrix was acquired by Sandisk in 2005, at which point my affiliation with Matrix ended. Between 1998 and 2000, I was also a visiting research engineer at the University of California, Berkeley, where I performed research on high-

performance transistors. In that same period, I was also a consulting assistant professor at Stanford University, where I performed research on large area and flat panel electronics, among other topics. In 2000, I was offered a professorship at Berkeley, and moved there full time. I received tenure in 2005, and became a full professor in 2011. In 2018, I was awarded with a Chancellor's professorship. In 2018, I also accepted a position at EPFL. I currently live in Switzerland and am on partial leave from Berkeley during the transition.

8. My professional career has been focused largely on semiconductor technology and technology for large area electronics. Of particular relevance to this matter, I have maintained continuous research activities related to touch screens and touch sensor technology for much of my professional career. As a graduate student, I developed materials and processes for implementation of large area touch screens and displays. Once I became a professor, I continued and expanded these activities. I performed research on technology for flexible touch screens, developed low cost processes for fabrication of touch screens, and developed and taught the main undergraduate and graduate courses at Berkeley dealing with touch screen technology, including all aspects including materials, physics of operation, design of circuits for operation, and the underlying manufacturing technology. This specifically included capacitive touch screen

technology, including design of the electrodes, underlying materials and fabrication technology, and design of the associated sensing circuitry.

9. I have authored or co-authored more than 200 publications in journals and major international conference proceedings. A list of my publications is included in my CV, which is attached as Exhibit A.

10. I have previously offered testimony as an expert witness. A list of my prior engagements in which I testified as an expert at trial or by deposition is also included in my CV.

11. Based on my background and experience, as set forth more fully in my CV, I am familiar with the state of the art in the field of touch sensors, including capacitive touch sensors, at least in the mid 2000's to mid 2010's. I am a technical expert in the fields relating to the asserted patents and other related fields, and I remain an active researcher in these fields.

12. Based on my professional experience, I believe I am qualified to testify as an expert on matters related to the patent at issue.

III. UNDERSTANDING OF THE LAW

13. I am not a legal expert and therefore I offer no opinions on the law. However, I have been informed and am aware of legal standards that are relevant to my analysis, as summarized below.

14. I have been informed and understand that an issued patent claim is presumed valid and establishing a patent claim to be unpatentable requires proof by "preponderance of the evidence," which I understand means proof that it is more likely than not that the claim is unpatentable.

15. I have been informed and understand that the first step in an unpatentability analysis involves construing claims, as necessary, to determine their scope. Second, the construed claim language is then compared to the disclosures of the prior art.

16. I have been informed and understand that claims are generally given their ordinary and customary meaning as understood by a POSITA at the time of the alleged invention, in light of the patent specification and prosecution history. I have been informed that claim construction is a matter of law and that the final claim constructions for this proceeding will be determined by the Patent Trial and Appeal Board.

17. I have been informed and understand that a patent claim may be declared unpatentable if it is anticipated by, or rendered obvious in view of, prior art.

18. I have been informed and understand that a patent is to be understood from the perspective of a POSITA. Such an individual is considered to possess normal skills and knowledge in a particular technical field (as opposed to being a

genius). I have been informed and understand that in considering what the claims of a patent require, what was known prior to that patent, what a prior art reference discloses, and whether an invention is obvious or not, one must use the perspective of such a person of ordinary skill in the art.

19. I have been informed and understand that a patent claim is obvious under 35 U.S.C. § 103, and therefore unpatentable, if the claimed subject matter, as a whole, would have been obvious to a person of ordinary skill in the art as of the priority date of the patent based on one or more prior art references and/or the knowledge of one of ordinary skill in the art.

20. I have been informed and understand that an obviousness analysis must consider (1) the scope and content of the prior art, (2) the differences between the claims and the prior art, (3) the level of ordinary skill in the pertinent art, and (4) secondary considerations, if any, of non-obviousness (such as unexpected results, commercial success, long felt but unmet need, failure of others, copying by others, and skepticism of experts).

21. I have been informed and understand that a single prior art reference can render a patent claim obvious under 35 U.S.C. § 103 if any differences between that reference and the claims would have been obvious to a person of ordinary skill in the art. Alternatively, I have been informed and understand that a prior art reference may be combined with other references to disclose each

element of the invention under 35 U.S.C. § 103. Thus, the teachings of two or more references may be combined in the same way as disclosed in the claims, if such a combination would have been obvious to one having ordinary skill in the art. I have been informed and understand that a reference may also be combined with the knowledge of a person of ordinary skill in the art, and that this knowledge may be used to combine multiple references. I have further been informed and understand that a person of ordinary skill in the art is presumed to know the relevant prior art. I have been informed and understand that the obviousness analysis may take into account the inferences and creative steps that a person of ordinary skill in the art would employ.

22. In determining whether a prior art reference would have been combined with other prior art or other information known to a person of ordinary skill in the art, I have been informed and understand that the following principles may be considered:

a. whether the references to be combined involve non-analogous art;

b. whether the references to be combined are in different fields of endeavor than the alleged invention in the Patent;

c. whether the references to be combined are reasonably pertinent to the problems to which the inventions of the Patent are directed;

d. whether the combination is of familiar elements according to known methods that yields predictable results;

e. whether a combination involves the substitution of one known element for another that yields predictable results;

f. whether the combination involves the use of a known technique to improve similar items or methods in the same way that yields predictable results;

g. whether the combination involves the application of a known technique to a prior art reference that is ready for improvement, to yield predictable results; h. whether the combination is "obvious to try";

i. whether the combination involves the known work in one field of endeavor prompting variations of it for use in either the same field or a different one based on design incentives or other market forces, where the variations are predictable to a person of ordinary skill in the art;

j. whether there is some teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill in the art to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed invention;

k. whether the combination requires modifications that render the prior art unsatisfactory for its intended use;

l. whether the combination requires modifications that change the principle of operation of the reference;

m. whether the combination is reasonably expected to be a success; and

n. whether the combination possesses the requisite degree of predictability at the time the invention was made.

23. I have been informed and understand that in determining whether a combination of prior art references renders a claim obvious, it is helpful to consider whether there is some teaching, suggestion, or motivation to combine the references and a reasonable expectation of success in doing so. I understand, however, that a teaching, suggestion, or motivation to combine is not required.

IV. MATERIALS CONSIDERED FOR THIS DECLARATION

24. In addition to my general knowledge, education, and experience, I considered the ’574 patent, its file history, the references cited by the ’574 patent, and the materials discussed in this declaration and the materials listed as exhibits in this IPR, in forming my opinions.

V. SUMMARY OF OPINIONS

25. Based on my review of the ’574 patent and its prosecution history, the other materials I have considered, and my knowledge and experience, my opinions are as follows:

- Claims 1-4, 6-11, and 13-15 of the ’574 patent are obvious over the combination of Hsu and Mozdzyn
- Claims 1-4, 6-11, and 13-15 of the ’574 patent are obvious over the combination of Hsu and Philipp
- Claims 1-3, 7-10, and 14-15 of the ’574 patent are obvious over the combination of Hsu and Chang
- Claims 4, 6, 11, and 13 of the ’574 patent are obvious over the combination of Hsu, Chang and Frey

VI. OVERVIEW OF THE ’574 PATENT

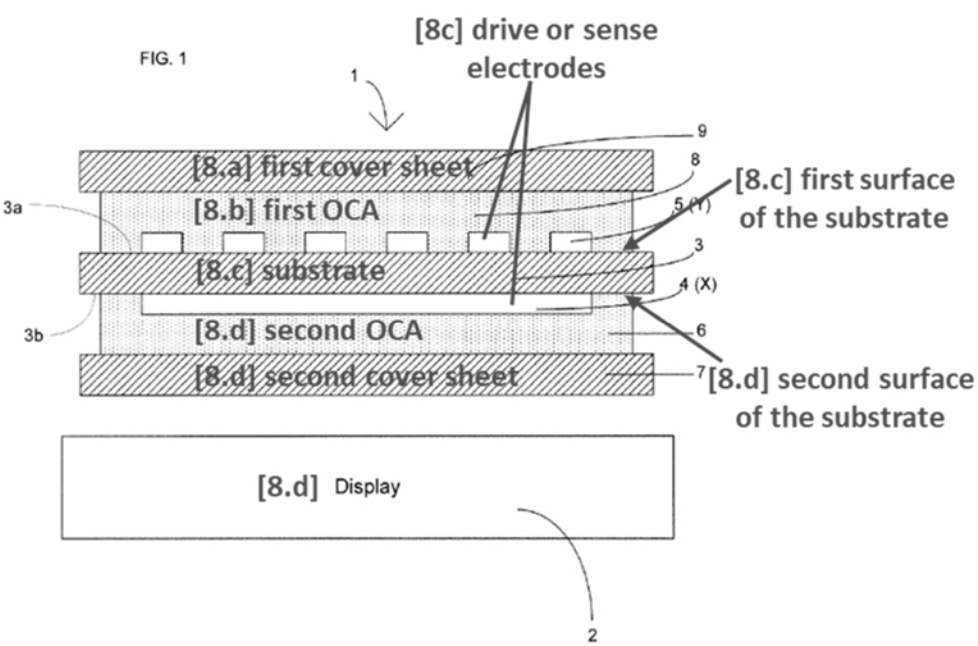
26. The ’574 patent generally relates to touch sensors. EX1001, 1:10. The title of the ’574 patent is “Two Layer Sensor Stack,” but as indicated in the’574 patent’s “Background” section, touch screens in mutual-capacitance configurations with two layers of overlapping electrodes separated by a dielectric layer were well known. EX1001, 1:37-42.

27. As discussed above, the independent claims of the ’574 patent are directed to general features of a touchscreen in a mutual capacitance configuration whereby the distinguishing feature advocated by the Applicant in the prosecution history was that “a portion of the second cover sheet is positioned between the second surface of the substrate and the display” as recited in the independent

claims. EX1001, 15:10-26 and 16:14-27, EX1003, 56-59. Representative independent claim 8 is as follows:

> [8.pre] A device comprising:
>
> [8.a] a first cover sheet;
>
> [8.b] a first optically clear adhesive layer (OCA) between the first cover sheet and a substrate;
>
> [8.c] the substrate, with drive or sense electrodes of a touch sensor disposed on a first surface and a second surface of the substrate, the first surface being opposite the second surface, the drive or sense electrodes being made of a conductive mesh conductive material comprising metal;
>
> [8.d] a display separated from the second surface of the substrate by a second OCA and a second cover sheet ***such that at least a portion of the second cover sheet is positioned between the second surface of the substrate and the display***; and
>
> [8.e] one or more computer-readable non-transitory storage media embodying logic that is configured when executed to control the touch sensor.

Annotated Figure 1 is illustrated below and mapped to representative independent claim 8:



VII. LEVEL OF ORDINARY SKILL IN THE PERTINENT ART

28. A person of ordinary skill in the art at the time of the ’574 patent’s earliest claimed priority date (a “POSITA”) would have had a bachelor’s degree in electrical engineering, computer engineering, computer science, or a related field, and at least two years of experience in the research, design, development and/or testing of touch sensors or the equivalent, with additional education substituting for experience and vice-versa.

VIII. STATE OF THE ART

A. Mutual Capacitance Touch Screens

29. Prior to the earliest priority date claimed by the ’574 patent, touch screens with mutual-capacitance configurations in which sensing nodes, or sensors, formed by the intersections of one set of electrodes arranged in a first direction (*e.g.*, a row direction) and driven by a drive circuit, with a second set of electrodes arranged in a second direction (*e.g.*, a column direction) and connected to a sensing circuit, were well-known in the art as evidenced by Fig. 1 of EX1009 reproduced below.

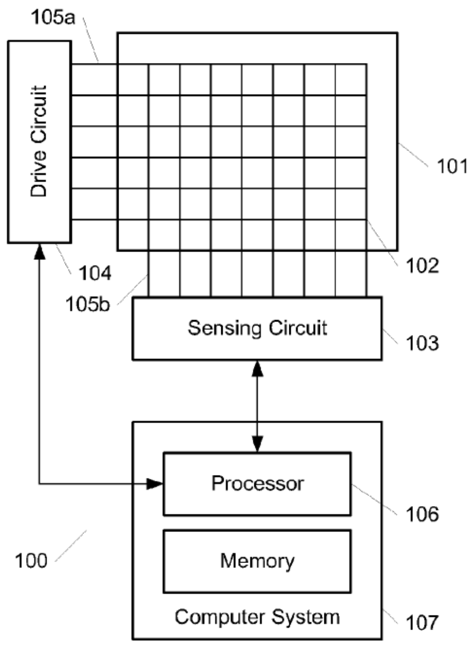


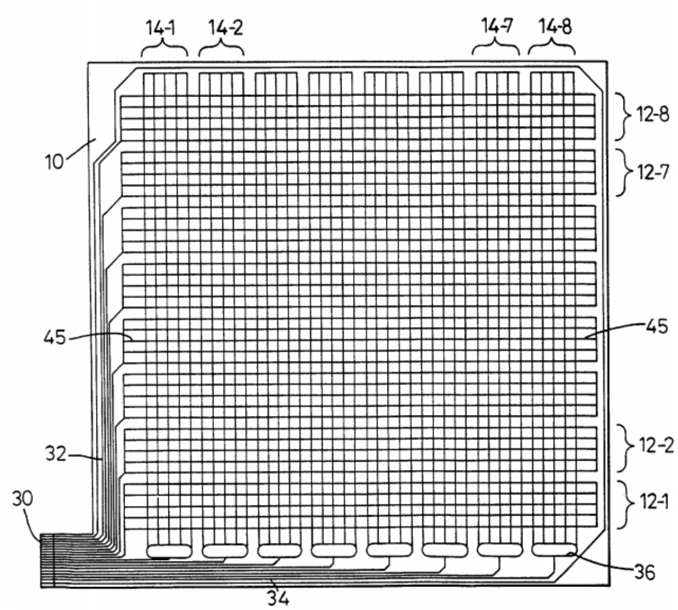
Fig. 1

30. Mutual-capacitance touch screens are configured to be capacitively coupled such that a pulsed or alternating voltage applied on a drive electrode induces a charge on a sense electrode that overlaps with the drive electrode. EX1008, ¶¶[0028], [0030], Fig. 3. Each of the intersections (*i.e.*, nodes) of the drive and sense electrodes are capacitively coupled together. *Id.* at ¶[0030]. In this configuration, the touch screen senses the location of an object (*e.g.*, a finger or conductive stylus) that is brought near the intersections because the object alters the local electric field (*i.e.*, the mutual capacitance) between the drive and sense electrodes at the intersections. *Id.* at ¶[0030]. Mutual capacitance touch screens can sense multiple touches simultaneously and provide two-dimensional images of the changes in the electric field. *See id.* at ¶[0031].

31. It was also well-known in the art to position the drive and sense electrodes on opposite sides of a transparent substrate. *See, e.g.*, EX1008, ¶ [0028] (in mutual capacitance systems, driving lines may be formed on a first layer and sensing lines may be formed on a second layer, and the "different layers may be different substrates, *different sides of the same substrate*, or the same side of the same substrate with dielectric separation.") (emphasis added); EX1009, ¶[0009] and Fig. 21.

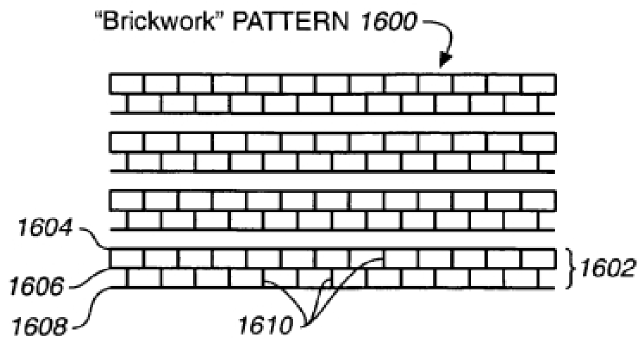
B. Mesh Electrodes

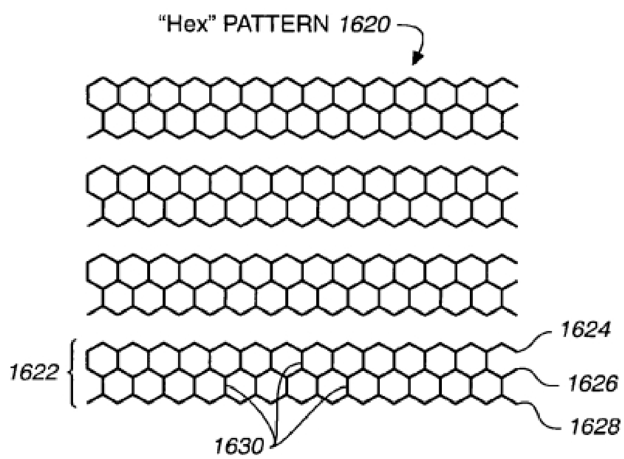
32. Mesh electrodes were also known well in advance of the priority date of the '574 patent. For example, U.S. Patent No. 6,137,427 issued on October 24, 2000 discloses a touchpad with mesh electrodes 12-1 - 12-8 and 14-1 - 14-8 formed by thin wires:



EX1016, 5:16-31 and Fig. 4.

33. Similarly, U.S. Patent No. 7,129,935, issued on October 31, 2006, discloses mesh electrodes formed from fine wires arranged in "brickwork" and "hex" patterns as shown in the figures below:





EX1017, 9:15-10:5 and Fig. 16. U.S. Pat. Pub. Nos. 2010/0026664 and 2010/0123670 similarly disclose mesh electrodes. EX1018, ¶¶[0064], [0067] and Figs. 4, 4a; EX1009, ¶[0155] and Fig. 17.

34. Thus, as of ’574 patent’s claimed priority date, mesh electrodes were nothing new.

IX. CLAIM CONSTRUCTION

35. As discussed above, it is my understand that in this proceeding, the claim terms should be given their plain and ordinary meaning as understood by one of ordinary skill in the art at the time of the alleged invention, in light of the patent specification, consistent with the disclosure and the prosecution history.

36. For the purposes of this analysis, I have construed certain terms of the ’547 patent as follows, which I believe is consistent with their plain and ordinary meaning.

A. “cover sheet” (claims 1, 8, 15)

37. This term should be construed to mean “sheet that covers something.” This construction is consistent with how the phrase is used in the ’574 patent. The term “cover sheet” is only used in the claims and in the Abstract. The specification uses a similar term, “covering sheet,” at 3:3-20, where it is referred to as a “transparent covering sheet” with no further description. Thus, a “cover sheet” should be construed broadly to mean a “sheet that covers something.”

B. “mesh” (claims 1, 8, 15)

38. This term should be construed to mean “set of wires that surround open spaces in a net or network.” EX1015, page 3 (first and second definitions of “mesh”). This construction is consistent with all of the examples of mesh

electrodes disclosed in the specification in Figs. 2A-B, 3A-C, and 4-14. EX1001, 3:61-12:60.

X. DETAILED INVALIDITY ANALYSIS

A. Ground 1: Claims 1-4, 6-11, and 13-15 Are Obvious Over Hsu and Mozdzyn

1. Summary of Hsu

39. Hsu is directed toward a "Flexible Transparent Touch Sensing System For Electronic Devices." EX1004, Title. Hsu discusses problems with known resistive and capacitive touchscreens, including lack of transparency, the need for frontal shielding, and the need for a uniformly electrically conductive surface. EX1004, 1:27-2:21.

40. Hsu discloses several embodiments of multiple layer, low cost, low power, transparent capacitive sensors suitable for uses in devices such as cell phones, pagers, personal digital assistants, remote controls and computers. EX1004, 2:55-60. The ability to use flexible substrates in some embodiments allows for sensors integrated onto curved, three-dimensional surfaces. EX1004, 3:19-25.

41. Among the embodiments disclosed in Hsu are various stacks including transparent substrates, transparent or nearly transparent electrodes arranged in perpendicular row and column arrangements formed of ITO (indium tin oxide) or thin layers of gold and silver, and transparent insulators/adhesives to

bind the layers together. EX1004, 6:14-9:21 and Figs. 4, 5A-5D, and 6-9. Fig. 7 shown below includes a multi-layer stack including a transparent substrate 86 with transparent electrodes 64, 70 on opposing sides. Fig. 7 is annotated below with the comparable features of the independent claims of the ’574 patent.

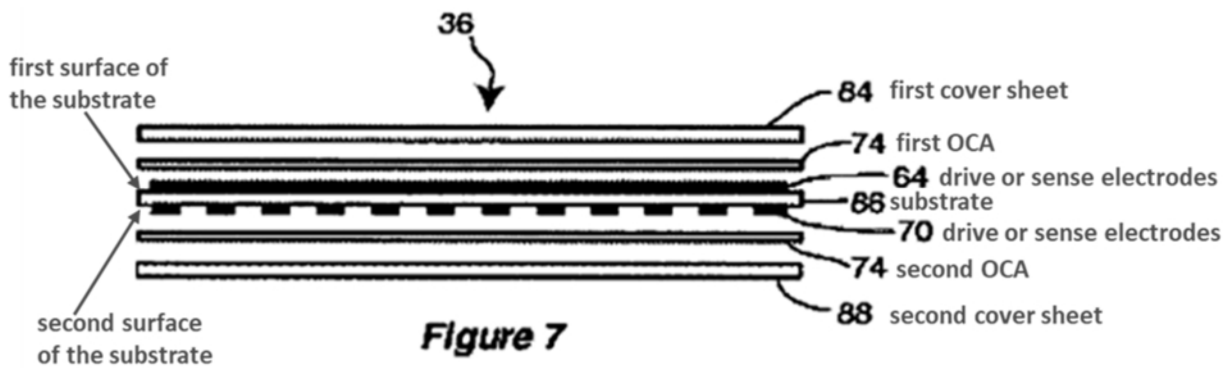


Figure 7

42. Further details of Hsu’s sensors will be discussed in the detailed claim analysis section below.

2. Summary of Mozdzyn

43. Mozdzyn discusses problems with transparent conductors formed of materials such as ITO, including high resistance. EX1005, ¶[0005]. Mozdzyn discloses a solution in the form of mesh electrodes that reduce overall electrode resistance, thereby increasing the electrical performance, without sacrificing optical quality. *Id*., ¶[0006]. Mozdzyn discloses that the mesh is preferably formed of a mesh pattern of conductive material (e.g., opaque metals such as copper and gold) having a very small width such that the conductors are essentially invisible. *Id*. Examples of such patterns are shown in Figs. 3 and 6:

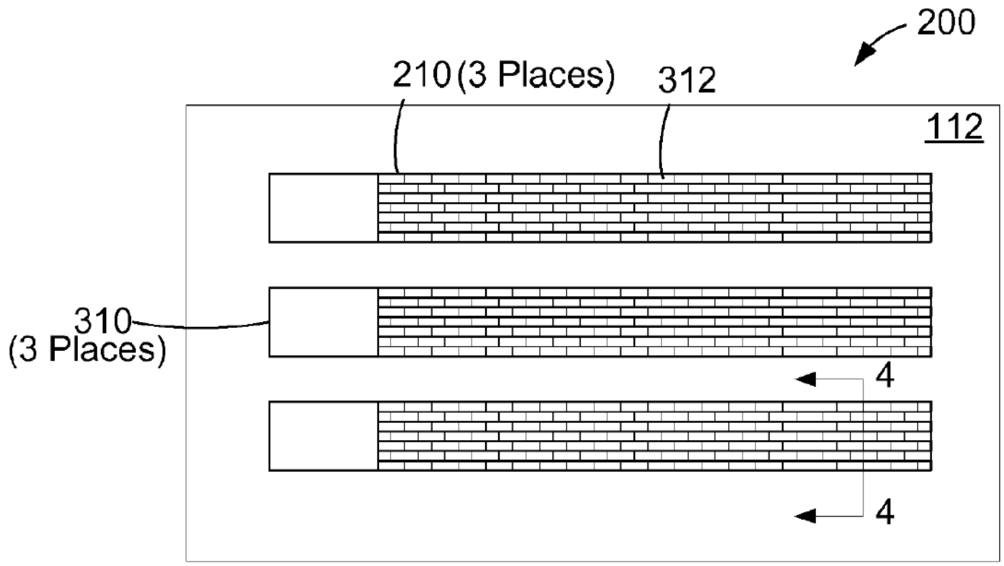

200
210 (3 Places)
312
112
310
(3 Places)
4
4

FIG. 3

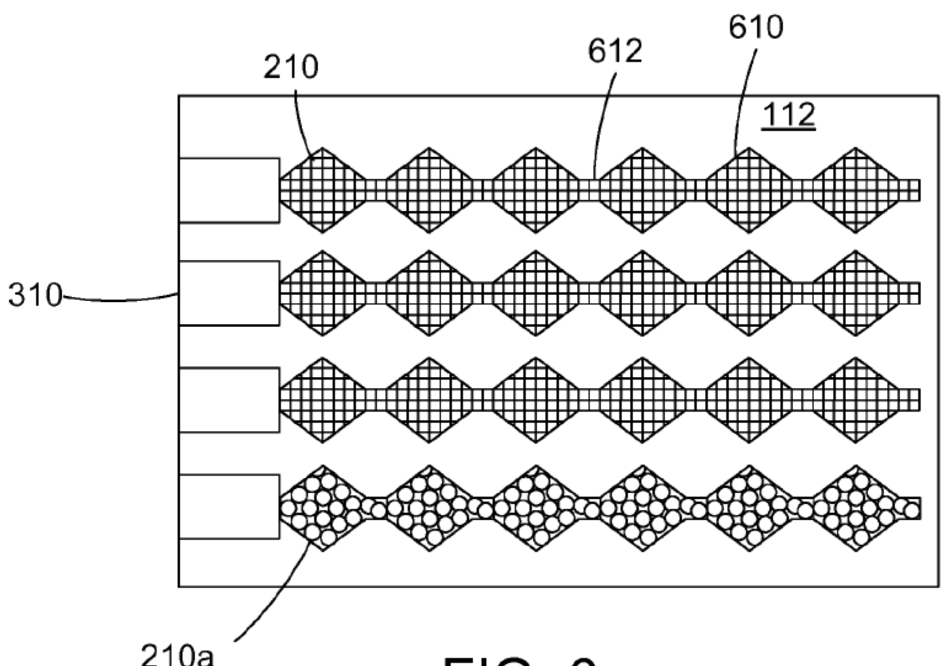

610
612
210
112
310
210a

FIG. 6

3. Detailed Claim Analysis

44. Hsu, together with Mozdzyn and the knowledge of a POSITA, renders claims 1-4, 6-11, and 13-15 of the ’574 patent obvious. The ’574 claims include three groups (apparatus claims 1-7, device claims 8-14, and apparatus claim 15), each of which is partially duplicative of the other. Accordingly, I will group similar elements of the three claim groups together for my analysis below.

a. 1.pre: “An apparatus comprising”

8.pre: “A device comprising”

15.pre: “An apparatus comprising”

45. Hsu discloses an apparatus and a device comprising the limitations discussed below.

b. 8.a: “a first cover sheet”

46. Hsu discloses a first cover sheet 84 (annotated in Fig. 7 below). For example, Hsu discloses an embodiment of a two dimensional capacitive sensor that includes a plurality of layers as shown in Fig. 7 below:

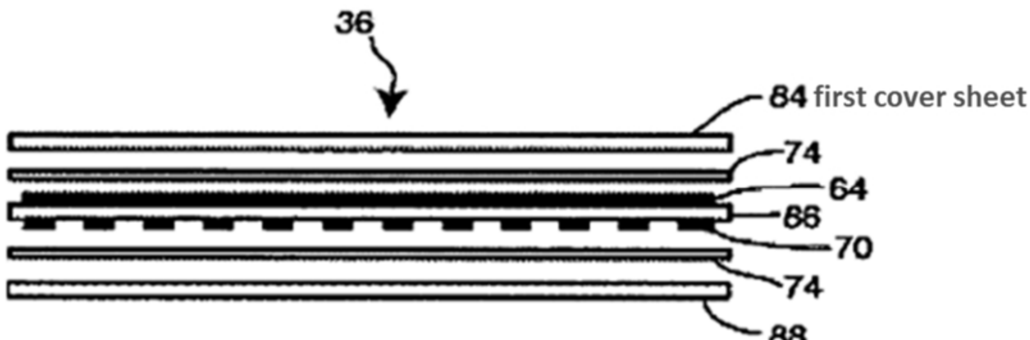


Figure 7

The top-most layer 84 in Hsu is a "transparent substrate." EX1004, 8:1-4. Hsu further discloses that transparent, electrically insulating substrates (including layer 84) had been described in previous embodiments of Hsu. *Id.*, 8:22-25. In one of those earlier embodiments depicted in Fig. 2, a top-most insulating substrate 52 was described in Hsu as being formed from a polyester film, glass, and polycarbonate plastic. EX1004, 4:53-55. Each of these materials is transparent, and any of them would be considered by a POSITA to be a "first cover sheet" as construed herein (i.e., a sheet that covers something) and recited in these limitations since this layer covers the underlying structures.

c. 1.a: "a first optically clear adhesive (OCA) layer between a first cover sheet and a substrate"

8.b: "a first optically clear adhesive layer (OCA) between the first cover sheet and a substrate"

15.a "a first optically clear adhesive (OCA) layer between a first cover sheet and a substrate"

47. Hsu discloses that the "transparent substrate 84 [i.e., the top-most layer in Fig. 7] is adhered using transparent insulator 74 to transparent conductor layer 64." EX1004, 8:2-4.

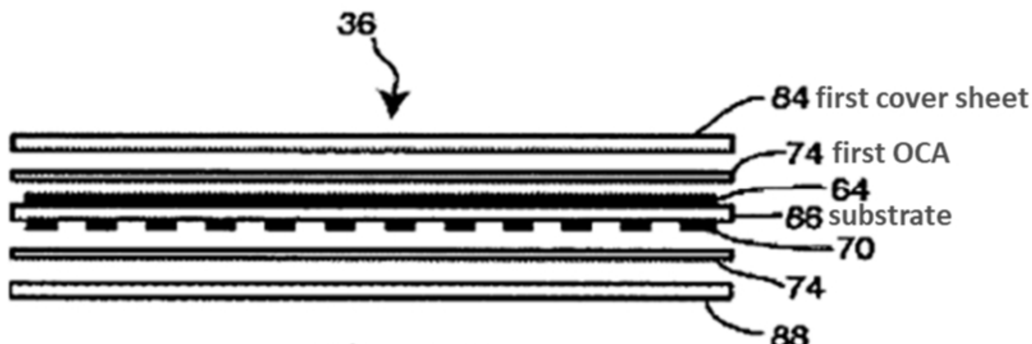


Figure 7

Thus, Hsu discloses that the layer 74 acts as both an adhesive and an insulator.

48. Hsu also discloses that the transparent, electrically insulating layer 84, which layer 74 adheres to layer 64, was described in previous embodiments. A POSITA therefore would have looked to the earlier embodiments for a suitable insulating material that could also serve to adhere such an electrically insulating layer to a layer such as layer 64 of Fig. 7, which is described as a "transparent conductor layer . . . [that] contains the X trace pattern." EX1004, 8:4-6.

49. Hsu discloses in connection with the embodiment of Fig. 2 an electrically insulating adhesive 54 that is used to adhere an electrically insulating

substrate 52 to a substrate 58 that is covered with a transparent conductor 56.

EX1004, 4:38-42.

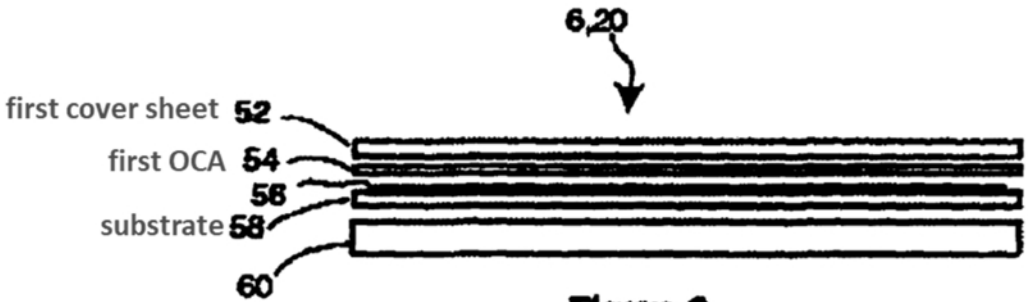


Figure 2

The example given for the electrically insulating adhesive layer 54 is the "transparent, electrically insulating adhesive . . . 3M adhesive #8142." *Id.*, 4:55-56. Because this upper part of the layer stack of Fig. 2 (shown above) is the same as the upper part of the layer stack in Fig. 7, and because the layer 54 of Fig. 2 is described as performing the same adhesion and insulation functions as the layer 74 of Fig. 7, a POSITA would have found it obvious, and would have been motivated, to use "transparent, electrically insulating adhesive . . . 3M adhesive #8142" for layer 74 of Fig. 7.

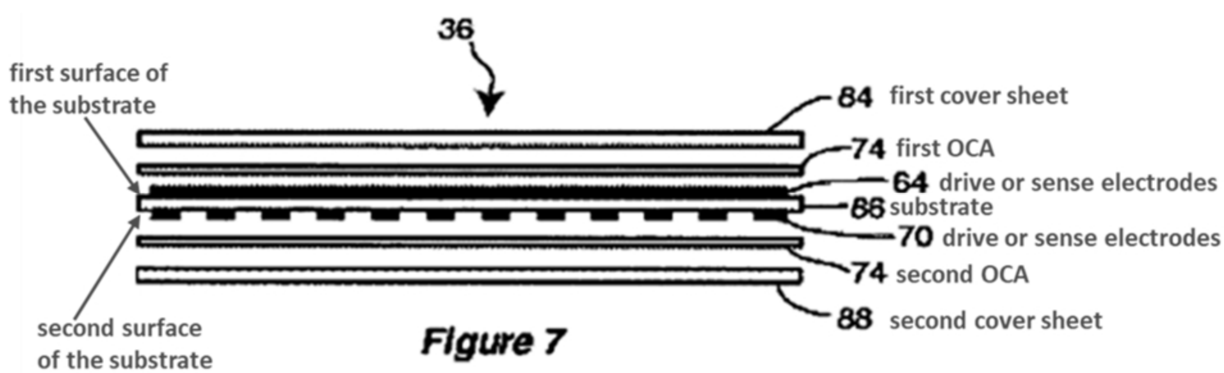
d. 1.b: "the substrate, with drive or sense electrodes of a touch sensor disposed on a first surface and a second surface of the substrate, the first surface being opposite the second surface, the drive or sense electrodes being made of a conductive mesh conductive material comprising metal"

8.c: "the substrate, with drive or sense electrodes of a

touch sensor disposed on a first surface and a second surface of the substrate, the first surface being opposite the second surface, the drive or sense electrodes being made of a conductive mesh conductive material comprising metal"

15.b: "the substrate, with sense electrodes of a touch sensor disposed on a first surface and drive electrodes of the touch sensor disposed on a second surface of the substrate, the first surface being opposite the second surface, the drive and sense electrodes being made of a conductive mesh of conductive material comprising metal"

50. Hsu discloses a "transparent substrate 86" with an upper surface onto which a transparent conducting layer 64 containing an X pattern has been coated, and an lower surface onto which a transparent conducing layer 70 containing a Y pattern has been coated. EX1004, 8:3-21.



51. Hsu further discloses that X and Y patterns 64 and 70 are the preferred embodiments shown in Figs. 5A and 5B, reproduced below. *Id*.

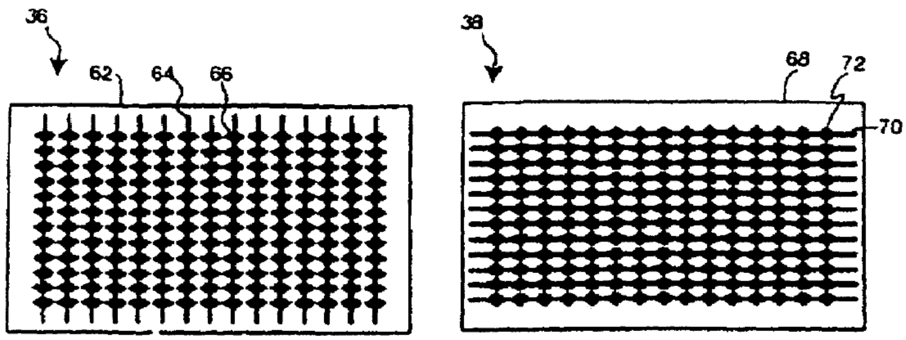


Figure 5A Figure 5B

As seen in Figs. 5A and 5B, each side of the transparent substrate includes a plurality of linear column (Fig. 5A) or row (Fig. 5B) electrodes 64, 70, with each electrode having a plurality of diamonds 66, 72 formed therein. *Id*. 6:38-50.

52. Hsu discloses that the electrodes 64,70 are transparent conductors that may be formed using a photolithography process from indium tin oxide (ITO), gold or silver. *Id*., 6:64-7:22. The electrodes 64, 70 with the diamonds 66,72 are illustrated as solid shapes in Figs. 5A and 5B, but Hsu does not discuss whether or not they are solid, and therefore also does not indicate any preference for solid shape electrodes over other types of electrodes.

53. Conductor layers 64 and 70 include "drive or sense electrodes," as would have been understood by a POSITA. The '574 patent does not explicitly define "drive electrode" or "sense electrode," but it uses those terms to describe a touch sensor "in a mutual capacitance configuration." A POSITA would have understood this usage as providing context to understand the meaning of "drive electrode" and "sense electrode." For example, the '574 patent explains that "a

mutual capacitance configuration" includes "an array of conductive drive electrodes or lines and conductive sense electrodes or lines" that "may be separated by an insulator" and "capacitively coupled" such that "a pulsed or alternating voltage applied on a drive electrode may therefore induce a charge on the sense electrodes that overlap with the drive electrode" and "[t]he amount of induced charge may be susceptible to external influence, such as from the proximity of a nearby finger." EX1001, 1:37-48. Hsu discloses this same configuration of electrodes separated by an insulator, such as in Hsu's Fig. 7, without explicitly referring to them as "drive" or "sense" electrodes, as explained below.

54. Hsu's conductor layers 64 and 70 in Fig. 7 correspond to sensor traces 64 and 70 in Figs. 5A and 5B (EX1004, 8:4-8), in which "[e]ach trace 64 is a transparent conductor" and "[e]ach trace 70 is also a transparent conductor." EX1004, 6:40-41, 6:46-48. Conductor layers 64 and 70 are also separated by an insulator, i.e., electrically insulting substrate 86. *See* EX1004, 8:4-8, 8:22-25, 7:34-37, 4:53-55. Hsu explains that the system "can determine finger presence as finger position along two direction axes" because a "[f]inger 4 capacitively couples to sensor traces in sensor 36," and the system "measure[s] capacitance values of sensor traces in the X and Y trace arrays." *Id*., 6:14-20. Thus, Hsu's sensor performs the capacitive sensing function described (but not claimed) by the '574 patent.

55. A POSITA would have understood that the traces in Hsu's conductor layers 64 and 70 are configured to be "capacitively coupled" such that "a pulsed or alternating voltage applied on a drive electrode may therefore induce a charge on the sense electrodes that overlap with the drive electrode" (like the "drive" and "sense" electrodes of the '574 patent) because those characteristics are inherent to electrodes separated by an insulator in that way, as further supported by the references described below.

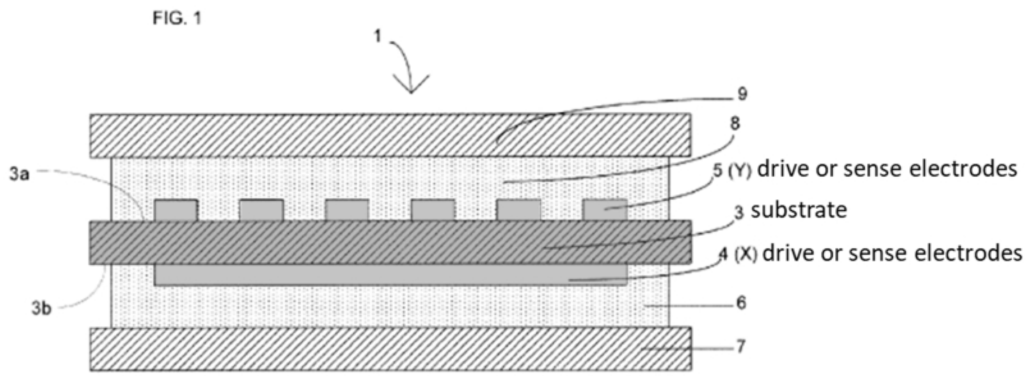
56. Prior art patents referenced and incorporated by Hsu confirm that a POSITA would have had this understanding. Hsu incorporates by reference U.S. Patent Nos. 5,880,411 ("Gillespie") (EX1007) and 5,305,017 ("Gerpheide") (EX1006), and describes them as disclosing "suitable algorithms and means for implementing this [capacitive] sensor." EX1004, 6:31-34. Both Gillespie and Gerpheide describe that a first set of electrodes and a second set of electrodes separated by a substrate are configured to perform mutual capacitance measurement in a touch sensor. S*ee*, *e.g.*, EX1007, 9:3-19, 10:18-12:24, Figs. 2C-2D; EX1006, 5:12-6:12, 8:17-54, 9:36-10:13, Figs. 8a-8b). Further, Gillespie explains that position sensing with mutual capacitance measurements includes using the first and second sets of electrodes as drive or sense electrodes. S*ee* EX1007, 11:7-19, 11:58-12-24 (describing "drive and sense methods" for driving and sensing voltage on X and Y electrode lines). A POSITA would therefore have

understood that Hsu's sensor, like Gillespie's and Gerpheide's, includes drive and sense electrodes capable of performing mutual capacitance measurements.

57. Gerpheide further explains that the "well-known mutual capacitance" between two electrodes is "well known from the theory of parallel plate capacitors." EX1006, 9:62-67, 10:34-50. A POSITA would have been familiar with the theory of parallel plate capacitors and would have understood that mutual capacitance between electrodes separated by dielectric insulator inherently involves the inducement of charge by one electrode on the other. *See* EX1014, 28-29 (explaining theory of parallel plate capacitors), 37 (defining mutual capacitance as ratio of induced charge on a first conductor to the potential of a second conductor having the inducing charge); EX1013, 199-204 (explaining theory of parallel plate capacitors), 170-174 (explaining charge inducement on conductors and dielectric insulators). Thus, a POSITA would have understood that electrodes separated by a dielectric insulator in a touch sensor, like sensor 36 of Hsu, have a mutual capacitance configuration and would function as drive and sense electrodes.

58. As shown below, the relative arrangement of Hsu's electrodes (i.e., traces on conductor layers 64 and 70) and substrate (substrate 86) is the same as that of the '574 patent. A POSITA would therefore have understood Hsu's sensor 36 to include drive and sense electrodes within the meaning of the '574 patent.

Hsu, Fig. 7 (annotated)



'574 patent, Fig. 1 (annotated)

59. Based on Hsu's disclosure and the knowledge of a POSITA, which would have included knowledge of the prior art disclosures of EXS. 1006, 1007, 1013, and 1014 and all background art, a POSITA would have understood Hsu's conductor layers 64 and 70 to include "drive or sense electrodes," as recited in claim 1.b.

60. As discussed above, mesh electrodes were known in the art. *See* Section VIII.B above. Indeed, Mozdzyn discloses mesh electrodes 210 having diamond shapes 610 very similar to those disclosed in Hsu:

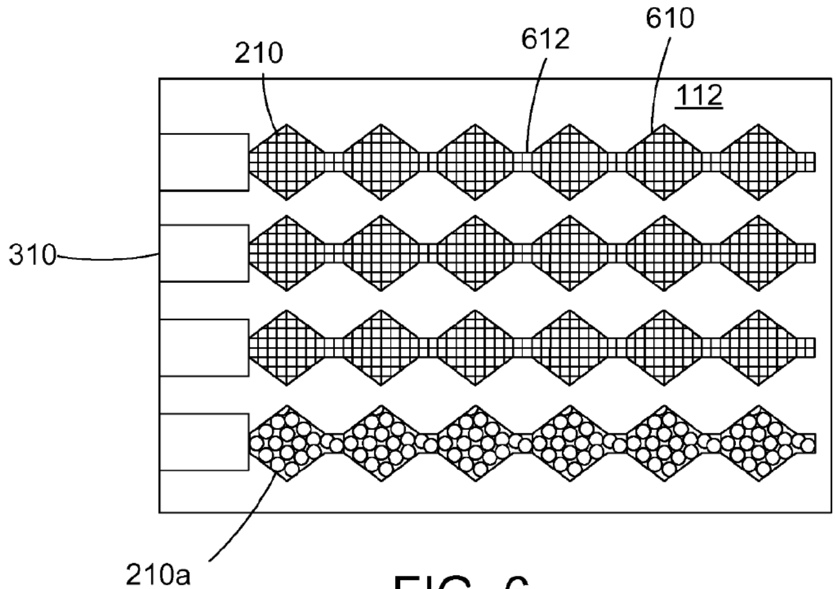
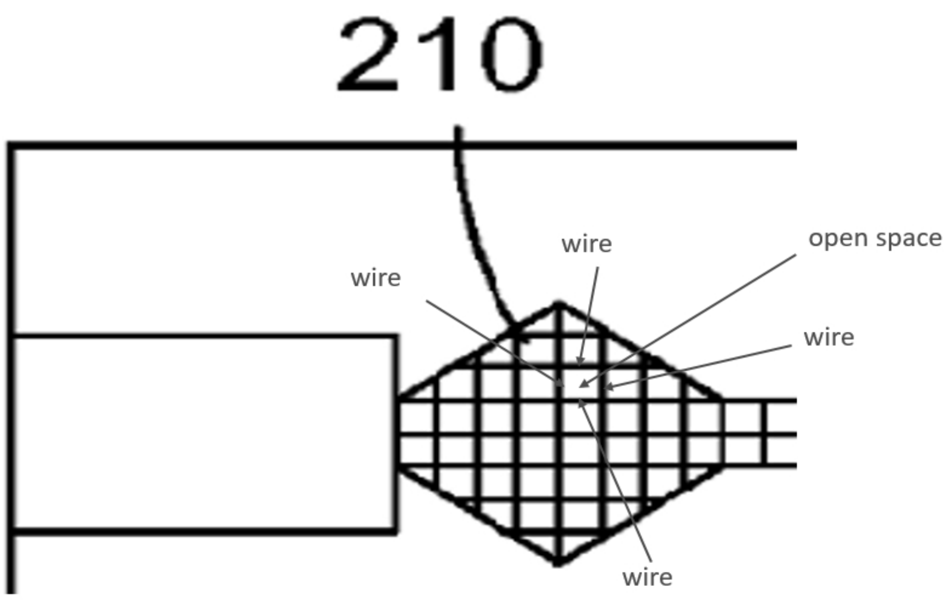


FIG. 6

EX1005, ¶[0026]. In each of Mozdzyn's electrodes 210, each square open space is surrounded by parts of 4 wires are part of the network of wires that form the electrode as shown in the annotated portion of figure below:



Mozdzyn is directed toward an improvement in capacitive touch screens, such as those touch screens typically having a transparent substrate with transparent conductive coatings formed of ITO formed on both sides. *Id*., ¶[0004]. Mozdzyn discloses that forming electrodes from a conductive mesh improves electrodes in such touch screens by improving electrical performance by reducing overall resistance without sacrificing optical quality. *Id*., ¶¶ [0006], [0017]. Reducing electrode resistance allows for reduced scan times in touch screens. *Id*. ¶[0005]. The conductors in the mesh have a very small width such that the conductors are essentially invisible. *Id*., ¶[0017]. Mozdzyn discloses that the conductors may be formed from metals including nickel, copper, gold, silver, tin, aluminum and alloys and combinations of these materials. *Id*., ¶[0023].

61. Mozdzyn further discloses that these electrodes can be dedicated drive electrodes and dedicated sense electrodes. *Id*., ¶[0021]. While claim 1 does not require that either type of electrodes be on one side or another (particularly in light of claim 7), in such embodiments with dedicated touch and sense electrodes, it would have been obvious to a POSITA for the dedicated sense electrodes to be located on one side of the substrate and the dedicated drive electrodes to be located on the other side of the substrate as such an arrangement was well-known in the art for mutual capacitance-type touch screens. *See, e.g.,* EX1009, ¶[0009] and Fig. 21.

62. A POSITA would have been motivated to substitute the metal mesh electrodes with diamond shapes as taught by Mozdzyn for the ITO electrodes with diamond shapes as taught by Hsu in the embodiment of Hsu's Fig. 7 in order to obtain the benefit of improved electrical performance (i.e., conductivity) without sacrificing optical quality as taught by Mozdzyn. EX1005 ¶¶[0002], [0006]. As described in Mozdzyn, the diamond shapes are made of conductive traces in a mesh that have a very small width. EX1005, ¶[0027], Fig. 6. With traces this small, they are essentially invisible to a user of a touch screen. *Id.*, ¶¶[0006], [0017]. By using conductive traces in a mesh, optical quality is not sacrificed as it would be in an ITO layer, which would require an increase in layer thickness causing the ITO layer to become more visible to a user. *Id.*, ¶[0005]. A POSITA would further have been motivated to configure Hsu's system to utilize these electrodes as drive or sense electrodes as taught by Mozdzyn. *See*, *e.g.*, EX1005 ¶[0002], Fig. 6. A POSITA would have had a reasonable expectation of success in doing so given the similarities in the capacitive touch screens of Hsu and Mozdzyn and the express teachings of Mozdzyn regarding improved electrical performance without sacrifice of optical quality. Additionally, a POSITA would have appreciated that improving conductivity (i.e., reducing resistance) of the electrodes would reduce electrode scan times, thereby increasing the performance of the touchscreen. EX1005 ¶[0005].

e. 1.c: "a display separated from the second surface of the substrate by a second OCA and a second cover sheet such that at least a portion of the second cover sheet is positioned between the second surface of the substrate and the display"

8.d: "a display separated from the second surface of the substrate by a second OCA and a second cover sheet such that at least a portion of the second cover sheet is positioned between the second surface of the substrate and the display"

15.c: "a display separated from the second surface of the substrate by a second OCA and a second cover sheet such that at least a portion of the second cover sheet is positioned between the second surface of the substrate and the display"

63. The embodiment of Hsu's Fig. 7 includes a second cover sheet in the form of transparent substrate 88, which is separated from the substrate 86 by a second layer 74. EX1004, Fig. 7, 8:8-10. A POSITA would have been motivated to use the same optically clear adhesive, 3M adhesive #8142, for this second layer 74 both for the reasons discussed above in Section X.A.3.d in connection with the upper layer 74, and further because the layers 74 have the same reference numeral.

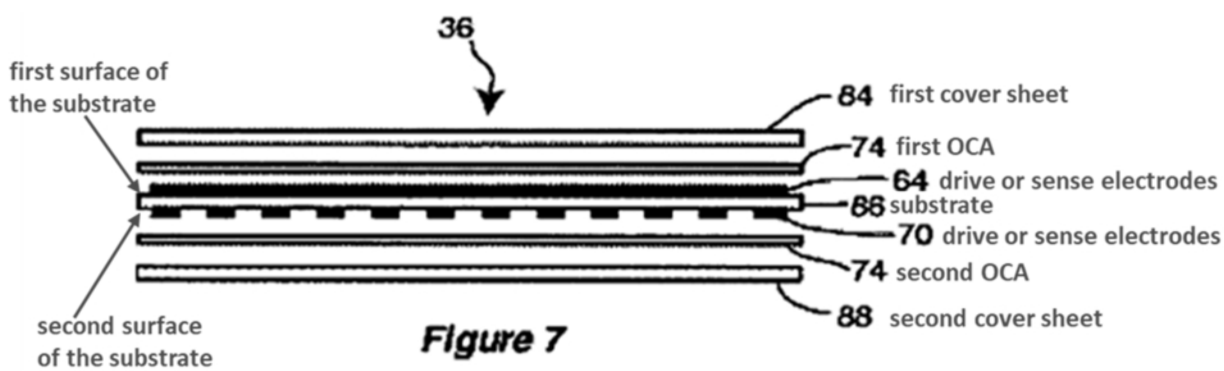


Figure 7

64. Hsu further discloses that its multi-layer capacitive touch devices can be used above a display. For example, Hsu discloses that transparent capacitive touch device may be used over an active display such as an LCD (liquid crystal display) or CRT (cathode ray tube) screen. EX1004, 1:27-31. Hsu further discloses that a display 60 such as an LCD can be position beneath the Fig. 5 embodiment discussed above as shown in Fig. 5D:

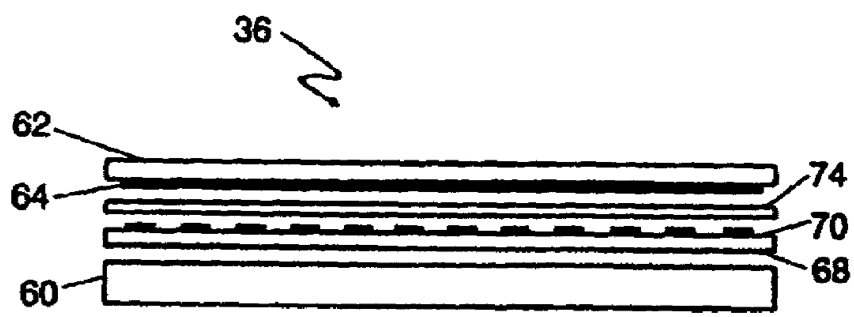


FIG. 5D

Id., 5:6-15.

65. Given that the touch screen of Fig. 7 is another embodiment of the touch device formed by layers 62-70 of Fig. 5D, and is formed of optically clear materials, it would have been obvious to a POSITA that the touch device of Fig. 7 could be positioned over an LCD screen such as LCD screen 60 of Fig. 5D. When so positioned, the second cover sheet of Fig. 7, transparent substrate 88, would be positioned between the underlying display 60 and the second, lower surface of substrate 86. Moreover, the LCD screen 60 would be separated from the second,

lower surface of substrate 86 by layer 74 (a second OCA layer) and transparent substrate 88 (the second cover sheet).

f. 8.e: "one or more computer-readable non-transitory storage media embodying logic that is configured when executed to control the touch sensor"

66. Hsu discloses that signals from a capacitive touch device may be connected to an input processing block 8 for digitizing and then processing by an arithmetic unit 10 and a gesture unit 12 to determine if a finger is present. EX1004, 4:4-22. Hsu incorporates by reference U.S. Patent Nos. 5,880,411 (EX1007) and 5,305,017 (EX1006) for details concerning these three devices. *Id*., 4:15-22. U.S. Patent No. 5,305,017 discloses a control circuit 50 that may be a microprocessor or microcontroller and that outputs a selection signal S containing row and column selection components to a touch device 20 as shown in Fig. 1:

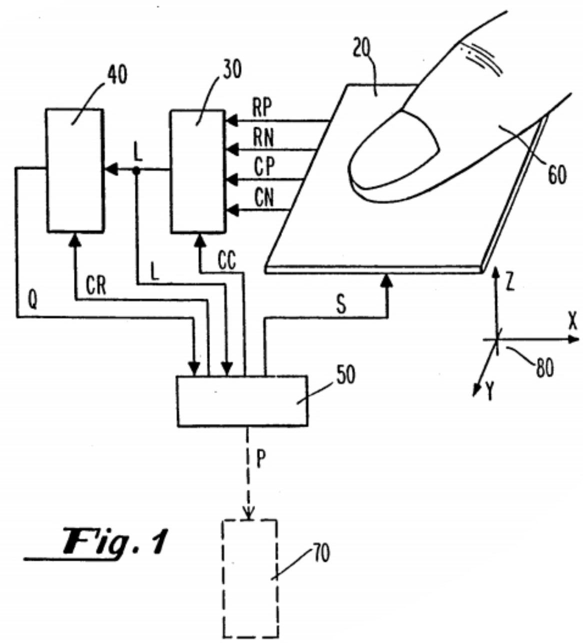


Fig. 1

EX1006, 13:11-20. Selection signal S is a control signal. It is inherent, and to the extent not inherent, a POSITA would have found it obvious, to control such a microprocessor or microcontroller with logic (i.e., software instructions/code) stored in a non-transitory storage medium such as a computer readable memory as this was notoriously well-known in the art. *See* EX1009, ¶[0094] (referring to suitably ***programmed*** microprocessor for implementing a touch screen controller) and Fig. 12. It is inherent that a programmed microprocessor must have access to a non-transitory storage medium in which the program is stored.

g. 2.: "The apparatus of claim 1, wherein the conductive material is copper, silver, gold, aluminum, or tin."

9.: "The device of claim 8, wherein the conductive material is copper, silver, gold, aluminum, or tin."

67. Mozdzyn discloses that the conductive material that forms the mesh electrodes is ***copper***, ***gold***, ***silver***, ***tin***, ***aluminum*** and alloys and combinations of these materials in the Fig. 3-4 embodiment. EX1005, ¶[0023] (emphasis added). A POSITA would have found it obvious, and would have been motivated, to use the same materials in the Fig. 6 embodiment, and thus in Hsu's Fig. 7 embodiment as discussed above for claim limitation 1.b, because Mozdzyn discloses that the mesh of Fig. 6 is similar to the mesh of Fig. 3. EX1005, ¶[0027].

h. 3.: "The apparatus of claim 1, wherein the conductive mesh comprises a plurality of mesh segments, each of the mesh segments having a width of approximately 10 µm."

10.: "The device of claim 8, wherein the conductive mesh comprises a plurality of mesh segments, each of the mesh segments having a width of approximately 10 µm."

68. Mozdzyn discloses that the conductive mesh comprises a plurality of mesh segments. For example, Fig. 6 of Mozdzyn shows "diamond shaped mesh electrodes 210 [that] comprise a mesh of conductors similar to that described above with reference to Fig. 3." EX1005 ¶[0027], Fig. 6. As shown in Fig. 6, the "mesh of conductors" are the recited "plurality of mesh segments." Mozdzyn further discloses that the line geometries of the mesh in the embodiment of Figs. 3 and 4 "are preferably less than 0.025 millimeters (mm) in width and most

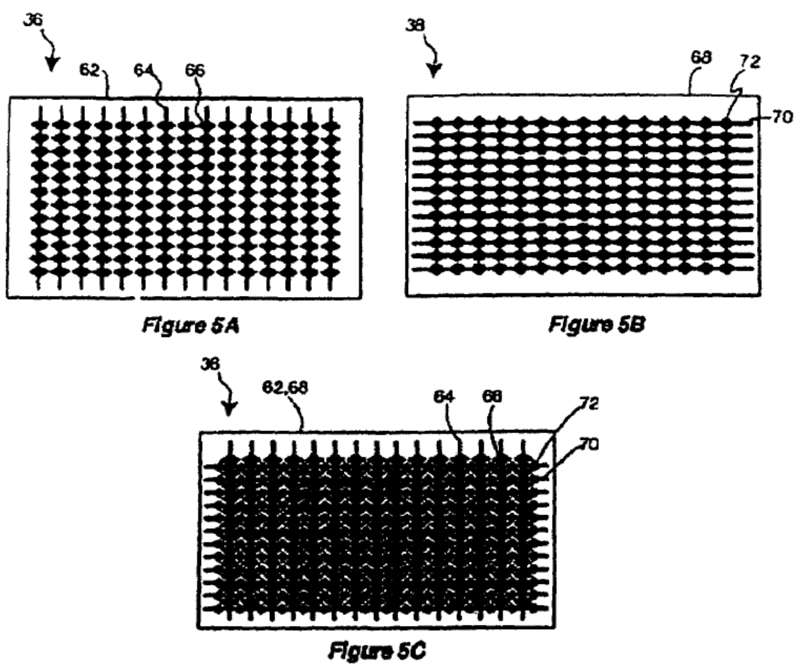
preferably about 0.010 mm or less." EX1005, ¶[0025]. 0.010 mm is equal to 10 µm. It would have been obvious to a POSITA to use the same line geometries for the Fig. 6 embodiment with the electrodes having diamond shapes, and thus in Hsu's Fig. 7 embodiment as discussed above for claim limitation 1.b, because Mozdzyn discloses that the mesh of Fig. 6 is similar to the mesh of Fig. 3. EX1005, ¶[0027].

i. 4.: "The apparatus of claim 3, wherein approximately 5% of an active area of the touch sensor is covered by the one or more mesh segments."

11.: "The device of claim 10, wherein approximately 5% of an active area of the touch sensor is covered by the mesh segments."

69. Mozdzyn discloses that the mesh electrodes of the embodiment of Fig. 3 and 4 cover 5% or less than the total area covered by the mesh electrodes of the touch device. EX1005 ¶[0025]. A POSITA would have found it obvious, and would have been motivated, to configure the embodiment of Fig. 6 such that the mesh electrodes covered approximately the same surface area as the embodiment of Figs. 3 and 4 in view of Mozdzyn's disclosure that this amount of coverage was desirable. Thus, assuming that an area covered by the mesh electrode (i.e., excluding any spaces between the mesh electrode) is the claimed "active area," Mozdzyn discloses this limitation.

70. To the extent that "active area" is construed to refer to the entire area of the touch sensor rather than just the areas of the touch sensor covered by electrodes, the combination of Hsu and Mozdzyn discloses this limitation. Hsu discloses that the electrodes with diamond shaped conductors shown in Figs. 5A and 5B should be positioned and sized such that the Y trace diamonds 72 fill in the spaces between the X traces 66, so that the sensor 36 appears to have a single uniform layer of transparent conductive material as shown in Fig. 5C. EX1004, 7:4-22.



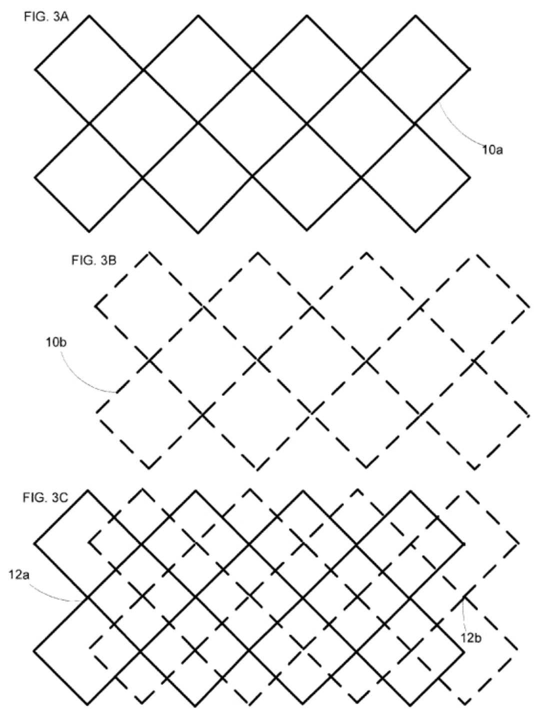
71. In an embodiment such as shown in Fig. 5C with the diamond areas 66 of the Y electrodes 64 positioned in the diamond shaped areas between the X electrodes on the opposite substrate so as to create of a single uniform layer of conductive material, approximately 5% of the touch sensor active area is covered

by mesh segments if the electrodes are formed from meshes with 5% the mesh area covered by the electrical conductors as taught by Mozdzyn.

j. 6.: "The apparatus of claim 1, wherein the conductive meshes have an optical transmissivity of approximately 90%."

13.: "The device of claim 8, wherein the conductive meshes have an optical transmissivity of approximately 90%."

72. The '574 patent indicates that transmissivity of a conductive mesh may be determined based on the percentage of the surface area covered by the conductors of the conductive mesh. EX1001, 4:7-19. In particular, the '574 states that if the conductors in one mesh pattern on one side of a substrate covers 5% of the surface of the substrate, then the total transmissivity for all (i.e., both) electrode patterns is 90%. *Id*. In other words, if the conductors of the electrode pattern on each side covers about 5% of the surface, and if the electrode patterns are offset from each other as shown in Figs. 3A-C, then the offset patterns cover a total of 10% of the surface area, and the total transmissivity of both patterns is 100% - 10% = 90%.



73. Mozdzyn discloses that the embodiment of Figs. 3-4 includes mesh electrodes with conductors that cover preferably 15% or less of the electrode area (i.e., 15% of the area covered by the mesh electrode is covered by the conductors that make up the mesh), and more preferably 5% or less of the electrode area. EX1005, ¶[0025]. This disclosure would have rendered obvious to a POSITA a mesh electrode with conductors covering 10% of the electrode area as 10% is within the range disclosed by Mozdzyn. In this regard, I note that the ’574 patent does not ascribe any criticality to an optical transmissivity of 90%.

74. As discussed above, Hsu discloses that the electrodes with diamond shaped conductors shown in Figs. 5A and 5B should be positioned and sized such that the Y trace diamonds 72 fill in the spaces between the X traces 66 such that

the sensor 36 appears to have a single uniform layer of transparent conductive material as shown in Fig. 5C. EX1004, 7:4-22.

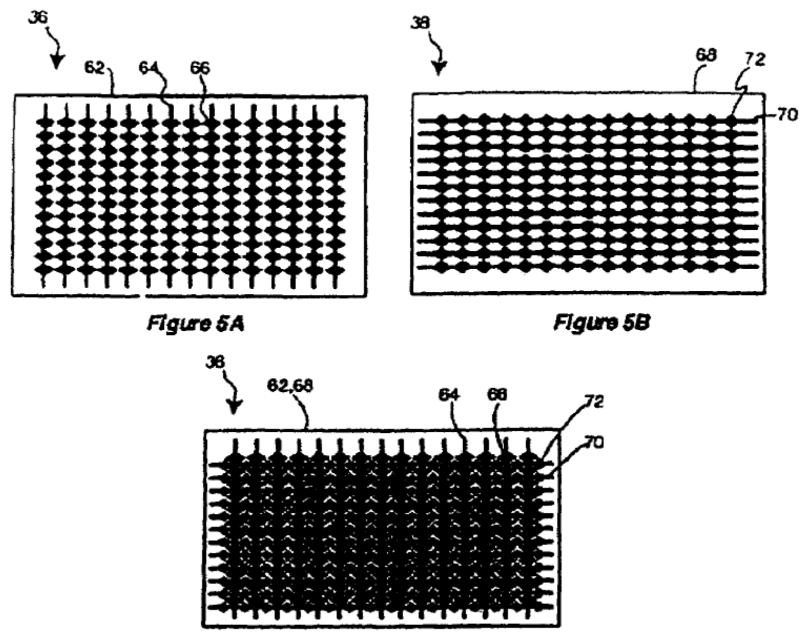


Figure 5C

In an embodiment such as shown in Fig. 5C with the diamond areas 66 of the Y electrodes 64 positioned in the diamond shaped areas between the X electrodes on the opposite substrate so as to give the appearance of a single uniform layer of conductive material as disclosed by Hsu, if electrodes are formed from meshes with 10% of the mesh area covered by the electrical conductors that form the mesh as made obvious by Mozdzyn, then the combined transmissivity of the meshes would be 100% - 10% = 90%. This is because any particular area is covered by only one or the other of the X electrodes and the Y electrodes, each of which includes conductors that cover only 10% of the surface area.

k. 7.: "The apparatus of claim 1, wherein the sense electrodes being disposed on the first surface of the substrate and the drive electrodes being disposed on the second surface of the substrate."

14.: "The device of claim 8, wherein the sense electrodes being disposed on the first surface of the substrate and the drive electrodes being disposed on the second surface of the substrate."

75. As discussed above in connection with Section X.A.3.d, Hsu discloses a "transparent substrate 86" with an upper surface onto which a transparent conducting layer 64 containing an X pattern has been coated, and an lower surface onto which a transparent conducing layer 70 containing a Y pattern has been coated. EX1004, 8:3-21. A POSITA would have found it obvious to utilize the electrodes of one pattern as drive electrodes and the electrodes of the other pattern as sense electrodes.

76. In addition, Mozdzyn discloses that, in some embodiments, separate sense and drive lines are utilized. EX1005, ¶[0021]. As discussed in the State of the Art Section VIII.A above, it is well-known in the art to use the electrodes on one side of a transparent substrate as drive lines and the electrodes on the other side of a transparent substrate as sense lines in a mutual-capacitance configuration in a touch device. *See, e.g.*, EX1008, Fig. 1 and ¶ [0028] (in mutual capacitance systems, driving lines may be formed on a first layer and sensing lines may be formed on a second layer, and the "different layers may be different substrates,

different sides of the same substrate, or the same side of the same substrate with dielectric separation.") (emphasis added); EX1009, ¶[0009] and Fig. 1 (shown below). A POSITA would have found it obvious to do so here.

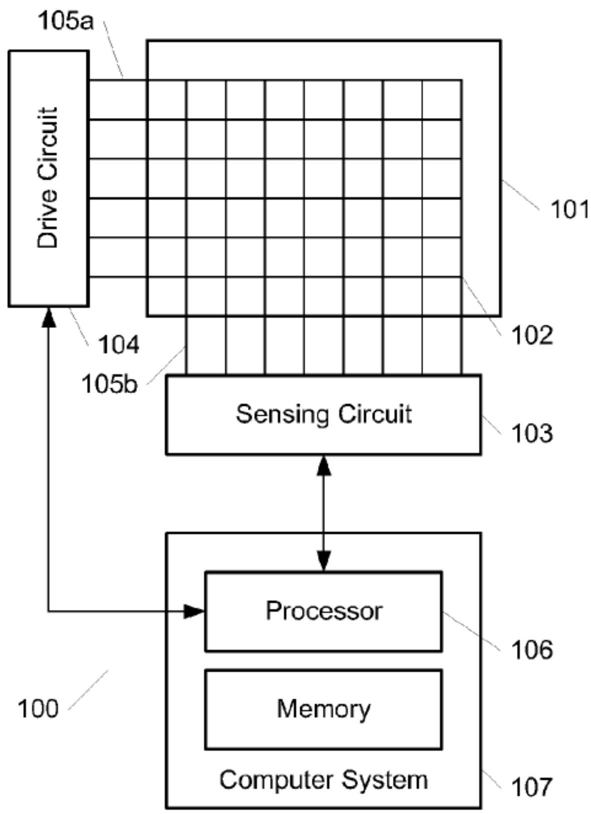


Fig. 1

EX1009, Fig. 1

B. Ground 2: Claims 1-4, 6-11, and 13-15 Are Obvious Over Hsu and Philipp

1. Summary of Philipp

77. Philipp is directed towards a "Touch Screen Sensor." EX1010, ¶[0001], Title. Philipp discloses a capacitive touch screen sensor having a

transparent PET substrate with conductive coating forged of fine-line printed metal deposited on both sides of the substrate. *Id.*, ¶¶[0006]-[0008]. The printed metal forms conductive electrodes arranged in a mesh pattern on the substrate. *Id*. This arrangement improves electrodes in touch screen sensors by improving optical quality while maintaining robust performance. Id.

78. In a mesh design, the electrodes also provide high optical transmissivity and conductivity to deliver a strong electric field. *Id.*at ¶¶ [0008], [0011], [0033], [0034]. This is done by using narrow conductive electrodes and highly-conductive metals. For example, the conductive electrodes in the mesh have a very small width, such as 10 µm wide or less, so as to be optically invisible. *Id.*, ¶¶ [0007], [0008], [0011], [0012], [0018], [0033], [0034]. At that size, the electrodes cover only 5% or less of the area covered by the mesh pattern. *Id.*, ¶¶ [0007], [0013], [0034]. To provide the electric field, the conductive electrodes are made of highly-conductive metals, such as copper, gold, silver, or other metals and alloys thereof. *Id.*, ¶¶ [0007], [0033].

79. In an alternate design, Philipp also discloses conductive electrodes that cover 10% or less of the area of each electrode (i.e., 10% of the area covered by the mesh electrode is covered by the conductors that make up the mesh), and more preferably 5% or less of the electrode area. *Id.*, ¶ [0013].

80. Philipp further discloses the conductive mesh arranged in diamond

shapes. Philipp illustrates the diamond-shaped mesh electrodes 32, 34, 38, 40, 42 in Figs. 3A-3B:

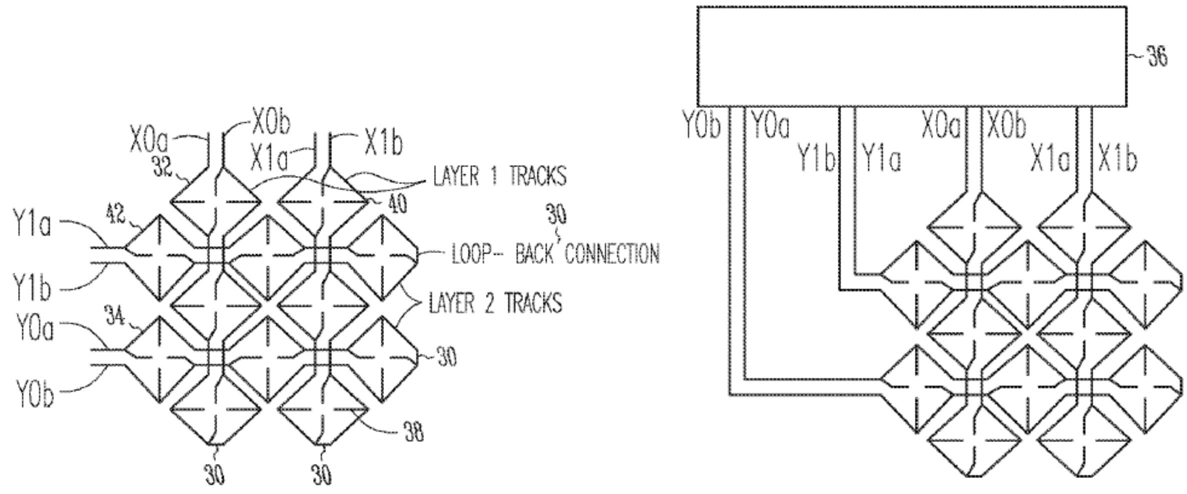


Fig. 3A

Fig. 3B

EX1010, ¶ [0052]. Philipp further discloses that these mesh electrodes can be arranged in two layers separated by a dielectric, which is also illustrated in Figs. 3A-3B. *Id.*, ¶¶[0014], [0052].

2. Detailed Claim Analysis

81. Hsu, together with Philipp and the knowledge of a POSITA, renders claims 1-4, 6-11, and 13-15 of the ’574 patent obvious. The ’574 claims include three groups (apparatus claims 1-7, device claims 8-14, and apparatus claim 15), each of which is partially duplicative of the other. Accordingly, I will group together similar elements of the three claim groups for the analysis below.

a. 1.pre: “An apparatus comprising”
8.pre: “A device comprising”

15.pre: "An apparatus comprising"

82. As discussed above for Ground 1, Hsu discloses this claim limitation. Section X.A.3.a, *supra*.

b. 8.a: "a first cover sheet"

83. As discussed above for Ground 1, Hsu in view of the knowledge of a POSITA discloses this claim limitation. Section X.A.3.b, *supra*.

c. 1.a: "a first optically clear adhesive (OCA) layer between a first cover sheet and a substrate"

8.b: "a first optically clear adhesive layer (OCA) between the first cover sheet and a substrate"

15.a "a first optically clear adhesive (OCA) layer between a first cover sheet and a substrate"

84. As discussed above for Ground 1, Hsu in view of the knowledge of a POSITA discloses this claim limitation. Section X.A.3.c, *supra*.

d. 1.b: "the substrate, with drive or sense electrodes of a touch sensor disposed on a first surface and a second surface of the substrate, the first surface being opposite the second surface, the drive or sense electrodes being made of a conductive mesh conductive material comprising metal"

8.c: "the substrate, with drive or sense electrodes of a touch sensor disposed on a first surface and a second surface of the substrate, the first surface being opposite the second surface, the drive or sense electrodes being made of a conductive mesh conductive material comprising metal"

15.b: "the substrate, with sense electrodes of a touch

sensor disposed on a first surface and drive electrodes of the touch sensor disposed on a second surface of the substrate, the first surface being opposite the second surface, the drive and sense electrodes being made of a conductive mesh of conductive material comprising metal"

85. As discussed above for Ground 1, Hsu in view of the knowledge of a POSITA discloses "the substrate, with sense electrodes of a touch sensor disposed on a first surface and drive electrodes of the touch sensor disposed on a second surface of the substrate, the first surface being opposite the second surface." Section X.A.3.d, *supra*. Philipp in view of the knowledge of a POSITA discloses "the drive and sense electrodes being made of a conductive mesh of conductive material comprising metal." A POSITA would have found it obvious, and would have been motivated, to combine the disclosure of Philipp with that of Hsu.

86. As discussed above in Section VIII.B, mesh electrodes were known in the art. Indeed, Philipp discloses mesh electrodes 32, 34, 38, 40, 42 having diamond shapes in Figs. 3A-3B very similar to those disclosed in Hsu:

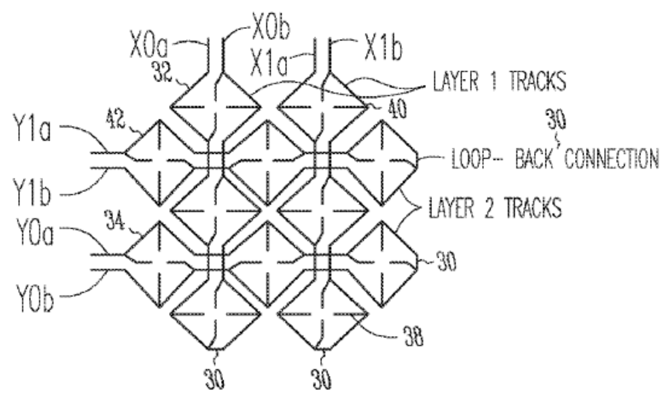


Fig.3A

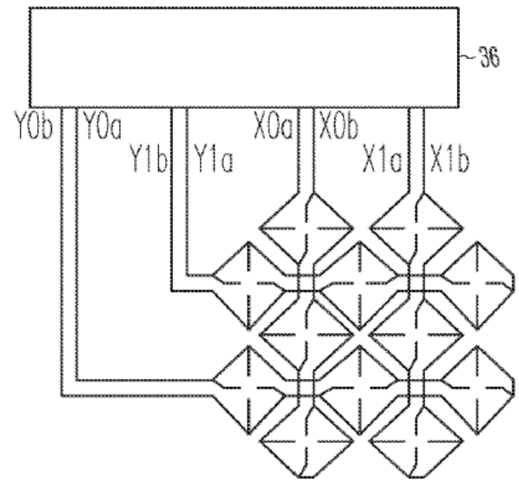


Fig.3B

EX1010, ¶ [0052]. Philipp is directed toward an improvement in capacitive touch screens, such as those touch screens typically having a transparent substrate with transparent conductive coatings formed of fine-line printed metal formed on both sides of a PET substrate. *Id.*, ¶¶ [0007], [0008]. Philipp discloses that forming electrodes from a conductive mesh improves electrodes in touch screens by improving electrical performance without sacrificing optical quality by reducing the metal densities and providing alternate paths around defects. *Id.*, ¶¶ [0007], [0008], [0011]. For example, fine line electrodes (*i.e.*, conductive mesh) with less than 5% metal coverage of the total screen area is "nearly as effective in propagating [electric] fields as the solid surfaces they replace." *Id.*; *see also id.*, ¶[0034] ("These fine metal traces can also be used to develop field-emitting structures, using a sparse mesh configuration which has been shown to emit copious amounts of electric field, almost the same as a solid electrode shape.").

The conductors in the mesh have a very small width such that the conductors are essentially invisible. *Id.*, ¶¶ [0008], [0011], [0018], [0034]. Philipp discloses that the conductors may be formed from metals including copper, gold, silver, and other metals and alloys thereof. *Id.*, ¶ [0007].

87. Philipp further discloses that these electrodes can be arranged in two layers separated by a dielectric substrate. *Id.*, ¶ [0014]. While claim 1 does not require that either drive or sense electrodes be on one side or another (particularly in light of claim 7), in such embodiments with dedicated touch and sense electrodes, it would have been obvious to a POSITA for the sense electrodes to be located on one side of the substrate and the drive electrodes to be located on the other side of the substrate as such an arrangement was well-known in the art for mutual capacitance-type touch screens. *See, e.g.,* EX1009, ¶ [0009] and Fig. 21. A POSITA would also have found this arrangement obvious because a POSITA would have recognized that it eliminates the need to provide either (1) separate substrates for each of the drive and sense electrodes, or (2) an additional dielectric layer between the electrodes if all of the electrodes are on the same side of a single substrate.

88. A POSITA would have been motivated to combine the teachings of Philipp with those of Hsu at least because substituting elements of Philipp for certain elements of Hsu would have yielded predictable results and would have

been reasonably successful. For example, a POSITA would have been motivated to substitute the metal mesh electrodes with diamond shapes as taught by Philipp for the ITO electrodes with diamond shapes as taught by Hsu in the embodiment of Hsu's Fig. 7 in order to obtain the benefit of improved electrical performance without sacrificing optical quality as taught by Philipp. A POSITA would further have been motivated to configure Hsu's system to utilize these electrodes as drive or sense electrodes in two layers separated by a substrate as taught by Philipp. A POSITA would have had a reasonable expectation of success in doing so given the similarities in the capacitive touch screens of Hsu and Philipp and the express teachings of Philipp.

89. As another example, a POSITA would have been motivated to substitute the metal mesh electrodes of Philipp for the ITO electrodes of Hsu in order to reduce the metal densities of the electrodes and provide alternate paths around any defects in the electrodes. A POSITA would have predictably found that the metal mesh electrodes with low metal densities of Philipp that replace the ITO electrodes of Hsu propagate nearly the same electrode field as the ITO electrodes. *See* EX1010 ¶¶[0007], [0034]. Both Hsu and Philipp disclose that the electrodes can be made from, for example, silver or gold. EX1004, 4:57-59; EX1010 ¶[0007]. A POSITA would have further been motivated to substitute the metal mesh electrodes of Philipp for the electrodes of Hsu at least because robust

improvements in performance can be achieved without sacrificing optical quality. This can be achieved because breaks in the metal mesh electrodes are cured by alternate paths around the defects, which provide for higher yields during the manufacturing process, and therefore manufacturing costs can be reduced. *See* EX1010 ¶¶[0003], [0008], [0034]. Thus, a POSITA would have had a reasonable expectation of success in substituting the metal mesh electrodes of Philipp for the ITO electrodes of Hsu.

e. 1.c: "a display separated from the second surface of the substrate by a second OCA and a second cover sheet such that at least a portion of the second cover sheet is positioned between the second surface of the substrate and the display"

8.d: "a display separated from the second surface of the substrate by a second OCA and a second cover sheet such that at least a portion of the second cover sheet is positioned between the second surface of the substrate and the display"

15.c: "a display separated from the second surface of the substrate by a second OCA and a second cover sheet such that at least a portion of the second cover sheet is positioned between the second surface of the substrate and the display"

90. As discussed above for Ground 1, Hsu in view of the knowledge of a POSITA discloses this claim limitation. Section X.A.3.e, *supra*.

f. 8.e: "one or more computer-readable non-transitory storage media embodying logic that is configured when executed to control the touch sensor"

91. As discussed above for Ground 1, Hsu in view of the knowledge of a POSITA discloses this claim limitation. Section X.A.3.f, *supra*.

g. 2.: "The apparatus of claim 1, wherein the conductive material is copper, silver, gold, aluminum, or tin."

9.: "The device of claim 8, wherein the conductive material is copper, silver, gold, aluminum, or tin."

92. Philipp discloses that the conductive material that forms the mesh electrodes is ***copper***, ***silver***, ***gold***, or other metals and alloys. EX1010, ¶¶ [0007], [0033] (emphasis added). A POSITA would have found it obvious, and would have been motivated, to use the same materials described in Philipp, and thus in Hsu's Fig. 7 embodiment as discussed above for claim limitation 1.b, because the mesh of Figs. 3A-3B of Philipp is similar to the diamond-shaped mesh of Hsu. EX1010, ¶¶ [0007], [0033], [0052], [0053]. While Aluminum and Tin are not explicitly called out by Philipp, these would be obvious to a POSITA since these are other metals with high electronic conductivity, as specifically called for by Phillipp.

h. 3.: "The apparatus of claim 1, wherein the conductive mesh comprises a plurality of mesh segments, each of the mesh segments having a width of approximately 10 µm."

10.: "The device of claim 8, wherein the conductive

mesh comprises a plurality of mesh segments, each of the mesh segments having a width of approximately 10 μm.”

93. Philipp discloses that “the conductive mesh comprises a plurality of mesh segments.” For example, Philipp discloses that “vertical columns 32, 40 and horizontal rows 34, 42 of diamonds which are interconnected so as to form an interleaved electrode set in both the X and y axis.” EX1010, ¶[0052]. Philipp also discloses that metal “in-fill” is used “to increase the effective surface area.” *Id*. The “interconnected” portions and “in-fill” of the electrode columns and rows are the recited “plurality of mesh segments.” Philipp further discloses that the line geometries of the mesh segments in Philipp “are 10 μm wide or less.” EX1010, ¶¶ [0007], [0008], [0012], [0033], [0034]. A POSITA would have found it obvious, and would have been motivated, to use the same line geometries as the mesh segments in Philipp with the electrodes having diamond shapes, and thus in Hsu’s Fig. 7 embodiment as discussed above for claim limitation 1.b, because the mesh of Figs. 3A-3B of Philipp is similar to the diamond-shaped mesh of Hsu. EX1010, ¶¶ [0028], [0052].

i. 4.: “The apparatus of claim 3, wherein approximately 5% of an active area of the touch sensor is covered by the one or more mesh segments.”

11.: “The device of claim 10, wherein approximately

5% of an active area of the touch sensor is covered by the mesh segments."

94. Philipp discloses that the mesh electrodes cover 5% or less of the total area covered by the mesh electrodes of the total screen area. EX1010 ¶¶ [0007], [0013], [0034]. A POSITA would have found it obvious, and would have been motivated, to configure the embodiment of Figs. 3A-3B of Philipp such that the mesh electrodes covered approximately the same surface area as Philipp's disclosure that this amount of coverage was desirable. Thus, assuming that an area covered by the mesh electrode (i.e., excluding any spaces between the mesh electrode) is the claimed "active area," Philipp discloses this limitation.

95. To the extent that "active area" is construed to refer to the entire area of the touch sensor rather than just the areas of the touch sensor covered by electrodes, the combination of Hsu and Philipp discloses this limitation. Hsu discloses that the electrodes with diamond shaped conductors shown in Figs. 5A and 5B should be positioned and sized such that the Y trace diamonds 72 fill in the spaces between the X traces 66, so that the sensor 36 appears to have a single uniform layer of transparent conductive material as shown in Fig. 5C. EX1004, 7:4-22.

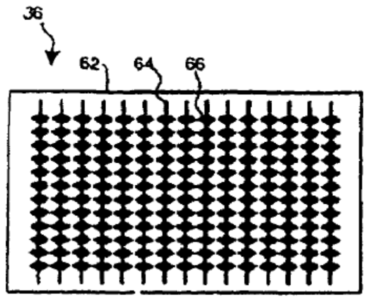


Figure 5A

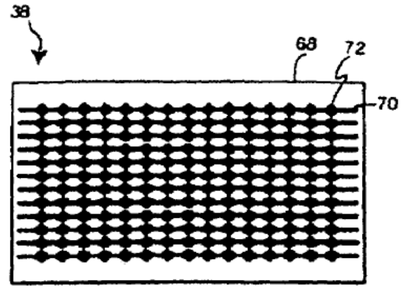


Figure 5B

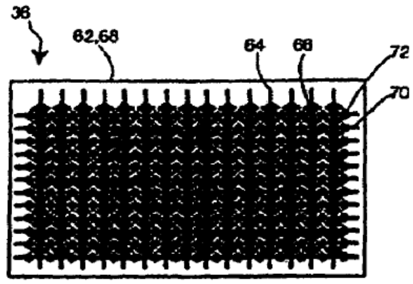


Figure 5C

96. In an embodiment such as shown in Fig. 5C with the diamond areas 66 of the Y electrodes 64 positioned in the diamond shaped areas between the X electrodes on the opposite substrate so as to create a single uniform layer of conductive material, if electrodes are formed from meshes with 5% the mesh area covered by the electrical conductors as taught by Philipp, the result is that approximately 5% of the touch sensor active area is covered by mesh segments.

j. 6.: "The apparatus of claim 1, wherein the conductive meshes have an optical transmissivity of approximately 90%."

13.: "The device of claim 8, wherein the conductive meshes have an optical transmissivity of approximately 90%."

97. As discussed above for Ground 1, the '574 patent indicates that the transmissivity of a conductive mesh may be determined based on the percentage of

the surface area covered by the conductors of the conductive mesh. Section X.A.3.j, *supra*.

98. Philipp discloses mesh electrodes with metal traces that cover 10% or less of the area of each electrode (i.e., 10% of the area covered by the mesh electrode is covered by the conductors that make up the mesh), and more preferably 5% or less of the electrode area. EX1010, ¶ [0013]. This disclosure would have rendered obvious to a POSITA a mesh electrode with conductors covering 10% of the electrode area as 10% is within the range disclosed by Philipp. In this regard, the '574 patent does not ascribe any criticality to an optical transmissivity of 90%.

99. As discussed above, Hsu discloses that the electrodes with diamond-shaped conductors shown in Figs. 5A and 5B should be positioned and sized such that the Y trace diamonds 72 fill in the spaces between the X traces 66 such that the sensor 36 appears to have a single uniform layer of transparent conductive material as shown in Fig. 5C. EX1004, 7:4-22.

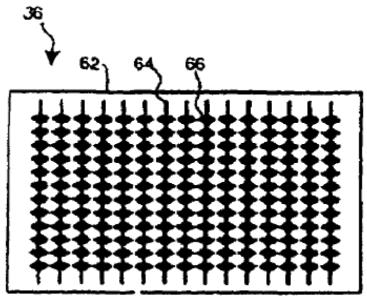


Figure 5A

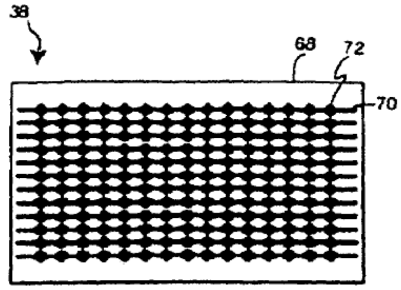


Figure 5B

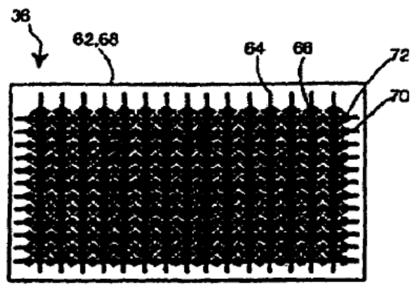


Figure 5C

In an embodiment such as shown in Fig. 5C with the diamond areas 66 of the Y electrodes 64 positioned in the diamond shaped areas between the X electrodes on the opposite substrate so as to give the appearance of a single uniform layer of conductive material as disclosed by Hsu, if electrodes are formed from meshes with 10% of the mesh area covered by the electrical conductors that form the mesh as made obvious by Philipp, then the combined transmissivity of the meshes would be 100% - 10% = 90%. This is because any particular area is covered by only one or the other of the X electrodes and the Y electrodes, each of which includes conductors that cover only 10% of the surface area.

k. 7.: "The apparatus of claim 1, wherein the sense electrodes being disposed on the first surface of the substrate and the drive electrodes being disposed on the second surface of the substrate."

14.: "The device of claim 8, wherein the sense electrodes being disposed on the first surface of the substrate and the drive electrodes being disposed on the second surface of the substrate."

100. As discussed above in connection with Section X.A.3.d, Hsu discloses a "transparent substrate 86" with an upper surface onto which a transparent conducting layer 64 containing an X pattern has been coated, and a lower surface onto which a transparent conducing layer 70 containing a Y pattern has been coated. EX1004, 8:3-21. A POSITA would have found it obvious to utilize the electrodes of one pattern as drive electrodes and the electrodes of the other pattern as sense electrodes. In addition, Philipp discloses that, in some embodiments, the electrodes are arranged in two layers separated by a dielectric. EX1010, ¶[0014]. This two-layer geometry of electrodes is illustrated in the diamond patterns of Figs. 3A-3B of Philipp. EX1010, ¶[0052]. As discussed in the State of the Art Section VIII.A above, it is well-known in the art to use the electrodes on one side of a transparent substrate as drive lines and the electrodes on the other side of a transparent substrate as sense lines in a mutual-capacitance configuration in a touch device. *See, e.g.*, EX1008, Fig. 1 and ¶ [0028] (in mutual capacitance systems, driving lines may be formed on a first layer and sensing lines may be formed on a second layer, and the "different layers may be different substrates, *different sides of the same substrate*, or the same side of the same substrate with

dielectric separation.") (emphasis added); EX1009, ¶[0009] and Fig. 21. A POSITA would have found it obvious to do so here.

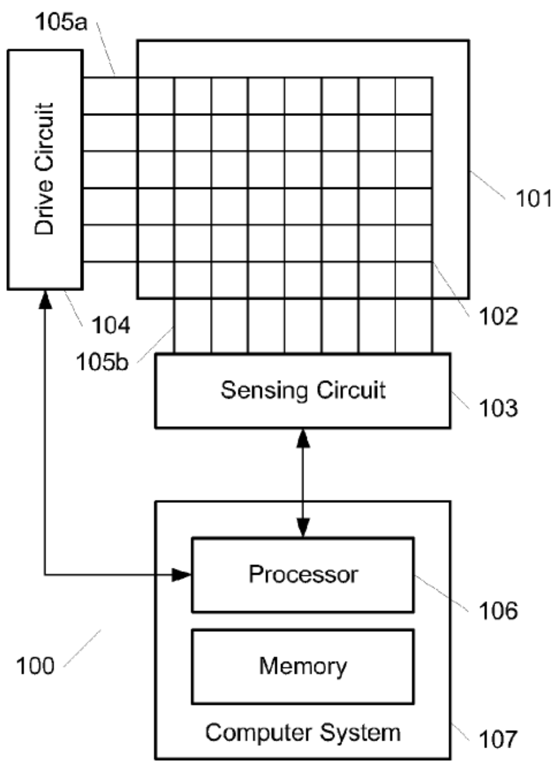


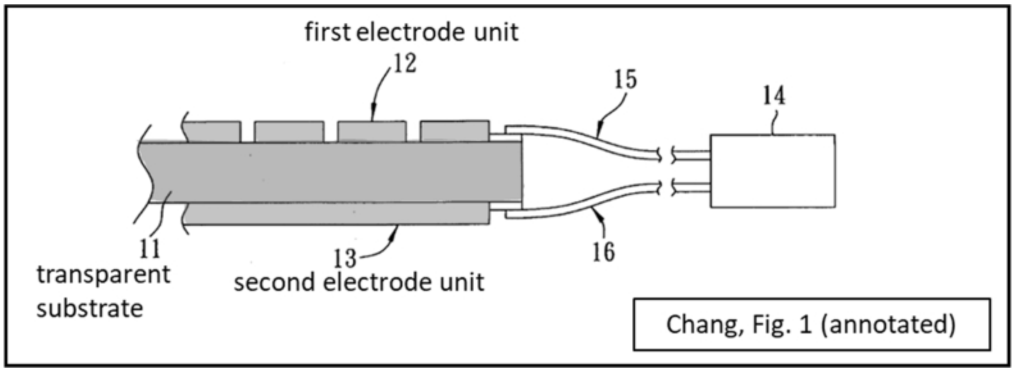
Fig. 1

C. Ground 3: Claims 1-3, 7-10, and 14-15 Are Obvious Over Hsu and Chang

1. Summary of Chang

101. Chang is directed to a "Capacitive-Type Touch Panel." See EX1011, Title and Abstract. Chang explains that "conventional capacitive-type touch panel[s]" include a first electrode unit (12, 22), a second electrode unit (13, 23),

and a transparent substrate (11, 21) or insulator layer (24) between the first and second electrode units. EX1011 ¶¶[0005]-[0006], Figs. 1 and 2.



Chang, Fig. 1 (annotated)

102. Chang states that "the first and second electrode units . . . are made from a transparent conductive material, such as indium tin oxide (ITO), which has a much higher sheet resistance compared to those of metals, such as Cu [(copper)], Ag [(silver)] and Au [(gold)]." *Id.*, ¶[0008]. Chang teaches the use of electrode sections (411 and 421, annotated in green below) having "a screen-like shape" (annotated in green shading below) that "permits enhancement in reduction of the sheet resistance of the capacitive-type touch panel." *Id.*, ¶[0036].

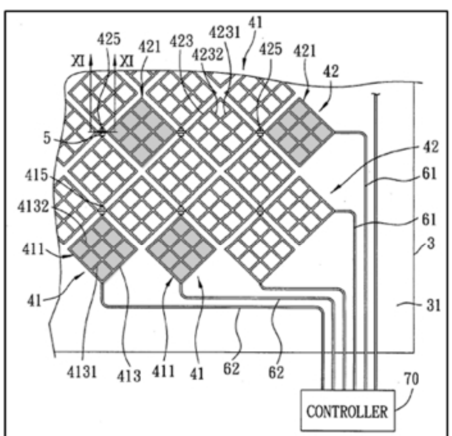


FIG. 9

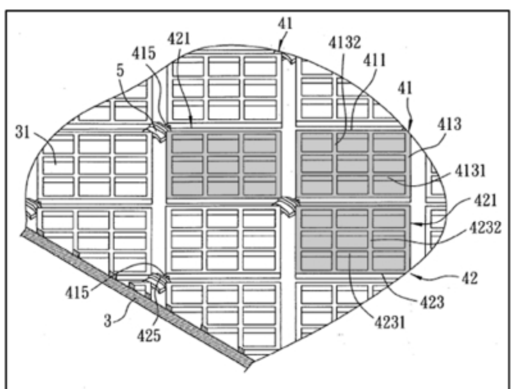


FIG. 10

EX1011, Figs. 9 and 10 (annotated)

2. Detailed Claim Analysis

103. Hsu, together with Chang and the knowledge of a POSITA, renders claims 1-3, 7-10, and 14-15 of the '574 patent obvious. The '574 claims include three groups (apparatus claims 1-7, device claims 8-14, and apparatus claim 15), each of which is partially duplicative of the other. Accordingly, as I have done previously herein, I will group together similar elements of the three claim groups for the analysis below.

a. 1.pre: "An apparatus comprising"

8.pre: "A device comprising"

15.pre: "An apparatus comprising"

104. As discussed above for Ground 1, Hsu discloses this claim limitation. Section X.A.3.a, *supra*.

b. 8.a: "a first cover sheet"

105. As discussed above for Ground 1, Hsu discloses this claim limitation. Section X.A.3.b, *supra*.

c. 1.a: "a first optically clear adhesive (OCA) layer between a first cover sheet and a substrate"

8.b: "a first optically clear adhesive layer (OCA) between the first cover sheet and a substrate"

15.a "a first optically clear adhesive (OCA) layer between a first cover sheet and a substrate"

106. As discussed above for Ground 1, Hsu discloses this claim limitation. Section X.A.3.c, *supra*.

d. 1.b: "the substrate, with drive or sense electrodes of a touch sensor disposed on a first surface and a second surface of the substrate, the first surface being opposite the second surface, the drive or sense electrodes being made of a conductive mesh conductive material comprising metal"

8.c: "the substrate, with drive or sense electrodes of a touch sensor disposed on a first surface and a second surface of the substrate, the first surface being opposite the second surface, the drive or sense electrodes being made of a conductive mesh conductive material comprising metal"

15.b: "the substrate, with sense electrodes of a touch sensor disposed on a first surface and drive electrodes of the touch sensor disposed on a second surface of the substrate, the first surface being opposite the second surface, the drive and sense electrodes being made of a conductive mesh of conductive material comprising metal"

107. As discussed above for Ground 1, Hsu discloses "the substrate, with sense electrodes of a touch sensor disposed on a first surface and drive electrodes of the touch sensor disposed on a second surface of the substrate, the first surface being opposite the second surface." Section X.A.3.d, *supra*.

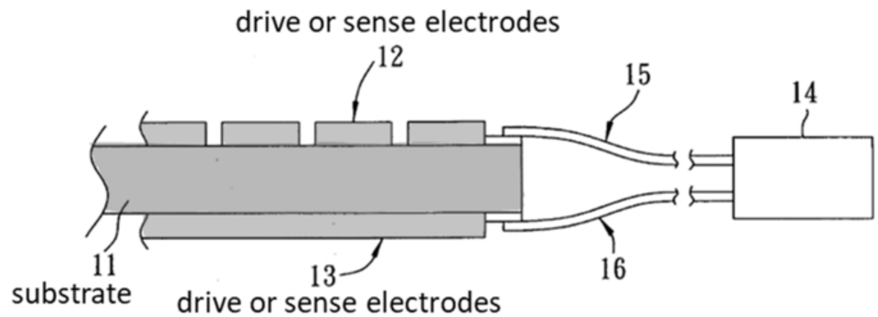
108. Hsu discloses that the drive or sense electrodes (i.e., traces in conductor layers 64 and 70) are made of a conductive material comprising metal.

See EX1004, 7:7:34-37 (referring to description of conductive layers in FIG. 2 for description of conductive layers 64 and 70), 4:57-59 (examples of transparent conductors include Indium Tin Oxide (ITO), silver, gold, and aluminum alloys). A POSITA would have understood that Indium Tin Oxide (ITO), silver, gold, and aluminum alloys are each a conductive material that comprises metal.

109. Further, it would have been obvious to a POSITA to modify the drive or sense electrodes of Hsu to be made of a conductive mesh in view of Chang.

110. According to Chang, "conventional capacitive-type touch panel[s]" include a first electrode unit (12, 22), a second electrode unit (13, 23), and a transparent substrate (11, 21) or insulator layer (24) between the first and second electrode units. EX1011 ¶¶[0005]-[0006], Figs. 1 and 2. As shown in the annotated figures below, Chang's "conventional" touch panel construction is similar to that of Hsu.

Hsu, Fig. 7 (annotated)



Chang, Fig. 1 (annotated)

111. Chang states that "conventional" touch panels permit the identification of a touch location through "a change in the capacitance between the first and second electrode units" when a user touches the panel. *Id.*, ¶[0007]. A POSITA would have understood that the "change in the capacitance between the first and second electrode units" described by Chang refers to mutual capacitance.

112. Chang states, however, that "[s]ince the first and second electrode units . . . are made from a transparent conductive material, such as indium tin oxide (ITO), which has a much higher sheet resistance compared to those of metals, such as Cu [(copper)], Ag [(silver)] and Au [(gold)], the sheet resistance of the conventional capacitive-type touch panels will be larger than 1KΩ/square and the capacitance . . . from one peripheral end to an opposite peripheral end will be larger than 400 pF (pico-farad) when the capacitive-type touch panel has

dimensions larger than 7x7 inches, which can result in relatively poor identification of coordinates of a location touched by the user, which in turn, limits production of larger sizes of the capacitive-type touch panels." *Id.*, ¶[0008].

113. To solve this problem, Chang teaches the use of electrode sections (411 and 421, annotated in green below) having "a screen-like shape." *Id.*, ¶[0036].

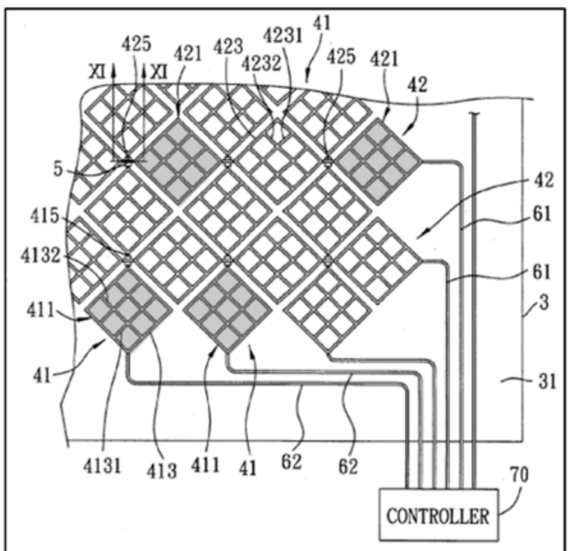


FIG. 9

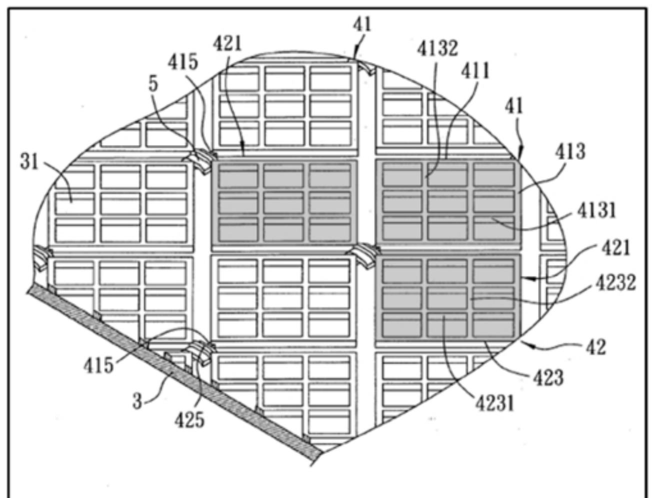


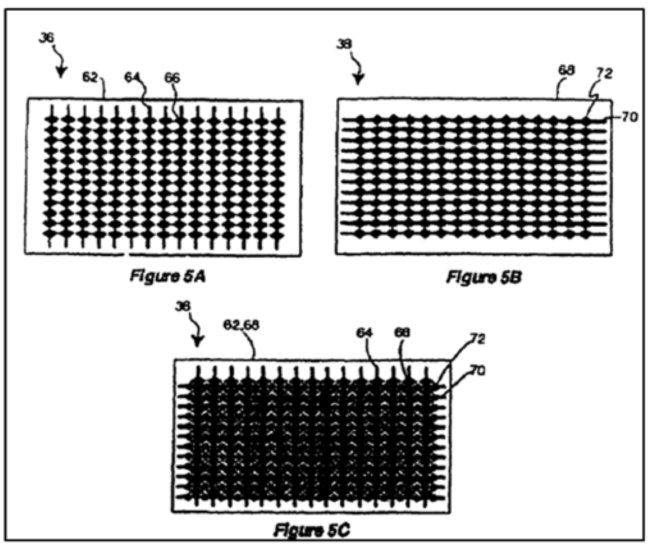
FIG. 10

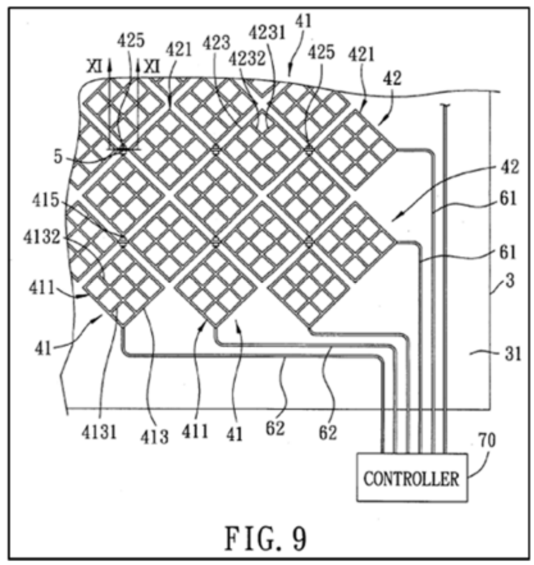
EX1011, Figs. 9 and 10 (annotated)

114. A POSITIA would have understood that Chang's "screen-like shape" is a mesh, because it includes wires that surround open spaces. For example, with reference to Figs. 9 and 10 above, each of the nine small square open areas in an electrode section 411 is surrounded by a set of four wires that are part of a larger network of wires. Chang explains that "[t]he screen-like structure permits

enhancement in reduction of the sheet resistance of the capacitive-type touch panel." *Id.*, ¶[0036].

115. Similar to Chang, Hsu's electrodes (i.e., conductor layers 64 and 70) are made of Indium Tin Oxide (ITO), silver, or gold (EX1004, 4:57-59) and include a pattern of parallelogram- or rhomboid-shaped regions ("diamonds" 66 and 72) that fill similarly shaped regions between adjacent electrodes. *See* EX1004, 6:40-50, 7:6-19, Figs. 5A-5C; EX1011, ¶¶[0029], [0035]-[0036], Fig. 9.





EX1004 (Hsu), Figs. 5A-5C EX1011 (Chang), Fig. 9

116. It would have been obvious to a POSITA to modify the diamonds (66, 72) of Hsu's electrode traces (64 and 70) to include the mesh structure (i.e., "screen-like structure") disclosed by Chang in view of Chang's teaching that "[t]he screen-like structure permits enhancement in reduction of the sheet resistance of the capacitive-type touch panel" in order to overcome negative effects of the

relatively high sheet resistance of ITO, including poor identification of coordinates and limitations on the size of capacitive-type touch panels. EX1011, ¶¶ [0008], [0036].

117. A POSITA would have had a reasonable expectation that modifying Hsu's electrodes to be made of mesh material as taught by Chang would successfully yield "drive or sense electrodes being made of a conductive mesh." Hsu and Chang describe similarly shaped and arranged electrodes made of similar materials. *See* EX1004, 4:57-59, 6:40-50, 7:6-19, Figs. 5A-5C; EX1011, ¶¶[0029], [0035]-[0036], Fig. 9. And a POSITA would have readily expected that forming electrodes with the shape described by Chang would achieve the recited "electrodes being made of a conductive mesh." For instance, Chang explains that the mesh electrodes can be achieved by simply changing the shape of the electrode. EX1011, ¶[0036] (describing the embodiments of Fig. 9-11 as "the first and second conductors 41, 42 [having] *a screen-like shape*."). (Emphasis added). Chang also teaches that the conductors can be made using "vapor deposition techniques," which a POSITA would have understood was well-known. *Id*. ¶[0029].

e. 1.c: "a display separated from the second surface of the substrate by a second OCA and a second cover sheet such that at least a portion of the second cover sheet is positioned between the second surface of the substrate and the display"

8.d: "a display separated from the second surface of the substrate by a second OCA and a second cover

sheet such that at least a portion of the second cover sheet is positioned between the second surface of the substrate and the display"

15.c: "a display separated from the second surface of the substrate by a second OCA and a second cover sheet such that at least a portion of the second cover sheet is positioned between the second surface of the substrate and the display"

118. As discussed above for Ground 1, Hsu discloses this claim limitation. Section X.A.3.e, *supra*.

f. 8.e: "one or more computer-readable non-transitory storage media embodying logic that is configured when executed to control the touch sensor"

119. As discussed above for Ground 1, Hsu discloses this claim limitation. Section X.A.3.f, *supra*.

g. 2.: "The apparatus of claim 1, wherein the conductive material is copper, silver, gold, aluminum, or tin."

9.: "The device of claim 8, wherein the conductive material is copper, silver, gold, aluminum, or tin."

120. Hsu in view of Chang discloses the apparatus of claim 1 (*see* claim 1 analysis, *supra*), and Hsu further discloses that the conductive material is copper, silver, gold, aluminum, or tin. EX1004, 4:57-59 ("Examples of substantially transparent conductors include . . . Indium Tin Oxide (ITO) . . . silver, [and] gold."), 7:15-19 (identifying the same materials). Chang also discloses that the conductor material can be copper, silver, gold, or aluminum. EX1011, ¶0029].

h. 3.: "The apparatus of claim 1, wherein the conductive mesh comprises a plurality of mesh segments, each of the mesh segments having a width of approximately 10 µm.

121. Hsu in view of Chang discloses the apparatus of claim 1 (*see* claim 1 analysis, *supra*). Hsu further discloses that the conductors (i.e., traces of conductor layers 64 and 70) comprise a plurality of segments referred to as "diamonds," as shown in Figs. 5A-5C using reference numbers 66 and 72. *See* EX1004, 6:40-50. Hsu describes the conductors as "relatively thin" and "transparent" or "substantially transparent" but does not explicitly disclose that each segment has a width of approximately 10 µm or that each segment is a "mesh segment." EX1004, 6:38-50, 7:34-41, 8:1-10.

122. Chang discloses the use of a "mesh [that] comprises a plurality of mesh segments." For example, Chang discloses, with reference to Fig. 9, that "each of the first and second electrode sections 411,421 of the first and second conductors 41, 42 has a plurality of intersected weft and warp metal lines 4131, 4132 (4231, 4232)." EX1011, ¶[0036]. The "intersected weft and warp metal lines" are the recited "plurality of mesh segments." It would have been obvious to a POSITA to modify the "diamond" segments of Hsu to be mesh segments in view of Chang for the same reasons discussed with respect to claim element 1.b, *supra*.

123. Chang also teaches that mesh ("screen-like") electrode sections 411 and 421 have a "fine conductor line-constructed structure which is constructed

from a fine line-shaped conductor having a dimension that permits the fine line-shaped conductor to be substantially not visible to the naked eye." EX1011 ¶[0029]. Chang teaches that the fine line-shaped conductor has a layer thickness less than 250 angstroms (i.e., less than 0.025 µm), preferably ranging from 10-50 angstroms (i.e., 0.001-0.005 µm). *Id.* Chang also teaches using a line width of less than 200 microns (i.e., less than 200 µm) "so as to be substantially not visible to the naked eye." *Id.* Thus, Chang teaches that electrode components are substantially not visible to the naked eye along a given dimension (either thickness or width) when the dimensional length is less than 200 µm, which encompasses 10 µm.

124. It would have been obvious to a POSITA to modify the "diamond" segments of Hsu to have a width of approximately 10 µm in view of Chang because Hsu's conductor layers are intended to be "transparent" or "substantially transparent" for use "directly on top of a display device like and LCD screen" (EX1004, 6:38-50, 7:34-41, 8:1-10, 9:36-48), and Chang teaches that electrode segments are "substantially not visible to the naked eye" with a dimensional length less than 200 µm, including between 200 µm and 0.001 µm, which encompasses 10 µm.

i. 7.: "The apparatus of claim 1, wherein the sense electrodes being disposed on the first surface of the

substrate and the drive electrodes being disposed on the second surface of the substrate."

125. A POSITA would have understood that Hsu's "conductor 64" that "contains the X trace pattern," which is disposed on the first surface of substrate 86 (*see*, *e.g.*, EX1004, 8:1-7, Fig. 7) is a sense electrode as meant by the '574 patent.

126. To the extent Respondent argues that Hsu's conductor 64 does not include sense electrodes, Hsu discloses that the stacked layers of sensor 36 "can be reversed in order without loss of functionality. EX1004, 7:24-25; *see also id*., 5:16-17. Thus, whether the traces of conductor layer 64 or 70 are considered "drive" or "sense" electrodes, a POSITA would have understood that their order in the stack can be reversed such that the sense electrodes are disposed on the first surface of the substrate and the drive electrodes are disposed on the second surface of the substrate.

127. Furthermore, disposing the sense electrodes on the first surface and the drive electrodes on the second surface would have been obvious to a POSITA as a mere rearrangement of parts because reversing the order of the stacked layers would not change the operation of Hsu's sensor 36. *See* EX1004, 7:24-25 (reversing the order does not change functionality).

D. Ground 4: Claims 4, 6, 11, and 13 Are Obvious Over Hsu in view of Chang and Frey.

1. Summary of Frey

128. Frey discloses a touch screen sensor (100) with a touch sensing area (105) having a "visible light transparent region (101)," which includes "an electrically conductive micropattern 140 disposed on or in [a] visible light transparent substrate 130." EX1012, ¶¶ [0056]-[0057].

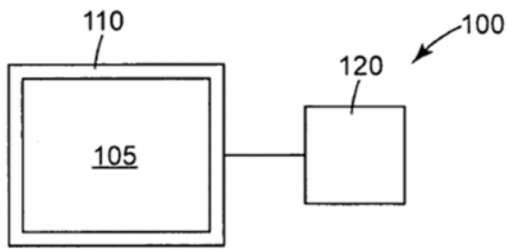
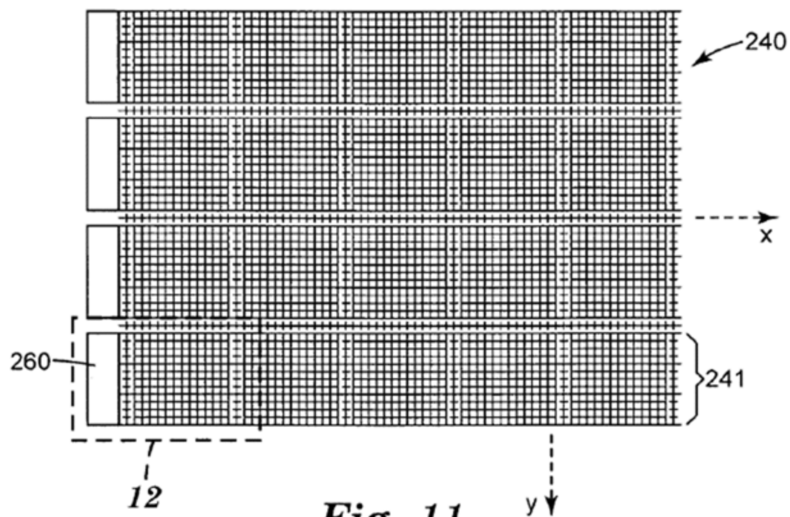


Fig. 1

EX1012, Fig. 1

129. Frey describes certain attributes of "[a]ppropriate micropatterns of conductor for achieving transparency of the sensor and viewability of a display through the sensor," including "an area fraction of the sensor that is shadowed by the conductor of . . . less than 10%, or less than 5%, . . . or less than 0.5%." *Id*. ¶[0074]. Frey also teaches that a touch screen sensor preferably has greater than 85% visible light transmittance (*id*., ¶[0006]) and provides an example achieving approximately 91% visible light transmittance using a mesh electrode pattern (*id*., ¶[0150]), as shown below.



EX1012, Fig. 11 (mesh electrode pattern)

2. Detailed Claim Analysis

130. The ’574 claims include three groups (apparatus claims 1-7, device claims 8-14, and apparatus claim 15), each of which is partially duplicative of the other. Accordingly, I again will group together similar elements of the three claim groups for the analysis below.

131. Hsu, together with Chang and Frey, and in view of the knowledge of a POSITA, renders claims 4, 6, 11, and 13 of the ’574 patent obvious.

a. 4: “The apparatus of claim 3, wherein approximately 5% of an active area of the touch sensor is covered by the one or more mesh segments.”

11: “The device of claim 10, wherein approximately

5% of an active area of the touch sensor is covered by the mesh segments."

132. Hsu in view of Chang discloses the apparatus of claim 3. *See* analysis, *supra*. Hsu's sensor is "transparent" or "substantially transparent." EX1004, 6:38-50, 7:34-41, 8:1-10.

133. Hsu explains that "in many applications it is desirable to display the surface underlying [a] touchpad. For example, the touchpad can be overlaid on an active display such as a LCD or CRT screen to facilitate input to a graphical user interface (GUI)." EX1004, 1:27-31. Hsu also explains that "transparent" conductive materials, including, gold, silver, and ITO are not "perfectly transparent," and that regions not covered by such "transparent" conductive material are even more visible. *Id*. at 7:15-22.

134. Further, Frey discloses a touch screen sensor (100) with a touch sensing area (105) having a "visible light transparent region (101)," which includes "an electrically conductive micropattern 140 disposed on or in [a] visible light transparent substrate 130." EX1012, ¶¶ [0056]-[0057]. Frey also describes certain attributes of "[a]ppropriate micropatterns of conductor for achieving transparency of the sensor and viewability of a display through the sensor," including "an area fraction of the sensor that is shadowed by the conductor of . . . less than 10%, or less than 5%, . . . or less than 0.5%." *Id*. ¶[0074]. A POSITA would have appreciated that the "area fraction of the sensor that is shadowed by the conductor"

is an active area of the touch sensor covered by conductive electrode elements. POSITA would have also understood Frey as teaching that approximately 5% of an active area of the touch sensor covered by conductive electrode elements would achieve transparency of the sensor and viewability of a display through the sensor.

135. It would have been obvious to a POSITA to modify the sensor of Hsu such that that approximately 5% of an active area of the touch sensor is covered by conductive electrode elements in order to achieve transparency of the sensor and viewability of a display through the sensor, as taught by Frey, which is consistent with the intended application of Hsu's sensor, i.e., to be combined with a display device. *See* EX1004, 9:36-48; EX1011 ¶[0074].

136. Furthermore, Hsu's stated objective is to provide a "flexible and transparent object position recognition device[] useful in applications such as cursor movement and user input for computing devices and other applications" and recognizes that regions not covered by "transparent" conductive material are indeed transparent. EX1004, 1:8-12, 7:15-22. Thus, it would have been obvious to a POSITA to modify Hsu's transparent touch sensing system in view of Frey's teachings to achieve improved sensor transparency and viewability of an underlying display, as taught by Frey, in accordance with Hsu's goals. *See id*.

b. 6: "The apparatus of claim 1, wherein the conductive meshes have an optical transmissivity of approximately 90%."

13: "The device of claim 8, wherein the conductive meshes have an optical transmissivity of approximately 90%."

137. Hsu in view of Chang discloses the apparatus of claim 1. *See* analysis, *supra*. Hsu's sensor is "transparent" or "substantially transparent" EX1004, 6:38-50, 7:34-41, 8:1-10.

138. Further, Frey teaches that "[t]he sensing area of a touch sensor is that region of the sensor that is intended to overlay, or that overlays, a viewable portion of an information display and is visible light transparent in order to allow viewability of the information display." EX1011 ¶[0052]. To that end, Frey teaches that a touch screen sensor preferably has greater than 85% visible light transmittance (*id*., ¶[0006]) and provides an example achieving approximately 91% visible light transmittance using a mesh electrode pattern (*id*., ¶[0150]).

139. It would have been obvious to a POSITA to modify the sensor of Hsu such that that the conductive mesh has an optical transmissivity of approximately 90% to allow viewability of an underlying information display, as taught by Frey, which is consistent with the intended application of Hsu's sensor, i.e., to be combined with a display device. *See* EX1004, 9:36-48; EX1011 ¶[0074].

XI. SECONDARY CONSIDERATIONS

140. I am informed that neither Patent Owner nor the '574 patent applicants identified any secondary considerations of non-obviousness with respect to the '574 patent.

141. I reserve the right to supplement this declaration should any evidence of secondary considerations of non-obviousness with respect to the '574 patent be produced during this proceeding.

XII. CONCLUSION

142. Claims 1-4, 6-11, and 13-15 of the '574 patent should be found unpatentable and should be canceled for the reasons I set forth above.

I hereby declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct, and that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true. I understand that willful false statements are punishable by fine or imprisonment or both. *See* 18 U.S.C. § 1004.

Date: February 14, 2020

By: Vivek Subramanian
Vivek Subramanian, Ph.D.

EXHIBIT A

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Education

3 / 96 - 6 / 98
Ph.D. in Electrical Engineering, Stanford University
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Honors earned: Graduate Fellowship, Eastman Kodak Company

9 / 94 - 3 / 96
MS in Electrical Engineering, Stanford University
Stanford, California

8 / 90 - 5 / 94
BS in Electrical Engineering, Louisiana State University
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Honors earned: Summa cum laude, College Honors, Outstanding Senior, Junior and Sophomore, Honors College

Professional Experience

2018 - present
École polytechnique fédérale de Lausanne
Switzerland
8/18 – present: Professor of Microengineering

2000 - present
Department of Electrical Engineering & Computer Sciences, University of California
Berkeley, CA
7/18 – present: Chancellor's Professor
7/11 – present: Professor
7/05 – 7/11: Associate Professor
7/00-7/05: Assistant Professor
Research, teaching and service in EECS Department
Honors Earned:
- 2015 IEEE Kiyo Tomiyasu Award
- Best in session and best in track awards, 2013 IMAPS Microelectronics Conference
- Outstanding paper award, 2012 IMAPS Microelectronics Conference
- 2008 Printed Electronics Champion, Printed Electronics USA Conference, November 2008
- Outstanding Teaching Award, EECS Department, UC Berkeley, 2005
- Best paper award, 2004 IEEE Device Research Conference
- Nominated to MIT's Technology Review top 100 young innovators list (TR100), 2002
- National Science Foundation Young Investigator (CAREER) Award, FY2002,
- Nominated to National Academy of Engineering's *Frontiers of Engineering*, 2002
- Winner of 2002 Paul Rappaport Award for best paper in an IEEE EDS Journal

2009 - present
Adjunct Professor, Sunchon National University
Sunchon, Korea
2013 to date: Adjunct Professor, BK21 Program
2009-2013: Adjunct Professor and Principal Investigator, WCU Program
Initiated, managed, and contributed to large multinational research program focused on printed electronics, including displays, energy devices, and RFID

2000 - present
Independent Consultant
Orinda, CA
Consultant to the semiconductor industry and its associated fields in the following areas:
- Memory technology and design, Silicon Process Technology
- Display / Imager and Flexible Electronics Technology, RFID Technology
- Intellectual Property Consulting
- Technology Evaluation / Venture Capital due diligence

2014- present

Founder and CTO, Locix Inc.
San Bruno, CA
Senior leadership role in venture-funded startup company working on wireless networking

2004 – 2013

Founding Scientific Advisor, Kovio, Inc.
Sunnyvale, CA
Scientific advising to printed electronics startup company

2008 - 2011

Chief Technical Advisor, QuSwami, Inc.
San Francisco, CA
Scientific advising to energy conversion device startup company
Served as CTO from July 2010-June 2011

1998 - 2000

Consulting Assistant Professor, Electrical Engineering Department, Stanford University.
Stanford, CA
Advisory role for research group of Prof. Krishna C. Saraswat

1998-2000

Visiting Research Engineer, Electrical Engineering Department, University of California.
Berkeley, CA
Research into 25nm MOSFET technologies for giga-scale integration

1998 - 2000

Founder, Matrix Semiconductor, Inc.
Santa Clara, CA
Co-founder and technical advisor of startup company working on high-density memory technology
Honors Earned:
Nominated to Scientific American's SA50 List for Visionary Technology
Finalist for 2003 World Technology Award for Information Technology Hardware
Winner, 2005 EDN Innovation Award

1998

Co-instructor, Electrical Engineering Department, Stanford University.
Stanford, CA
Co-teaching of EE311, Advanced Integrated Circuit Fabrication Processes

1997

Intern, Advanced Product Research and Development Laboratory, Motorola Inc.
Austin, TX
Research into process development issues affecting SiGe SEMFET devices

1996

Head Teaching Assistant EE410: IC Fabrication Laboratory, Stanford University
Stanford, CA
Coordination and instruction of EE410, graduate level laboratory course.

1994-1998

Research Assistant, Electrical Engineering, Stanford University
Stanford, CA
Research into crystallization of amorphous Si and SiGe films using low thermal budget processes.

Professional Affiliations and Activities

Technical Program Committee, IEEE Electronic Components and Technology Conference, 2014 to 2016
Chair, Scientific Advisory Board, iPACK, Royal Institute of Technology (KTH), Sweden, 2011 to 2016
Tampere Institute of Technology Faculty Search Committee, Finland, 2013
University of Oulu Faculty Search Committee, Finland, 2013
Served as external thesis committee member for several universities world-wide, including University of Cape Town (South Africa), Tampere Institute of Technology (Finland), Technical University of Eindhoven (Netherlands), Indian Institute of Science (India), Indian Institute of Technology (India), 2009 to date
Associate Editor, IEEE Journal of Display Technology, 2008 to date
Technical Program Chair, Large Area, Organic, and Printed Electronics Conference, 2012-2013
Scientific Committee, Large Area, Organic, and Printed Electronics Conference, 2009-2011
Scientific Committee, International Conference on Printed and Flexible Elecronics, 2009-2013
IEEE Electron Devices Society Organic Electronics Committee, 2003 - 2005
Executive Committee, International Electron Device Meeting, 2003 to 2009
Technical Program Committee, International Electron Device Meeting, 2001-2002
Technical Program Committee member, Device Research Conference, 2000-2002
Technical Program Committee member, VLSI-TSA Conference, 2005
Member, Institute of Electrical and Electronic Engineers

List of cases worked on by Vivek Subramanian

Completed

- Lexar Media v. Pretec Electronics Corp., et al (N.D. Cal., Case No. 00-CV-4770 MJJ, deposition) – retained by Pretec Electronics Corp, PNY Electronics, Memorex

- Motorola, Inc. v. Analog Devices, Inc., Civil Action No. 1:03-CV-0131 – retained by Analog Devices

- *Sandisk Corporation vs. Micron*, Case No. CV-01-3855 CW – retained by Micron

- In the Matter of CERTAIN NAND FLASH MEMORY CIRCUITS AND PRODUCTS CONTAINING SAME (ITC, Investigation No. 337-TA-526, deposition and trial) – retained by STMicroelectronics

- In the Matter of CERTAIN NAND FLASH MEMORY DEVICES AND PRODUCTS CONTAINING SAME (ITC, Investigation No. 337-TA-553, deposition and trial) – retained by Hynix

- In the Matter of CERTAIN NOR AND NAND FLASH MEMORY DEVICES AND PRODUCTS CONTAINING SAME (ITC, Investigation No. 337-TA-560, deposition and trial) – retained by STMicroelectronics

- STMicroelectronics, Inc. v. SanDisk Corporation (E.D. Texas, Civil Action No. 4:05-CV-45, deposition) – retained by STMicroelectronics

- Sandisk Corporation v. Memorex Products, Inc. et al, CV 01-4063 – retained by Memorex.

- Seagate Technology LLC et al v. STEC, Inc., Case No. 5:08-CV-01950 JW (HRL) – retained by STEC.

- In the Matter of CERTAIN NAND FLASH MEMORY DEVICES AND COMPONENTS THEREOF,AND PRODUCTS CONTAINING SAME (ITC, Investigation No. 337-TA-592) – retained by Hynix

- In the Matter of CERTAIN FLASH MEMORY CONTROLLERS, DRIVES, MEMORY CARDS, AND MEDIA PLAYERS AND PRODUCTS CONTAINING SAME (ITC, Investigation No. 337-TA-619, deposition and trial) – retained by Phison Electronics, Silicon Motion, Kingston, and Apacer

- Harari and Mehrotra v. Hollmer and Cleveland (Board of Patent Appeals and Interferences, Interference# 105,606, deposition) – retained by Spansion

- In the Matter of CERTAIN SEMICONDUCTOR INTEGRATED CIRCUITS USING TUNGSTEN METALLIZATION AND PRODUCTS CONTAINING SAME (ITC, Investigation No. 337-TA-648) – retained by STMicroelectronics

- In the Matter of CERTAIN SEMICONDUCTOR CHIPS HAVING SYNCHRONOUS DYNAMIC RANDOM ACCESS MEMORY CONTROLLERS AND PRODUCTS CONTAINING SAME (ITC, Investigation No. 337-TA-661, deposition and trial) – retained by NVidia

- Fast memory erase, LLC. v. Spansion, Inc. et al, Civil Action No. 3:08-CV-00977-M, retained by Spansion

- In the Matter of CERTAIN MOBILE TELEPHONES AND WIRELESS COMMUNICATIONS DEVICES FEATURING DIGITAL CAMERAS AND COMPONENTS THEREOF (ITC, Investigation No. 337-TA-663, deposition and trial) – retained by LG Electronics and Samsung Electronics

- In the Matter of CERTAIN MLC FLASH MEMORY DEVICES AND PRODUCTS CONTAINING SAME (ITC, Investigation No. 337-TA-683, deposition and trial) – retained by Samsung

- In the Matter of CERTAIN MOBILE TELEPHONES WIRELESS COMMUNICATION DEVICES FEATURING DIGITAL CAMERAS, AND COMPONENTS THEREOF (ITC, Investigation No. 337-TA-703, deposition and trial) – retained by Apple

- Vizio, Inc. v. L Electronics, Inc., et al, In the Unites States District Court For The District of Maryland, Civil action No. 1:09-CV-1481 (BEL), deposition – retained by LG

- In the Matter of CERTAIN ELECTRONIC DEVICES, INCLUDING MOBILE PHONES, PORTABLE MUSIC PLAYERS, AND COMPUTERS (ITC, Investigation No. 337-TA-701, deposition and trial) – retained by Apple

- Nokia v. Apple, 09-CV-791 and v09-CV-1002 – retained by Apple

- SanDisk Corporation v. Phison Electronics Corp., et al, In the United States District Court For The Western District of Wisconsin, Civil action No. 07-C-0605-C and 07-C-0607-C, deposition – retained by Phison Electronics Corp., Silicon Motion, Skymedi, and Kingston

- Microchip Technology Inc v. LSI Corporation and Agere Systems Inc., Case No. 2:11-cv-01326-DGC, retained by Microchip

- In the Matter of CERTAIN INTEGRATED CIRCUITS, CHIPSETS, AND PRODUCTS CONTAINING SAME INCLUDING TELEVISIONS, MEDIA PLAYERS AND CAMERAS (ITC, Investigation No. 337-TA-709, deposition and trial) – retained by Freescale Semiconductor, Inc.

- In the Matter of CERTAIN SEMICONDUCTOR PRODUCTS MADE BY ADVACNED LITHOGRAPHY TECHNIQUES AND PRODUCTS CONTAINING SAME, (ITC, Investigation No. 337-TA-729) – retained by Samsung

- In the Matter of CERTAIN MOBILE DEVICES AND RELATED SOFTWARE (ITC, Investigation No 337-TA-750, deposition and trial) – retained by Apple, Inc.

- In the Matter of CERTAIN SEMICONDUCTOR CHIPS AND PRODUCTS CONTAINING SAME (ITC, Investigation No 337-TA-753) – retained by NVidia

- In the Matter of CERTAIN MOBILE TELEPHONES AND MODEMS (ITC, Investigation No. 337-TA-758) – retained by LG.

- In the Matter of CERTAIN VIDEO GAME SYSTEMS AND WIRELESS CONTROLLERS AND COMPONENTS THEREOF (ITC, Investigation No. 337-TA-770, deposition and trial) – retained by Nintendo

- In the Matter of CERTAIN RANDOM ACCESS MEMORY DEVICES AND PRODUCTS CONTAINING SAME (ITC, Investigation No. 337-TA-595) retained by Renesas

- In the Matter of CERTAIN MICROPROCESSORS, COMPONENTS THEREOF, AND PRODUCTS CONTAINING SAME (ITC, Investigation No. 337-TA-781, deposition and trial) – retained by Intel

- In the Matter of CERTAIN DIGITAL TELEVISIONS CONTAINING INTEGRATED CIRCUIT DEVICES AND COMPONENTS THEREOF (ITC, Investigation No. 337-TA-806, deposition) – retained by Renesas

- In the Matter of CERTAIN INTEGRATED CIRCUITS, CHIPSETS, AND PRODUCTS CONTAINING SAME INCLUDING TELEVISIONS (ITC, Investigation No. 337-TA-786, deposition and trial) – retained by Freescale

- In the Matter of CERTAIN SEMICONDUCTOR INTEGRATED CIRCUIT DEVICES AND PRODUCTS CONTAINING SAME (ITC Investigation No. 337-TA-840) – retained by Microchip.

- In the Matter of CERTAIN DYNAMIC RANDOM ACCESS MEMORY AND NAND FLASH MEMORY DEVICES AND PRODUCTS CONTAINING THE SAME (ITC, Investigation No. 337-TA-803, deposition) – retained by Hynix

- AVM Technologies LLC v. Intel Corporation, Civil Action No. 10-610-RK – retained by Intel

- Round Rock Research LLC v. Dell Inc., No. 11-CV-976-RGA – retained by Dell

- Solid State Storage Solutions, Inc. v. STEC, Inc., OCZ Technology, Inc. Corsair Memory, Texas Memory Systems, Inc. PNY Technologies, Inc., Patriot Memory LLC, Fusion-IO, Inc., Other World Computing, Inc., and Mushkin, Inc., Civil Action No 2:11-CV-391, retained by Corsair, PNY, and Fusion-IO.

- Grail Semiconductor, Inc., v. Renesas Electronics America, Inc., Case No. C 11-03847, retained by Renesas.

- In The Matter of Certain Wireless Consumer Electronics Devices and Components Thereof (ITC, Inv. No. 337-TA-853), retained by Amazon.com, Acer, Barnes & Noble, Garmin, HTC, Huawei, Kyocera, LG, Nintendo, Novatel, Samsung, and ZTE.

- Invensas Corporation v Renesas Electronics Corporation, Civil Action No. 11-448-GMS-CJB, retained by Renesas (deposition)

- In the Matter of Certain Non-volatile Memory Chips and Products Containing Same (ITC, Inv. No. 337-TA-916), retained by Macronix (deposition)

- Sandisk Corporation v. PNY Technologies, Inc., Case No. 1-11-CV-205928, retained by PNY (deposition)

- *TPK Touch Solutions, Inc. v. Wintek Electro-Optics Corporation, et al.*, 3:13-cv-02218-NC (N.D. Cal.), and associated issues in front of the patent board, retained by Wintek (deposition)

- GSI Technology, Inv. V. Cypress Semiconductor Corporation, IPR2014-00121 and associated issues in front of the patent board, retained by Cypress (deposition)

- Grail Semiconductor, Inc. v Mitsubishi, Case No. 1-07-CV-098590, retained by Mitsubishi

- AVM Technologies, LLC v. Intel Corporation, C.A. No. 15-33-RGA, retained by Intel (deposition and testimony)

- Intellectual Ventures LLV v. Toshiba, C.A. No. 13-453-SLR-SRF, retained by Toshiba (deposition and testimony)

- In the Matter of CERTAIN MEMORY MODEULS AND COMPONENTS THEREOF, AND PRODUCTS CONTAINING SAME, US ITC 337-TA-1023, retained by Hynix (deposition and testimony)

- In the Matter of CERTAIN INTEGRATED CIRCUITS WITH VOLTAGE REGULATORS AND PRODIUCTS CONTAINING THE SAME, US ITC 337-TA-1024, retained by Intel (deposition)

- Technology Properties Ltd, LLC v. LG et al, Case No. 3:12-cv-03880-VC, retained by defendants.
- Longitude Licensing Ltd. V Apple, Case 3:14-CV-04275-EDL, retained by Apple.
- KAIST IP v. Samsung et al, 2:16-cv-01314-JRG-RSP – retained by Samsung (deposition and trial).
- Toshiba Corporation v Lone Star Silicon Innovations LLC, IPR – retained by Toshiba
- Samsung Electronics Co Ltd. Vs PROMOS Technologies Inc, IPRs – retained by Samsung (deposition)
- Samsung Electronics Co. Ltd vs. UUSI LLC d/b/a Narton, IPRs – retained by Samsung (deposition)
- Carl Zeiss AG and ASML v Nikon, 2:17-cv-03221 RGK – retained by ASML and Zeiss (deposition and trial testimony)
- In the matter of CERTAIN MEMORY MODULES AND COMPONENTS THEREOF (ITC, Inv. No. 337-TA-1089), retained by SK Hynix (deposition and trial testimony)
- In the Matter of CERTAIN SOLID STATE STORAGE DRIVES, STACKED ELECTRONICS COMPONENTS, AND PRODUCTS CONTAINING SAME, US ITC 337-TA-1097, retained by Samsung and Hynix (deposition)
- In the Matter of CERTAIN INFOTAINMENT SYSTEMS, COMPONENTS THEREOF, AND AUTOMOBILES CONTAINING THE SAME, US ITC 337-TA-1119, retained by Renesas, Denso, Pioneer, Panasonic, Socionext, and Toyota (deposition and trial testimony)
- In the Matter of CERTAIN MOVABLE BARRIER OPERATOR SYSTEMS AND COMPONENTS THEREOF, US ITC 337-TA-1118, retained by Chamberlain (deposition and trial testimony)
- Fereydun Tabaian and Ahmad Ashrafzadeh v Intel Corporation, 3:18-cv-326-HZ., retained by Intel

Active

- Innovative Memory Systems, Inc. v. Micron Tech, In.c 14-cv-01480 and associated IPRs, retained by Micron (deposition)
- Kingston Technology Company v. Polaris Innovations Ltd, IPRs – retained by Kingston (deposition)

- Intel Corporation v. Tela Innovations, 18-cv-02848-WHO, retained by Intel (deposition)
- VLSI Technology LLC v. Intel Corporation, 1:18-cv-00966-CFC, retained by Intel
- X2Y Attenuators LLC v. Intel Corporation, Case No. 3:18-cv-1394-HZ, retained by Intel (deposition)
- In the Matter of CERTAIN TOUCH-CONTROLLED MOBILE DEVICES, COMPUTERS, AND COMPONENTS THEREOF, US ITC 337-TA-1162, retained by Samsung et al

List of Patents, Publications and Presentations

Patents

1. "Systems and methods for coarse and fine time of flight estimates for precise radio frequency localization in the presence of multiple communication paths", Seth, M., Kong, L., Ylamurto, T., Subramanian, V., US Patent 10,470,156
2. "Methods and apparatus for monitoring wound healing using impedance spectroscopy", Maharbiz, M., Subramanian, V., Arias, A.C., Swisher, S., Liao, A., Lin, M., Pavinatto, F., Khan, Y., Cohen, D., Leeflang, E., Roy, S., Harrison, M., Young, D., US Patent 10,463,293.
3. "Systems and methods for using radio frequency signals and sensors to monitor environments", T. Bakhishev, V. Subramanian, V. Pavate T. Ylamurto, US Patent 10,156,852.
4. "Systems and methods for determining locations of wireless sensor nodes in a tree network architecture having mesh-based features", L. Kong, T. Bakhishev, T. Ylamurto, V. Subramanian, M. Seth, US Patent 10,104,508.
5. "Systems and methods for providing wireless asymmetric network architectures of wireless devices with power management features", V. Subramanian, E. Alon, V. Pavate, US Patent 10,028,220.
6. "Random delay generation for thin-film transistor based circuits", V Subramanian, M Mao, Z Wang, US Patent 9,985,664
7. "Systems and methods for determining locations of wireless sensor nodes in a network architecture having mesh-based features for localization", L. Kong, T. Bakhishev, T. Ylamurto, V. Subramanian, M. Seth, US Patent 9,846,220
8. "Systems and methods for determining locations of wireless sensor nodes in a tree network architecture having mesh-based features", L. Kong, T. Bakhishev, T. Ylamurto, V. Subramanian, M. Seth, US Patent 9,763,054
9. "Through silicon vias and thermocompression bonding using inkjet-printed nanoparticles", V. Subramanian and J. Sadie, US Patent 9,717,145
10. "Systems and methods for providing wireless asymmetric network architectures of wireless devices with anti-collision features", V. Subramanian, E. Alon, V. Pavate, US Patent 9,706,489
11. "Systems and methods for determining locations of wireless sensor nodes in an asymmetric network architecture", V. Subramanian, E. Alon, V. Pavate, US Patent 9,529,076
12. "Systems and methods for providing wireless sensor networks with an asymmetric network architecture", V. Subramanian, E. Alon, V. Pavate, US Patent 9,380,531
13. "Transparent metal oxide nanoparticle compositions, methods of manufacture thereof and articles comprising the same", V. Subramanian, S. K. Volkman, US Patent 9,343,202
14. "Three-dimensional nonvolatile memory and method of fabrication", M. G. Johnson, T. H. Lee, V. Subramanian, P. M. Farmwald, J. M. Cleeves, US Patent 9,214,243
15. "Dense arrays and charge storage devices", T. H. Lee, V. Subramanian, J. M. Cleeves, I. G. Kouznetsov, M. G. Johnson, P. M. Farmwald, US Patent 9,171,857
16. "Print compatible designs and layout schemes for printed electronics", Z. Wang, V. Subramanian, L. Cleveland, US Patent 9,155,202
17. "Wireless devices including printed integrated circuitry and methods for manufacturing and using the same", P. Smith, C. Choi, V. Pavate, J. M. Cleeves, V. Subramanian, R. Young, V. Biviano, US Patent 9,004,366.
18. "Dense arrays and charge storage devices ", T. H. Lee, V. Subramanian, J. M. Cleeves, M. G. Johnson, P. M. Farmwald, I. Kouznetzov, US Patent, 8,981,457.
19. "High reliability surveillance and/or identification tag/devices and methods of making and using the same", V. Subramanian, P. Smith, V. Pavate, A. Kamath, C. Choi, A. Chandra, J. M. Cleeves, US Patent, 8,933,806.
20. "Surveillance devices with multiple capacitors", P. Smith, C. Choi, J. M. Cleeves, V. Subramanian, A. Kamath, S. Molesa, US Patent, 8,912,890.
21. "Pillar-shaped nonvolatile memory and method of fabrication", M. G. Johnson, T. H. Lee, V. Subramanian, P. M. Farmwald, J. M. Cleeeves, US Patent 8,897,056
22. "Dense arrays and charge storage devices", T. H. Lee, V. Subramanian, J. M. Cleeves, I. G. Kouznetsov, M. G. Johnson, P. M. Farmwald, US Patent 8,853,765

23. "Dense arrays and charge storage devices", T. H. Lee, V. Subramanian, J. M. Cleeves, I. G. Kouznetsov, M. G. Johnson, P. M. Farmwald, US Patent 8,823,076
24. "Random delay generation for thin-film transistor based circuits", V. Subramanian, M. Mao, Z. Wang, US Patent 8,810,298
25. "Vertically stacked field programmable nonvolatile memory and method of fabrication", M. Johnson, T. Lee, V. Subramanian, M. Farmwald, and J. M. Cleeves, US Patent 8,503,215
26. "Process-variation tolerant series-connected NMOS and PMOS diodes, and standard cells, tags, and sensors containing the same", V. Subramanian, P. Smith, US Patent 8,471,308
27. "Printed compatible designs and layout schemes for printed electronics", Z. Wang, V. Subramanian, L. Cleveland, US Patent 8,383,952
28. "Method for making surveillance devices with multiple capacitors", P. Smith, C. Choi, J. M. Cleeves, V. Subramanian, A. Kamath, S. Molesa, US Patent 8,296,943
29. "High reliability surveillance and/or identification tag/devices and methods of making and using the same", V. Subramanian, P. Smith, V. Pavate, A. Kamath, C. Choi, A. Chandra, and J. M. Cleeves, US Patent 8,264,359
30. "High reliability surveillance and/or identification tag/devices and methods of making and using the same", V. Subramanian, P. Smith, V. Pavate, A. Kamath, C. Choi, A. Chandra, and J. M. Cleeves, US Patent 8,227,320
31. "Vertically stacked field programmable nonvolatile memory and method of fabrication", M. Johnson, T. Lee, V. Subramanian, M. Farmwald, and J. M. Cleeves, US Patent 8208282
32. "Reliable tag deactivation",J. M. Cleeves, V. Subramanian, US Patent 8138921
33. "Combined static and dynamic frequency divider chains using thin film transistors", V. Subramanian, US Patent 8085068
34. "Process-variation tolerant diode, standard cells including the same, tags and sensors containing the same, and methods for manufacturing the same", V. Subramanian, P. Smith, US Patent 7932537
35. "Three terminal nonvolatile memory Device with vertical gated diode", T. H. Lee, V. Subramanian, J. M. Cleeves, M. G. Johnson, P. M. Farmwald, I. G. Kouznetsov, US Patent 7825455
36. "Vertically stacked field programmable nonvolatile memory and method of fabrication", V. Subramanian, J. M. Cleeves, US Patent 7816189
37. "Multi-mode tags and methods of making and using the same", P. Smith, J. M. Cleeves, V. Pavate, V. Subramanian, US Patent 7750792
38. "Method of manufacturing complementary diodes", V. Subramanian, P. Smith, US Patent 7528017
39. "Vertically stacked field programmable nonvolatile memory and method of fabrication", V. Subramanian, J. M. Cleeves, US Patent 7319053
40. "Vertically stacked field programmable nonvolatile memory and method of fabrication", V. Subramanian, J. M. Cleeves, US Patent 7265000
41. "Vertically stacked field programmable nonvolatile memory and method of fabrication", V. Subramanian, J. M. Cleeves, US Patent 7160761
42. "Vertically stacked field programmable nonvolatile memory and method of fabrication", V. Subramanian, J. M. Cleeves, US Patent 7157314
43. "Dense arrays and charge storage devices", T. H. Lee, V. Subramanian, J. M. Cleeves, A. J. Walker, C. Petti, I. Kouznetzov, M. G. Johnson, P. M. Farmwald. B. Herner, US Patent 7129538
44. "Patterning three dimensional structures", C. K. Li, J. N. Knall, M. A. Vyvoda, J. M. Cleeves, V. Subramanian, US Patent 7071565
45. "Monolithic three dimensional array of charge storage devices containing a planarized layer", T. H. Lee, V. Subramanian, J. M. Cleeves, A. J. Walker, C. J. Petti, I. G. Kouznetzov, M. G. Johnson, P. M. Farmwald, and B. Herner, US Patent 6881994
46. "Thermal processing for three dimensional circuits", V. Subramanian, J. M. Cleeves, J. N. Knall, C. K. Li, and M. A. Vyvoda, US Patent 6,770,939

47. "Vertically stacked field programmable nonvolatile memory and method of fabrication", M. G. Johnson, T. H. Lee, V. Subramanian, and P. M. Farmwald, US Patent 6780711
48. "Multigate semiconductor device with vertical channel current and method of fabrication", J. M. Cleeves and V. Subramanian, US Patent 6677204
49. "Thermal processing for three dimensional circuits", V. Subramanian, J. M. Cleeves, J. N. Knall, C. K. Li, and M. A. Vyvoda, US Patent 6624011
50. "Multigate semiconductor device with vertical channel current and method of fabrication", J. M. Cleeves and V. Subramanian, US Patent 6580124
51. "Patterning three dimensional structures", C. K. Li, J. N. Knall, M. A. Vyvoda, J. M. Cleeves, and V. Subramanian, US Patent 6627530
52. "Low cost three-dimensional memory array", M. Johnson, T. Lee, V. Subramanian, P. Farmwald, J. Knall, US Patent 6515888
53. "Integrated circuit structure including three-dimensional memory array", M. Johnson, T. Lee, V. Subramanian, P. M. Farmwald, J. M. Cleeves, US Patent 6385074.
54. "FINFET transistor structures having double gate channel extending vertically from a substrate and methods of manufacture", C. Hu, T-J. King, V. Subramanian, L. Chang, X. Huang, Y-K. Choi, J. T. Kedzierski, N. Lindert, J. Bokor, W-C. Lee, US Patent 6413802
55. "Vertically stacked field programmable nonvolatile memory and method of fabrication", M. Johnson, T. Lee, V. Subramanian, M. Farmwald, and J. M. Cleeves, US Patent 6185122.
56. "Vertically Stacked Field Programmable Nonvolatile Memory and Method of Fabrication", M. Johnson, T. Lee, V. Subramanian, M. Farmwald, and J. M. Cleeves, US Patent 6034882.
57. "Vertically Stacked Field Programmable Nonvolatile Memory and Method of Fabrication", M. Johnson, T. Lee, V. Subramanian, M. Farmwald, and J. M. Cleeves, US Patent 6351406.
58. "Vertically Stacked Field Programmable Nonvolatile Memory and Method of Fabrication", M. Johnson, T. Lee, V. Subramanian, M. Farmwald, and J. M. Cleeves, US Patent 6483736.

Invited Magazine Articles, Books, Chapters, and Monographs

1. Chapter in "Inkjet Technology for Digital Fabrication", Editors: Ian M. Hutchings, Graham D. Martin, Wiley, ISBN: 978-0470681985
2. Chapter in "Applications of Organic and Printed Electronics: A Technology-Enabled Revolution (Integrated Circuits and Systems), Editor: E. Cantatore, ISB: 978-1-461-43159-6
3. Chapter in "Inkjet-based Micromanufacturing", Editors: Korvink, Smith, Shin, Wiley, ISBN: 978-3-527-31904-6
4. Chapter in "Organic Electronics II. More Materials and Applications", Editor: H. Klauk, Wiley, ISBN: 978-3-527-32647-1
5. Chapter in "Transparent Electronics: From Synthesis to Applications", Editors: A. Facchetti and T. Marks, Wiley, ISBN: 978-0-470-99077-3, 2010.
6. Chapter in "The chemistry of inkjet inks", Editor: S. Magdassi, World Scientific Publishing Company, ISBN: 978-9812818218, 2009
7. Chapter in "Organic Field-Effect Transistors", Editors: Z. Bao, and J. Locklin, CRC Press, ISBN: 978-0849380808, 2007
8. "Developments in printed RFID", V. Subramanian, Pira Publishing, UK, 2006.
9. "3D Chips: Future Possibilities", V. Subramanian, Silicon India, Feb 2003, pp. 24-25

Invited Conference Presentations

1. ***Invited,*** "High-Speed, High-Resolution Printing of Inorganic Devices", Vivek Subramanian and William J. Scheideler, 2018 Fall Materials Research Society Meeting, Boston, MA, Nov 25-30, 2018.
2. ***Invited,*** "Materials, Process, and Device Innovations for High-Performance Printed Electronics", PRINSE'18 – The 5th Printed Intelligence Industry Seminar on Manufacturing Solutions for Customer Needs and Vision to the Future, Oulu, Finland, Jan 31-Feb 1, 2018.

3. ***Invited*¸** "Highly scaled gravure printed organic transistors for high-performance printed organic electronics", High-frequency printed and direct-written organic-hybrid integrated circuits (HEROIC) Workshop, Milan, Italy, Nov 8-10, 2017.
4. ***Keynote,*** "Printed Electronics: Innovations in Materials, Processes, and Devices", Association of International Metallizers, Coaters, and Laminators (AIMCAL) R2R Conference USA 2017, Tampa, FL, Oct-15-18, 2017.
5. ***Invited,*** "High-performance gravure printed organic transistors", 2017 European Materials Research Society Meeting, Strasbourg, France, May 22-26, 2017
6. ***Invited,*** "Printed Electronics: Innovations in Materials, Processes, and Devices", 2017 International Thin Film Transistor Conference (ITC 2017), Austin, TX, February 23-24, 2017.
7. ***Invited,*** "High-speed Printing of Transistors: From Inks to Devices", 2016 International Society of Coating Science and Technology Symposium (ISCST), Pittsburgh, PA, September 18-21, 2016.
8. ***Keynote***, "Printed Electronics: Innovations in Materials, Processes, and Devices", 2016 Canadian Printable Flexible Wearable electronics Symposium (CPES2016), April 19-20, Oakville, Canada
9. ***Keynote***, "Printed Electronics: Innovations in Materials, Processes, and Device", 2016 Society of Vacuum Coaters Techcon, Indianapolis, IN, May 10-13, 2016.
10. ***Invited***, Subramanian, Vivek, Chung, Seungjun, Grau, Gerd and Scheideler, William J., "71-2: Invited Paper: Printed Transistors and MEMS for Large-Area Electronics", 2016 Society for Information Display Symposium, San Francisco, May 20-27, 2016.
11. ***Keynote,*** "Printed Electronics: Innovations in Materials, Processes, and Devices", 31st Philippine Chemistry Congress, Iloilo, Philippines, April 13-15, 2016.
12. ***Keynote,*** "Advanced Processes, Materials, and Devices for Emerging Printed Electronics Applications", 3rd Swiss Conference on Printed Electronics and Functional Materials, Neuchatel, Switzerland, Oct 1-2, 2015.
13. ***Invited,*** "High-performance printed organic transistors: Materials, processes, and devices", V. Subramanian, G. Grau, H. Kang, and R. Kitsomboonloha, 2015 American Chemical Society National Meeting and Exposition, Boston, MA, Aug 17th, 2015.
14. ***Invited***, Subramanian, Vivek, Jaewon Jang, William Scheideler, and Sarah Swisher. "39.1: Invited Paper: Printed Inorganic Transistors Based on Transparent Oxides." In SID Symposium Digest of Technical Papers, vol. 46, no. 1, pp. 587-590. 2015.
15. ***Plenary***, "Printed Electronics: Advanced Technologies Enabling New Applications", 2015 Flexible and Printed Electronics Conference, Monterey, CA, February 23-26, 2015.
16. ***Invited***, "High-resolution gravure printing of organic thin film transistors for high-performance printed electronic systems", V. Subramanian, R. Kitsomboonloha, J. Cen, H. Kang, G. Grau, and W. J. Scheideler, Materials Research Society Fall Meeting, Boston, MA, Dec 3, 2014.
17. ***Invited***, "Advanced printed electronics technologies for novel ubiquitous human interactive systems", 2014 CMOS Emerging Technologies Research Symposium, Grenoble, France, July 6-8, 2014.
18. ***Invited***, "Printed Electronics: A pathway to functionally-rich systems", 64th annual IEEE Electronic Components and Technology Conference, Orland, FL, May 27, 2014.
19. ***Invited***, "Printed Electronics: The Confluence of Printing and Semiconductors", Canadian Printed Electronics Symposium, Montreal, Canada, April 9, 2013.
20. ***Invited*** "Modeling, scaling, and integration of gravure printing for fast switching Organic FETs", V. Subramanian, S. J. S. Morris, H. Kang, Materials Research Society Fall 2012 Meeting, Boston, MA, Nov 25-30, 2012
21. ***Invited***, "Printed Nanoparticles as routes to high-performance printed conductors: Synthesis, Printing Processes, and Device Applications", V. Subramanian, H. Kang, R. Kitsomboonloha, and S. K. Volkman, The 2012 International Conference on Flexible and Printed Electronics ICFPE2012, Tokyo, Japan, September 6th - 8th, 2012
22. ***Invited*** "Advanced Printing Processes for High-Performance Printed Transistors", V. Subramanian, Flextech Workshop on Printing Electronics - Ink and Substrate Interactions, Kalamazoo, MI, August 1-2, 2012
23. ***Invited*** "High-performance Printed Transistors: Materials, Processes, and Devices", V. Subramanian, 2nd CPEM International Symposium "Organic Semiconductors and Printed Electronics", Gyeonggi, South Korea, May 10th, 2012.

24. ***Invited*** "Highly-Scaled Gravure and Inkjet Printed Organic Transistors: Tools, Processes, and Devices", Hongki Kang & Vivek Subramanian, 2012 Flextech Flexible Electronics and Display Conference, Phoenix, AZ, Feb 5-9, 2012.
25. ***Plenary*** "Nanomaterials for printed electronics: synthesis, design, and applications", V. Subramanian, International Conference on Nano Science and Nano Technology, Sunchon, Korea, November 11th, 2011.
26. ***Invited*** "Advances in scaling of printed transistors", V. Subramanian, International Seminar on Printed Electronics, Seoul, Korea, June 8th, 2011.
27. ***Invited*** "High-Performance Fully Printed Transistors: Materials, Processes, and Device Characteristics", V. Subramanian, H. Tseng, R. Kitsomboonloha, and A. de la Fuente Vornbrock, 2011 Electrochemical Society Meeting, Montreal, Canada, May 2011
28. ***Invited*** "From Droplets to Devices: Printed Transistor Processes, Integration, and Characteristics", Vivek Subramanian, Daniel Soltman, Huai-Yuan Tseng, Rungrot Kitsomboonloha and Alejandro de la Fuente Vornbrock, Materials Research Society Spring Meeting, San Francisco, CA, April 2011
29. ***Keynote*** "Printed electronics: Innovations in tools, materials, devices, and applications", V. Subramanian, 2011 Korea Printed Electronics Association (KoPeA) meeting, Seoul, Korea, March 2011
30. ***Keynote*** "Printed RF tags and sensors: the confluence of printing and semiconductors", V. Subramanian, F. Liao, and H-Y. Tseng, The European Microwave Integrated Circuits Conference 2010, Paris, France, September 2010.
31. ***Invited*** "Droplet-on-demand direct patterning of active materials: materials, modeling, and integration", V. Subramanian, The 2010 IEEE Lithography Workshop, Kuai, Hawaii, November 2010
32. ***Plenary*** "Printed electronics: where are we, and where are we going", V. Subramanian, 2010 Large Area Organic, and Printed Electronics Convention (LOPE-C), Frankfurt, Germany, June 2010.
33. ***Keynote*** "Printed RFID: Technology Trends and Outlook", V. Subramanian, IEEE International Conference on RFID 2010, Orlando, Florida, April 2010.
34. ***Invited*** "Mechanistic studies on sintering of nanoparticles for formation of solution-processed thin films", 2010 Spring meeting of the Materials Research Society, San Francisco, CA, April 2010.
35. ***Invited*** "Printed Electronics: the confluence of printing and semiconductors", Vivek Subramanian, 2009 International Conference on Flexible and Printing Electronics, Jeju Island, Korea, Nov 2009.
36. ***Invited*** "Organic Transistor Vapor and Biosensors – Technology Status and Implementation Issues", Vivek Subramanian, Frank Liao, Lakshmi Jagannathan, Electrochemical Society Meeting, Vienna, Austria, October 2009.
37. ***Invited*** "Printed transistors for low-cost electronics: the confluence of printing and printable electronic materials", Vivek Subramanian, Alejandro de la Fuente Vornbrock, Steven Molesa, Daniel Soltman, Huai-Yuan Tseng, and Steven K. Volkman, SPIE Optics + Photonics, August 2-6, 2009, San Diego, CA
38. ***Invited*** "Printed Zinc Oxide Based Electronics: Materials, Devices, and Outlook", V. Subramanian, S. K. Volkman, and D. R. Redinger, LOPE-C, June 23-25, 2009, Frankfurt, Germany
39. ***Invited*** "Printed Devices for Low-Cost Electronics: Technology Status and Outlook", V. Subramanian, PETEC Inaugural Event, March 17, 2009, Durham, United Kingdom
40. ***invited*** "Printed Electronic Tags and Sensors for Smart Packaging Applications", Vivek Subramanian, Josephine Chang, Lakshmi Jagannathan, Frank Liao, Steve Molesa, David Redinger, Daniel Soltman, Huai-Yuan Tseng, Steve Volkman, Shong Yin, 2009 Flexible Electronics and Display Conference, Phoenix, AZ, Feb 2-5, 2009.
41. ***invited*** "Electronic Nose Sensors for Consumer Packaging", V. Subramanian, IDTechEx Printed Electronics USA, San Jose, CA, Dec 2-5, 2008.
42. ***invited*** "Solution-Processed Transparent Transistors for Low-Cost, Flexible Displays", V. Subramanian, S. K. Volkman, and D. R. Redinger, LEOS 2008: The 21st Annual Meeting of the IEEE Lasers and Electro-Optics Society, Newport Beach, CA, 9-13 November, 2008.
43. ***invited*** "Organic chemical and biosensors for smart packages", V. Subramanian, IDTechEx Printed Electronics Asia, Tokyo, Japan, Oct 8-9, 2008.
44. ***invited*** "Printed Electronics for Low-Cost Tags, Displays, and Sensors", V. Subramanian, 1st International Conference on R2R Printed Electronics, Seoul, Korea, April 30-May 2, 2008.

45. ***invited*** "Printed organic RFID tags: technology, roadmaps, and challenges", V. Subramanian, 1st Plastic Electronics Asia Conference and Showcase, Seoul, Korea, June 24-26, 2008
46. ***invited*** "Power supply considerations and solutions for printed electronic tags and sensors", V. Subramanian, IDTechEx Printed Electronics Europe, Dresden, Germany, April 8-9, 2008
47. ***invited*** "Printed Chemical and Biosensors: Technology, Design and Challenges", GOSPEL Workshop on Plastic Chemical Sensors, Dresden, Germany, April 9, 2008
48. ***Plenary*** "Printed Electronics For Low-Cost Electronic Systems: Technology Status and Application Development", Vivek Subramanian, Josephine B. Chang, Alejandro de la Fuente Vornbrock, Daniel C. Huang, Lakshmi Jagannathan, Frank Liao, Brian Mattis, Steven Molesa, David R. Redinger, Daniel Soltman, Steven K. Volkman, Qintao Zhang, 38th European Solid State Device Research Conference, Edinburgh, Scotland, September 15-19, 2008
49. ***invited*** "Printed Organic Transistors for Low-cost Tags, Displays, and Sensors: Technology, Modeling and Challenges", Vivek Subramanian, Alejandro de la Fuente Vornbrock, Huai-Yuan Tseng and Shong Yin, Materials Research Society Fall Meeting, Boston, MA, Dec 1-4, 2008.
50. ***invited*** "Printed Electronics for Low-Cost Tags and Sensors", Vivek Subramanian, Sixth Annual Workshop on Microelectronics and Electron Devices, April 18, 2008.
51. ***invited*** "Printed organic RF tags, chemical sensors and biosensors", Vivek Subramanian, International Symposium for Flexible Electronics and Display, Hsinchu, Taiwan, Nov 18, 2007.
52. ***invited*** "Printed Tags and Sensors for RFID: Opportunities and Challenges", Vivek Subramanian, Printed Electronics USA 2007, San Francisco, CA, Nov 14, 2007.
53. ***invited*** "Printed RFID Tags: Materials, Processes, and Devices", Vivek Subramanian, Daniel Soltman, Daniel Huang, Steven Molesa, 2007 AiChE Annual Meeting, Salt Lake City, UT, Nov. 8, 2007.
54. ***invited*** "Printed organic RFID tags: technology, roadmaps, and challenges", Vivek Subramanian, 3rd Global Plastic Electronics Conference and Showcase, Frankfurt, Germany, Oct 30, 2007.
55. ***invited*** "Printed organic transistors: technology, characteristics, and modeling", Vivek Subramanian, Alejandro de la Fuente Vornbrock, Daniel Soltman, Huai-Yuan Tseng, and Steve Molesa, 212th meeting of the Electrochemical Society, Washington, DC, Oct 8, 2007.
56. ***invited*** "Printed electronic tags and sensors - device, materials, and circuit issues", Vivek Subramanian, 2007 Organic Electronics Conference and Exhibition, Frankfurt, Germany, Sept 25, 2007.
57. ***invited*** "Inkjet printing of transistors, diodes, and passive components for smart tags", Vivek Subramanian, Innovations in Inkjet: 3rd DPI Inkjet Workshop, Eindhoven Institute of Technology, Netherlands, June 28-29, 2007.
58. ***invited*** "Printed organic transistors", A. de la Fuente and V. Subramanian, Industry Forum on Printed Electronics, Chicago, IL, April 23-24, 2007
59. ***invited*** "From Materials to Circuits: Implications of printed materials on printed RFID", V. Subramanian, 2007 Pira printed RFID conference, Frankfurt, Germany, June 4-6, 2007.
60. ***keynote*** "Droplet on demand lithography: An enabling technology for low-cost electronics", V. Subramanian, A. de la Fuente Vornbrock, S. Molesa, D. Redinger, Q. Zhang, and S. K. Volkman, SPIE Advanced lithography, 27th February, 2007
61. ***invited*** "Printed RFID tags: performance needs and technology trends", V. Subramanian, 2007 IDTechEx Smart labels USA , Boston, MA, Febraury 20-23, 2007.
62. ***keynote*** "Printed Organic Transistors for low-cost tagging and sensing applications", V. Subramanian, J. Chang, A. de la Fuente Vornbrock, S. Molesa, D. Soltman, and Q. Zhang. 6th International IEEE Conference on Polymers and Adhesives in Microelectronics and Photonics, Tokyo, January 15th-18th, 2007.
63. ***invited*** "Nano Inks for Printed RFID", V. Subramanian, Pira Nanoscale Inks and Pigment Technologies Conference, Chicago, IL, Sept 27-28, 2006.
64. ***invited*** "Toward Printed RFID: Materials, Processes, and Devices", V. Subramanian, 5th Annual Printed Electronics and Displays Conference and Trade Fair, Las Vegas, Oct 11-13, 2006.
65. ***invited*** "Inkjetted Organic Transistors for Smart Tagging Applications", Vivek Subramanian, Jean M. J. Frechet, Steven Molesa, Josephine Chang, Amanda R. Murphy, Alejandro de la Fuente Vornbrock, Steven Volkman, 2006 AiChE Annual Meeting, Nov 17th, 2006

66. ***invited focal paper*** "All-printed electronics: Materials, Devices, and Circuit Implications", V.Subramanian, J. Chang, S. Molesa, D. Redinger, and S. Volkman, Digital Fabrication 2006, Denver, CO, Sept 17-22, 2006.
67. ***invited*** "Printed transistors and passive components for low-cost electronics applications", V. Subramanian, J. B. Chang, S. E. Molesa, S. K. Volkman, and D. R. Redinger, International Symposium on VLSI Technology, Systems and Applications (VLSI-TSA) April, 2006, pp. 68-9.
68. ***invited*** "Advanced printed materials and devices for RFID applications", V. Subramanian, IDTechEx Printed Electronics Europe, April 19-21, 2006.
69. ***invited*** "Printed Electronic Nose Vapor Sensors for Consumer Product Monitoring", V. Subramanian, J. Lee, V. Liu, S. Molesa, IEEE International Solid State Circuits Conference, Paper 15.3, February, 2006.
70. ***invited*** "Nanotechnology in Printed Electronics: Nanoparticles, Nanorods, and Nanowhy", V. Subramanian, Pira Pack Electronics Conference, January 25-26, 2006.
71. ***invited*** "All-printed RFID Tags: Materials, Devices, and Circuit Implications", Vivek Subramanian, Paul C. Chang, Daniel Huang, Josephine B. Lee, Steven E. Molesa, David R. Redinger, and Steven K. Volkman, VLSI Design, 2006, Hyderabad India, Jan 2006.
72. ***invited*** "Printed organic transistors: materials and technology", Vivek Subramanian, Pacifichem 2005: American Chemical Society Pacific Basin meeting, December 15-20, 2005, Honolulu, HI,
73. ***invited*** "Low-cost arrayed gas sensors for environmental monitoring". Vivek Subramanian, Josephine Lee and Vincent Liu, Materials Research Society Fall Symposium, Paper S2.1, Boston, MA, December 2005.
74. ***invited*** "Prospects for All-printed RFID: Materials, Devices, Circuits", V. Subramanian, International Workshop on Radio Frequency Identification (RFID) and Wirelss Sensors, 11-13 November, 2005, Kanpur, India.
75. ***invited*** "Printed electronics for low-cost tagging applications", V. Subramanian, 2005 International Symposium on Flexible Electronics and Display, Hsinchu, Taiwan, October 2005.
76. ***invited*** "Printed electronic nose gas sensors", Vivek Subramanian, Plastic Electronics 2005, Frankfurt, Germany, Oct 4-5, 2005
77. ***invited*** "Uses of nanotechnology in printed electronics", Vivek Subramanian, Printed Electronics 205, Pira International, Thistle Marble Arch, London, UK, Sept 14-15, 2005
78. ***invited*** "Printed organic transistors for low-cost RFID applications", Vivek Subramanian, Proceedings of SPIE-The International Society for Optical Engineering vol. 5940, (594013/1-594013/9) , pp. 170-178, 2005.
79. ***invited*** "Advanced printed materials and devices for ultra-low-cost RFID", Vivek Subramanian, Printed RFID: Achieving low cost tags through printed electronics – Pira International, Gatwick, Surrey, UK, May 10-11, 2005.
80. ***Plenary session invited talk*** "Printed Organic Transistors for Ultra-low-cost RFID Applications", Vivek Subramanian, Paul C. Chang, Josephine B. Lee, Steven E. Molesa, and Steven K. Volkman, Polytronic 2004: 4th International IEEE Conference on Polymers and Adhesives in Microelectronics and Photonics, Portland, Oregon, USA, 12 September 2004.
81. ***invited*** "Materials, Device, and Circuits Issues for low-cost printed RFID", V. Subramanian, 2nd Cintelliq Organic Semiconductor Conference, 2004 (OSC-2004), Cambridge, England, October 2004.
82. ***invited*** "All-printed flexible organic thin film transistors: Current status and outlook for the future", V. Subramanian, J. M. J. Fréchet, P. C. Chang, D. C. Huang, J. B. Lee, F. Liao, B. A. Mattis, S. Molesa, A. R. Murphy, D. R. Redinger, and S. K. Volkman, 206th meeting of the Electrochemical Society, Honolulu, HI, October 2004.
83. ***invited*** "Nanoscale organic transistors: towards gain in molecular devices", V. Subramanian, P. C. Chang, J. B. Lee, T. Le, A. Murphy, J. M. J. Frechet, and A. Liddle, 2004 IEEE Nanoscale Devices and Systems Integration Conference, Miami, FL, 2004.
84. ***invited*** "Towards Printed Low-Cost RFID Tags: Device, Materials and Circuit Technologies", V. Subramanian, 2nd Advanced Technology Workshop on Printing an Intelligent Future: Printed Organic and Molecular Electronic Technologies, Boston, MA, March 16-19, 2003.
85. ***invited*** "Prospects for organic semiconductor based devices and circuits: applications, performance, and reliability considerations", V. Subramanian, 2002 Topical Research Conference on Reliability, Oct 2002.
86. ***invited*** "FinFET - quasi-planar double-gate MOSFET", S. H. Tang, L. Chang, N. Lindert, Y-K. Choi, W-C. Lee, X. Huang, V. Subramanian, J. Bokor, T-J. King, C. Hu, 20001 IEEE International Solid-State Circuits Conference Digest of Technical Papers, pp. 118-119, 437, 2001.

87. ***invited*** "3-D ICs with Multiple Si Layers: Performance Analysis, and Technology", K. Saraswat, K. Banerjee, A. Joshi, P. Kalavade, S. Souri, and V. Subramanian, *presented at* The Fifth International Symposium on Low and High Dielectric Constant Materials: Materials Science, Processing, and Reliability Issues, 197th meeting of the Electrochemical Society, Toronto, Ontario, Canada, May 14-18, 2000.

88. ***invited*** "Novel 3-D Structures", K. C. Saraswat, S. J. Souri, V. Subramanian, A. R. Joshi, and A. W. Wang, 1999 IEEE International SOI Conference Proceedings, pp. 54-55.

89. ***invited*** "Seeding Technology for High Performance TFTs", K. C. Saraswat and V. Subramanian, Proceedings of the Electronic Display Forum 98, EIAJ/SEMI, Yokohama, April 1998, pp. 2.7-2.15.

90. ***invited*** "A Low-Temperature Polycrystalline Si TFT Technology for Large-Area AMLCD Drivers", K. C. Saraswat, V. Subramanian, and S. Jurichich, Polycrystalline Thin Films III - Structure, Texture, Properties, and Applications, MRS Symposium Proceedings pp 439-449, 1997.

91. ***invited*** "A low temperature polycrystalline SiGe CMOS TFT technology for large area AMLCD drivers", K. C. Saraswat, S. Jurichich, T.-J. King, V. Subramanian, and A. Wang, Proceedings of Thin Film Transistor Technologies III, ECS Symposium, 1996, pp. 186-196.

Journal Papers

1. ***invited*** William Scheideler and Vivek Subramanian, "Printed flexible and transparent electronics: enhancing low-temperature processed metal oxides with 0D and 1D nanomaterials", 2019 Nanotechnology 30 272001

2. R. Kumar, K. M. Johnson, N. X. Williams, V. Subramanian, "Scaling Printable Zn–Ag2O Batteries for Integrated Electronics", Adv. Energy Mater. 2019, 1803645.

3. William J. Scheideler, Matthew W. McPhail, Rajan Kumar, Jeremy Smith, and Vivek Subramanian, "Scalable, High-Performance Printed InOx Transistors Enabled by Ultraviolet-Annealed Printed High-k AlOx Gate Dielectrics", ACS Applied Materials & Interfaces 2018 10 (43), 37277-37286.

4. J. Smith, S. Chung, J. Jang, C. Biao, V. Subramanian, "Solution-processed complementary resistive switching arrays for associative memory", IEEE Transactions on Electron Devices 64 (10), pp 4310, 2017

5. A. Zeumault, V. Subramanian, "Use of high-k encapsulation to improve mobility in trap-limited metal oxide semiconductors", physica status solidi (b) 254 (10), 1700124, 2017

6. A. Zeumault, W. Scheideler, V. Subramanian, "Electrostatic tuning of spray-deposited ZnO for controlled mobility enhancement", Advanced Functional materials, 27 (30), pp. 1701021, 2017

7. W. J. Scheideler, R. Kumar, A. R. Zeumault, V. Subramanian, "Low-Temperature-Processed Printed Metal Oxide Transistors Based on Pure Aqueous Inks", Advanced Functional Materials 2017, 1606062.

8. Jaewon Jang, Vivek Subramanian, "Effect of electrode material on resistive switching memory behavior of solution-processed resistive switches: Realization of robust multi-level cells", Thin Solid Films, Volume 625, Pages 87-92, 1 March 2017.

9. S. Chung, M. A. U. Karim, H. J. Kwon, W. Scheideler and V. Subramanian, "A High-Speed Inkjet-Printed Microelectromechanical Relay With a Mechanically Enhanced Double-Clamped Channel-Beam," Journal of Microelectromechanical Systems, vol. 26, no. 1, pp. 95-101, Feb. 2017.

10. G. Grau, E. J. Frazier, and V. Subramanian, "Printed unmanned aerial vehicles using paper-based electroactive polymer actuators and organic ion gel transistors", Nature Microsystems & Nanoengineering, vol 2, pp. 16032, 2016

11. ***invited*** Gerd Grau, Jialiang Cen, Hongki Kang, Rungrot Kitsomboonloha, William J Scheideler, and Vivek Subramanian "Gravure-printed electronics: recent progress in tooling development, understanding of printing physics, and realization of printed devices", IOP Journal of Flexible and Printed Electronics, vol. 1, No. 2, pp. 023002, 2016

12. Scheideler, William J., Jeremy Smith, Igal Deckman, Seungjun Chung, Ana Claudia Arias, and Vivek Subramanian. "A robust, gravure-printed, silver nanowire/metal oxide hybrid electrode for high-throughput patterned transparent conductors." Journal of Materials Chemistry C 4, no. 15 (2016): 3248-3255.

13. Karim, Muhammed Ahosan Ul, Seungjun Chung, Elad Alon, and Vivek Subramanian. "Fully Inkjet-Printed Stress-Tolerant Microelectromechanical Reed Relays for Large-Area Electronics." Advanced Electronic Materials (2016).

14. Khan, Yasser, Felippe J. Pavinatto, Monica C. Lin, Amy Liao, Sarah L. Swisher, Kaylee Mann, Vivek Subramanian, Michel M. Maharbiz, and Ana C. Arias. "Bioelectronic Interfaces: Inkjet-Printed Flexible Gold Electrode Arrays for Bioelectronic Interfaces (Adv. Funct. Mater. 7/2016)." Advanced Functional Materials 26, no. 7 (2016): 981-981.

15. Jang, Jaewon, Seungjun Chung, Hongki Kang, and Vivek Subramanian. "P-type CuO and Cu 2 O transistors derived from a Sol–Gel Copper (II) acetate monohydrate precursor." Thin Solid Films (2016).
16. Grau, Gerd, and Vivek Subramanian. "Fully High-Speed Gravure Printed, Low-Variability, High-Performance Organic Polymer Transistors with Sub-5 V Operation." Advanced Electronic Materials (2016).
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2. Carlos Biaou, Matt McPhail, Vivek Subramanian and Oscar Dubon, "Comprehensive Multifactorial Studies on the Degradation of Perovskite Solar Cells in Operation", 2019 Spring Materials Research Society Meeting, Phoenix, AZ, April 22-26, 2019.

3. Rajan Kumar, Jessica E. Nichols, Bryan D. McCloskey, and Vivek Subramanian, "Low-Temperature-Processing of Printed Cathodes for Aqueous Metal-Air Batteries", ECS AiMES 2018 Meeting, September 30, 2018 - October 4, 2018, Cancun, Mexico

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