



US007173281B2

(12) **United States Patent**
Hirakata et al.

(10) **Patent No.:** **US 7,173,281 B2**
(45) **Date of Patent:** ***Feb. 6, 2007**

(54) **SEMICONDUCTOR DEVICE AND METHOD OF FABRICATING THE SAME**

(75) Inventors: **Yoshiharu Hirakata**, Kanagawa (JP); **Yuugo Goto**, Kanagawa (JP); **Yuko Kobayashi**, Kanagawa (JP); **Shunpei Yamazaki**, Tokyo (JP)

(73) Assignee: **Semiconductor Energy Laboratory Co., Ltd.**, Kanagawa-ken (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **10/692,759**

(22) Filed: **Oct. 27, 2003**

(65) **Prior Publication Data**
US 2004/0084673 A1 May 6, 2004

Related U.S. Application Data

(62) Division of application No. 09/606,414, filed on Jun. 29, 2000, now Pat. No. 6,638,781.

(30) **Foreign Application Priority Data**
Jul. 6, 1999 (JP) 11-191102

(51) **Int. Cl.**
H01L 29/04 (2006.01)

(52) **U.S. Cl.** **257/72; 257/57; 257/59; 257/83; 257/257; 257/290; 257/351; 257/368**

(58) **Field of Classification Search** 257/57, 257/59, 72, 83, 257, 290, 347, 351, 36
See application file for complete search history.

(56) **References Cited**
U.S. PATENT DOCUMENTS
4,555,746 A 11/1985 Mochizuki et al.

(Continued)

FOREIGN PATENT DOCUMENTS
EP 0 604 006 6/1994

(Continued)

OTHER PUBLICATIONS

Furue et al., "Characteristics and Driving Scheme of Polymer-Stabilized Monostable FLCD Exhibiting Fast Response Time and High Contrast Ratio with Gray-Scale Capability", SID 98 DIGEST, pp. 782-785.

(Continued)

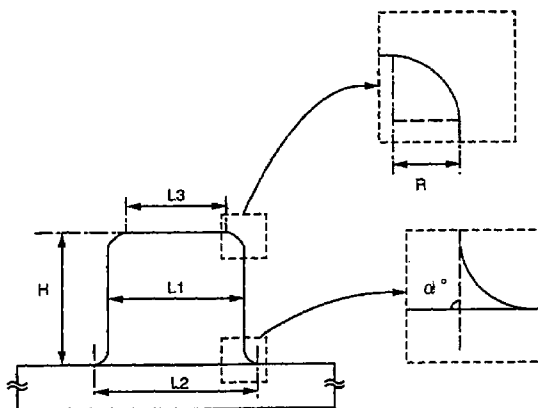
Primary Examiner—Wai-Sing Louie
(74) *Attorney, Agent, or Firm*—Nixon Peabody LLP

(57) **ABSTRACT**

There is provided a high quality liquid crystal panel having a thickness with high accuracy, which is designed, without using a particulate spacer, within a free range in accordance with characteristics of a used liquid crystal and a driving method, and is also provided a method of fabricating the same. The shape of a spacer for keeping a substrate interval constant is made such that it is a columnar shape, a radius R of curvature is 2 μm or less, a height H is 0.5 μm to 10 μm, a diameter is 20 μm or less, and an angle α is 65° to 115°.

By doing so, it is possible to prevent the lowering of an opening rate and the lowering of light leakage due to orientation disturbance.

124 Claims, 25 Drawing Sheets



U.S. PATENT DOCUMENTS

4,775,225 A 10/1988 Tsuboyama et al.
 4,874,461 A 10/1989 Sato et al.
 4,899,137 A 2/1990 Behrens et al.
 5,062,198 A 11/1991 Sun
 5,308,998 A 5/1994 Yamazaki et al.
 5,337,171 A 8/1994 Mase et al.
 5,379,139 A 1/1995 Sato et al.
 5,499,123 A 3/1996 Mikoshihba
 5,499,128 A * 3/1996 Hasegawa et al. 349/155
 5,518,078 A 5/1996 Tsujioka et al.
 5,594,569 A 1/1997 Konuma et al.
 5,605,846 A 2/1997 Ohtani et al.
 5,608,232 A 3/1997 Yamazaki et al.
 5,619,044 A 4/1997 Makita et al.
 5,637,515 A 6/1997 Takemura
 5,643,826 A 7/1997 Ohtani et al.
 5,666,173 A 9/1997 Mase et al.
 5,680,189 A 10/1997 Shimizu et al.
 5,691,793 A 11/1997 Watanabe et al.
 5,696,003 A 12/1997 Makita et al.
 5,739,882 A 4/1998 Shimizu et al.
 5,744,824 A 4/1998 Kousai et al.
 5,777,713 A 7/1998 Kimura
 5,814,835 A 9/1998 Makita et al.
 5,815,226 A 9/1998 Yamazaki et al.
 5,815,232 A 9/1998 Miyazaki et al.
 5,821,562 A 10/1998 Makita et al.
 5,824,573 A 10/1998 Zhang et al.
 5,831,710 A 11/1998 Colgan et al.
 5,843,225 A 12/1998 Takayama et al.
 5,852,485 A 12/1998 Shimada et al.
 5,879,977 A 3/1999 Zhang et al.
 5,915,174 A 6/1999 Yamazaki et al.
 5,922,125 A 7/1999 Zhang
 5,923,962 A 7/1999 Ohtani et al.
 5,952,554 A 9/1999 Umeda
 5,952,676 A 9/1999 Sato et al.
 5,962,871 A 10/1999 Zhang et al.
 5,969,784 A 10/1999 Miyazaki et al.
 5,978,061 A 11/1999 Miyazaki et al.
 5,978,063 A 11/1999 Crawford et al.
 5,986,729 A 11/1999 Yamanaka et al.
 6,013,929 A 1/2000 Ohtani
 6,016,181 A * 1/2000 Shimada 349/156
 6,088,070 A 7/2000 Ohtani et al.
 6,104,461 A 8/2000 Zhang et al.
 6,118,506 A 9/2000 Yamazaki et al.
 6,151,092 A 11/2000 Fujimura et al.
 6,162,667 A 12/2000 Funai et al.
 6,163,357 A 12/2000 Nakamura
 6,165,824 A 12/2000 Takano et al.
 6,225,645 B1 5/2001 Zhang
 6,236,445 B1 5/2001 Foschaar et al.
 6,238,754 B1 5/2001 Shohara et al.
 6,275,061 B1 8/2001 Tomita
 6,285,042 B1 9/2001 Ohtani et al.
 6,285,247 B1 9/2001 Shoji
 6,286,359 B1 9/2001 Umeda
 6,288,766 B1 9/2001 Mashiko et al.
 6,313,481 B1 11/2001 Ohtani et al.
 6,335,541 B1 1/2002 Ohtani et al.
 6,356,330 B1 3/2002 Ando et al.
 6,362,865 B2 3/2002 Yoshida
 6,411,360 B1 6/2002 Matsuyama et al.
 6,420,988 B1 7/2002 Azami et al.
 6,445,437 B1 9/2002 Miyazaki et al.
 6,555,420 B1 4/2003 Yamazaki
 6,576,926 B1 6/2003 Yamazaki et al.
 6,638,781 B1 * 10/2003 Hirakata et al. 438/30
 6,680,487 B1 1/2004 Yoshida et al. 438/30

6,888,608 B2 5/2005 Miyazaki et al.
 6,909,115 B2 6/2005 Kokubo et al.
 2001/0051398 A1 12/2001 Hirakata et al.
 2002/0013019 A1 1/2002 Ohtani et al.
 2002/0163457 A1 11/2002 Azami et al.
 2003/0057419 A1 3/2003 Murakami et al.
 2004/0084673 A1 5/2004 Hirakata et al.

FOREIGN PATENT DOCUMENTS

EP 0 978 877 2/2000
 EP 0 984 492 3/2000
 EP 1 006 664 6/2000
 EP 1 041 622 10/2000
 JP 61-184518 8/1986
 JP 63-050817 3/1988
 JP 5-281558 10/1993
 JP 6-51319 2/1994
 JP 6-59228 3/1994
 JP 06-232059 8/1994
 JP 6-244104 9/1994
 JP 6-265912 9/1994
 JP 7-130652 5/1995
 JP 07-321339 12/1995
 JP 08-006053 1/1996
 JP 08-008181 1/1996
 JP 08-213317 8/1996
 JP 8-248427 9/1996
 JP 9-073088 3/1997
 JP 9-073093 3/1997
 JP 9-120062 5/1997
 JP 09-162416 6/1997
 JP 9-197413 7/1997
 JP 10-068955 3/1998
 JP 10-96955 4/1998
 JP 10-153797 6/1998
 JP 10-206893 8/1998
 JP 10-228022 8/1998
 JP 10-247735 9/1998
 JP 10-268316 10/1998
 JP 10-268316 A 10/1998
 JP 10-268361 10/1998
 JP 10-319440 12/1998
 JP 10-325959 12/1998
 JP 10-339889 12/1998
 JP 11-84386 3/1999
 JP 11-95194 4/1999
 JP 11-095261 4/1999
 JP 11-097702 4/1999
 JP 11-133463 5/1999

OTHER PUBLICATIONS

Yoshida et al., "A Full-Color Thresholdless Antiferroelectric LCD Exhibiting Wide Viewing Angle with Fast Response Time", SID 97 DIGEST, pp. 841-844.
 U.S. Appl. No. 09/570,223—Satoshi Murakami, "Capacitor, Semiconductor Device and Manufacturing Method Thereof".
 H. Ohtani et al., "L-P-B: Late-News Poster: A 60-in. HDTV Rear-Projector with Continuous-Grain-Silicon Technology", Society for Information Display International Symposium Digest of Technical Papers, vol. XXIX, May 1998, pp. 467-470.
 European Search Report for Application No. 00110377.9-1528/; Dated: Oct. 15, 2004.
 European Search Report for Application No. 00109971.2-2203-; Dated Aug. 17, 2000.
 Ryuichi Shimokawa et al.; "Characteristics of High-Efficiency Cast-Si Solar Cell Wafers by MBIC Measurement"; Japanese Journal of Applied Physics, vol. 27, No. 5, May 1998, pp. 751-758.
 Shiroh Inui, et al. "Thresholdless Antiferroelectricity in Liquid Crystals and its Application to Displays"; Journal of Materials Chemistry, vol. 6, No. 4, 1996, pp. 671-673.

* cited by examiner

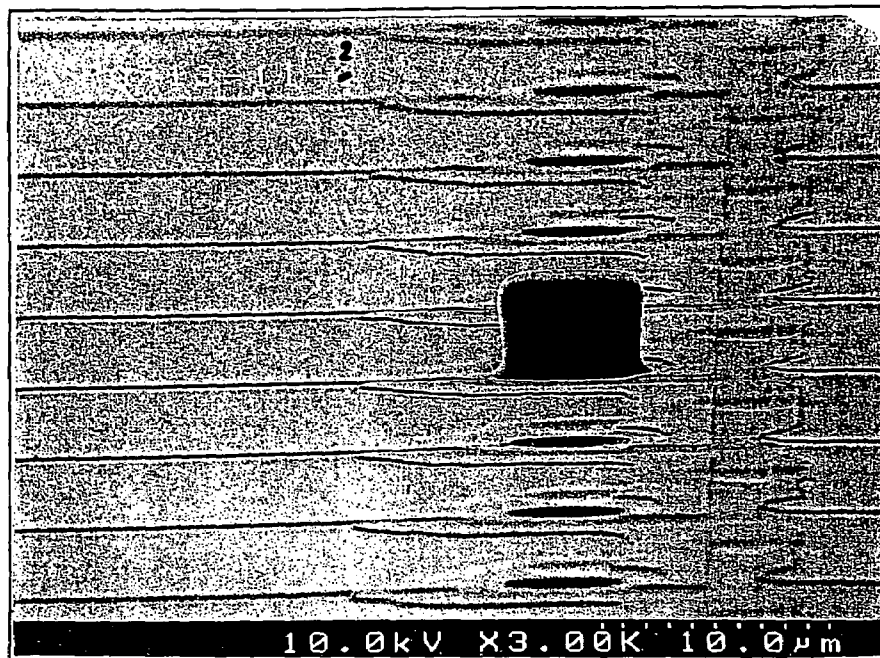


Fig. 1A

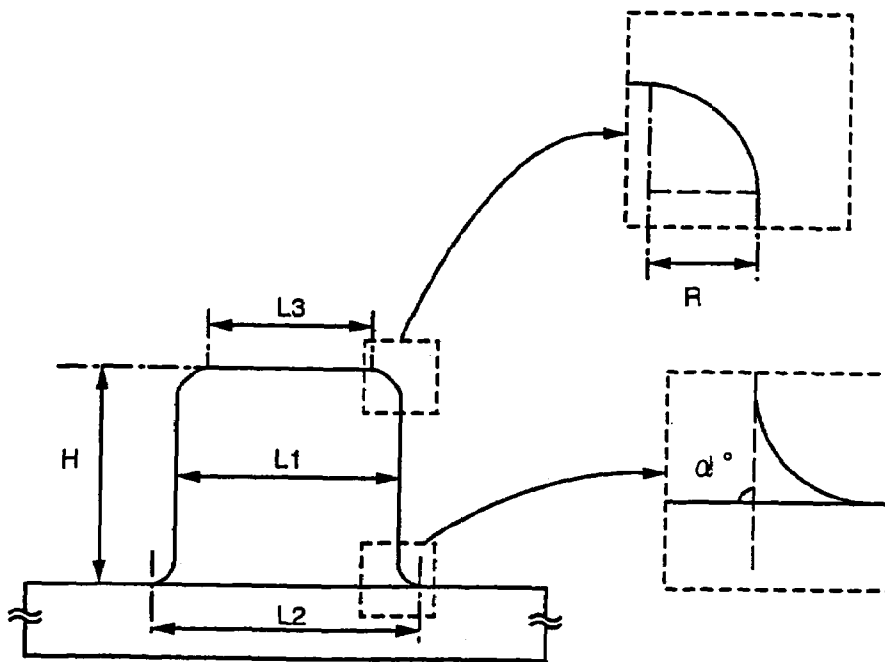


Fig. 1B

Fig. 2A

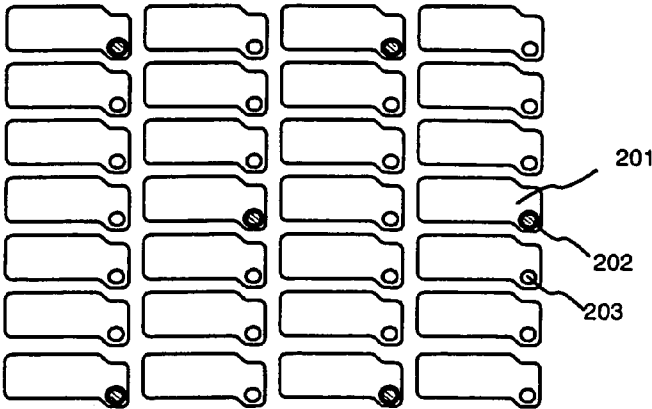


Fig. 2B

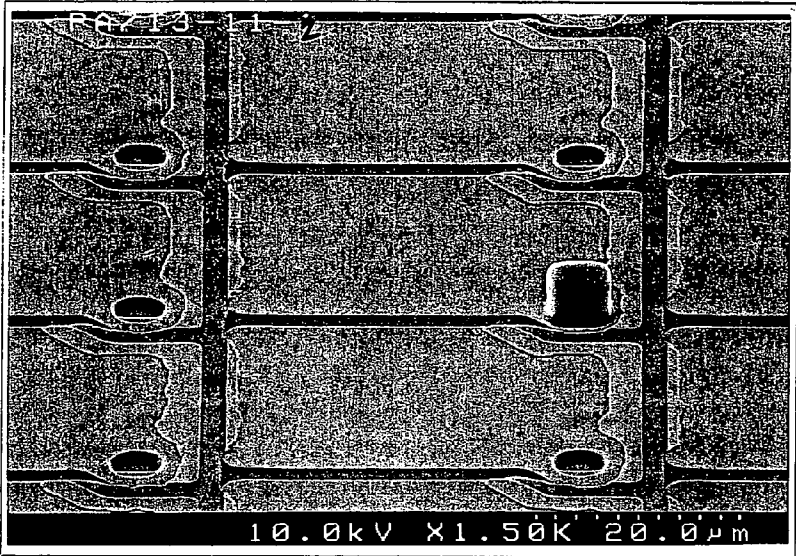
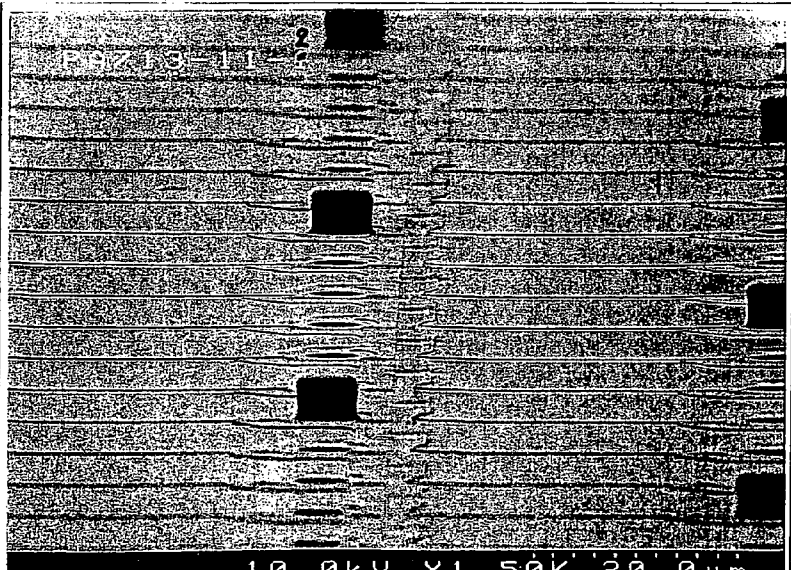
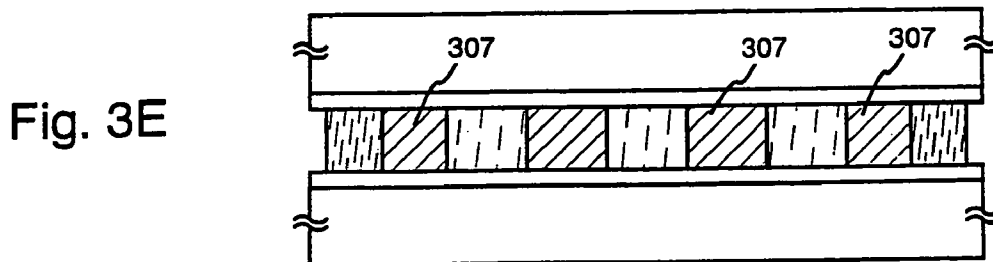
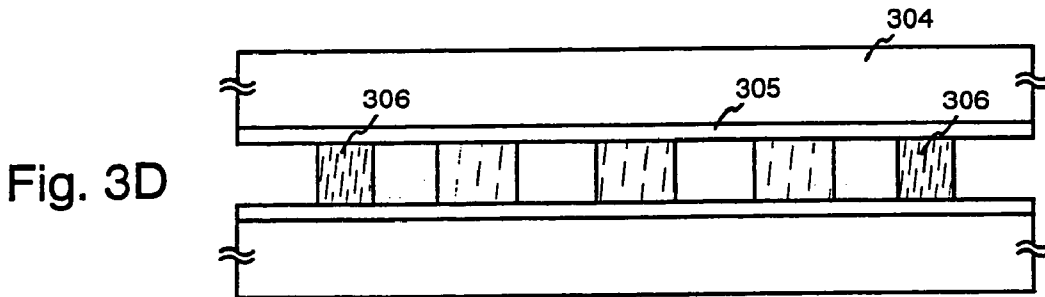
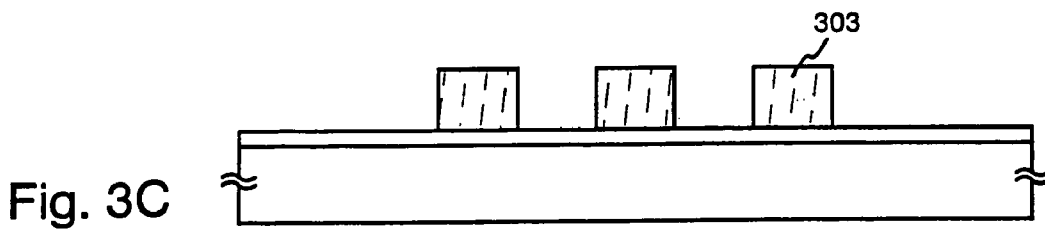
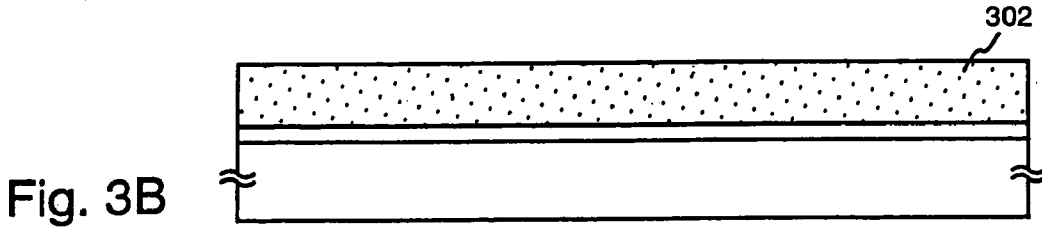
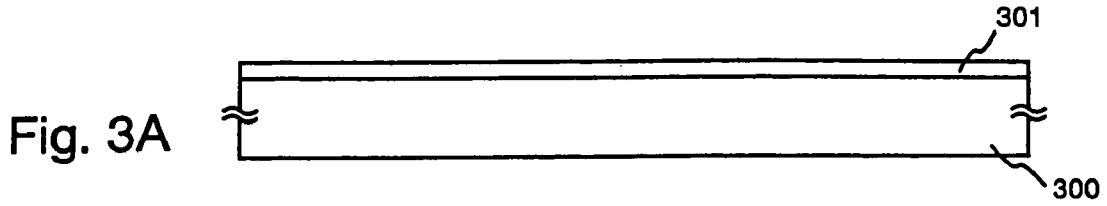


Fig. 2C





Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.