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# United States Patent [19]

Annavarapu et al.

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[54] **METHOD OF MAKING UNREACTED METAL/ALUMINUM SPUTTER TARGET**

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[51] **Int. Cl.**[7] ..... **B22F 3/02**

[52] **U.S. Cl.** ..... **148/513**; 419/23; 419/32; 419/68

[58] **Field of Search** ..... 419/23, 32, 62, 419/65, 68; 148/513, 514

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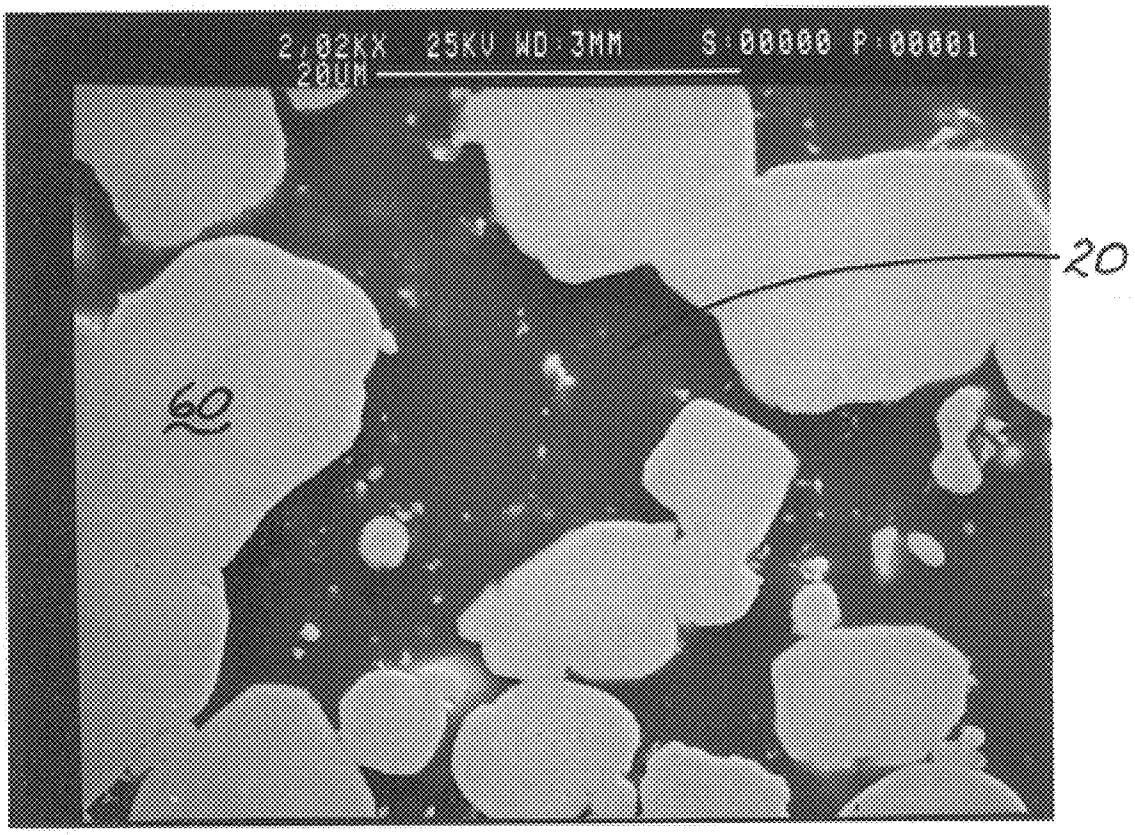
[57] **ABSTRACT**

A high performance, high density sputtering target and a method of making. An aluminum and non-aluminum reactive metal powder blend is subjected to cold pressing under pressure, machining, evacuating, and hot pressing under pressure. The aluminum and non-aluminum metal react directly to yield a high performance, high density sputter target containing greater than about 2% aluminum with substantially uniform composition across the body.

**23 Claims, 3 Drawing Sheets**



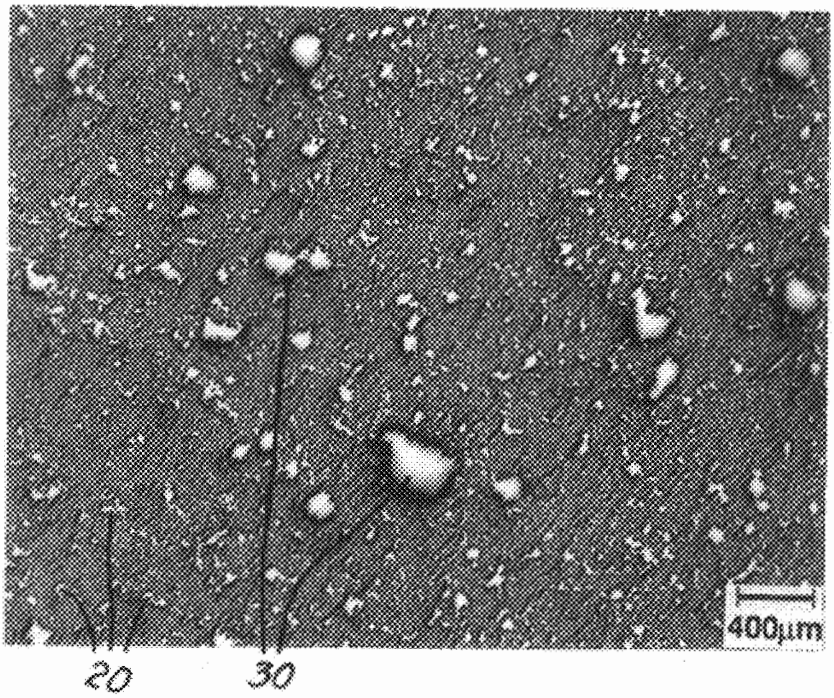



FIG. 1A

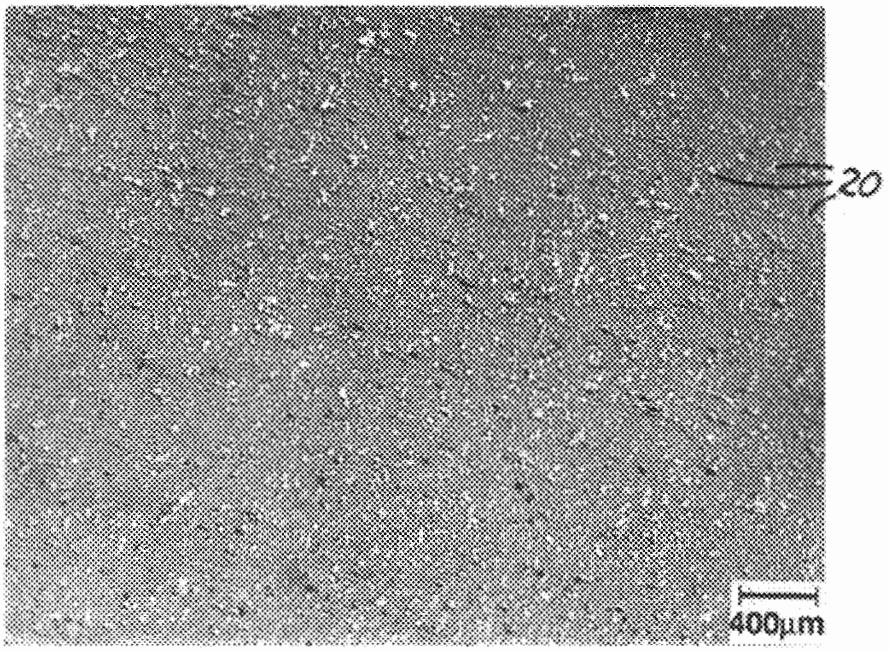



FIG. 2A

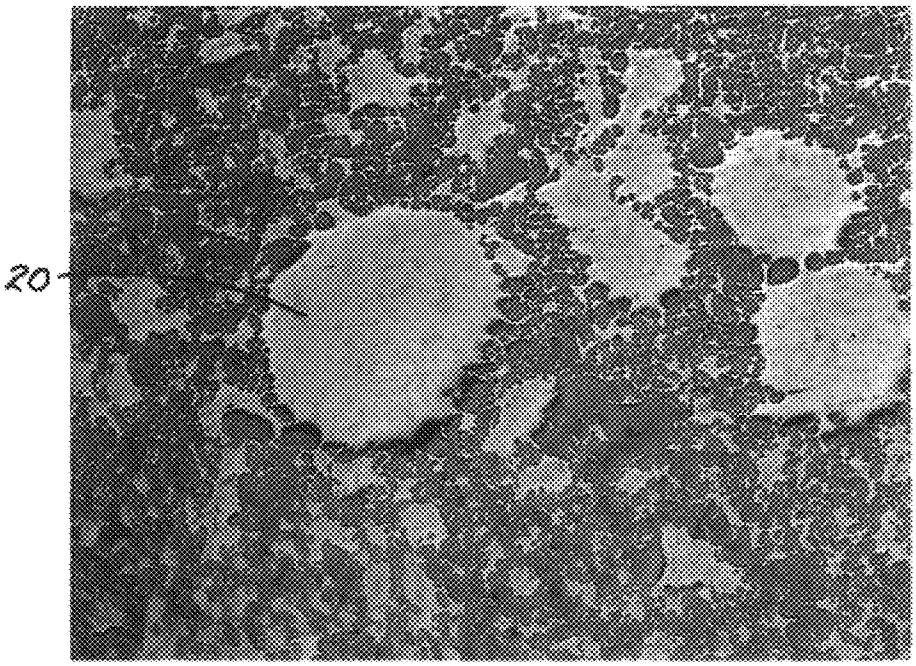



FIG. 1B

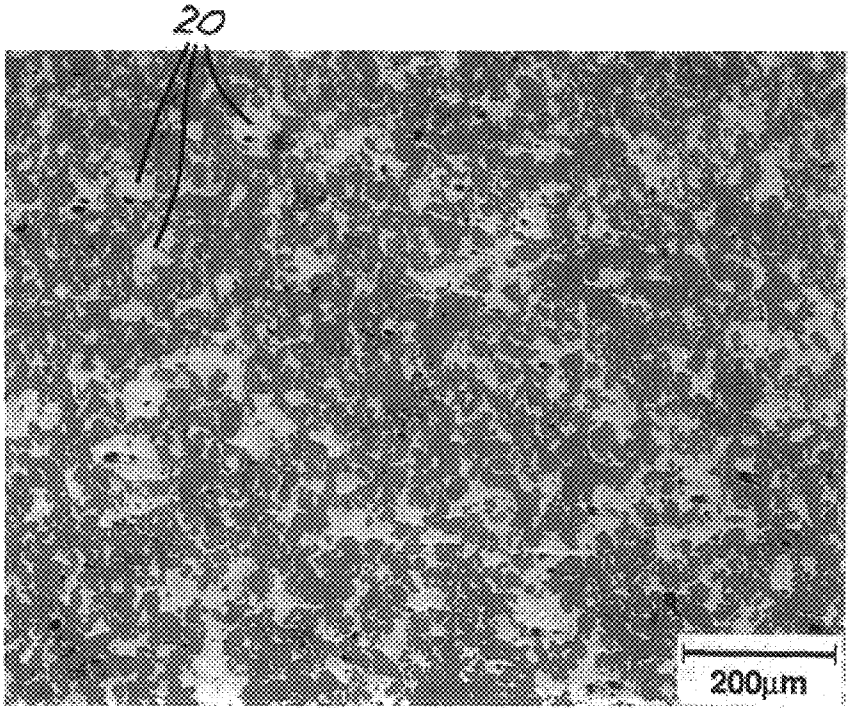



FIG. 2B

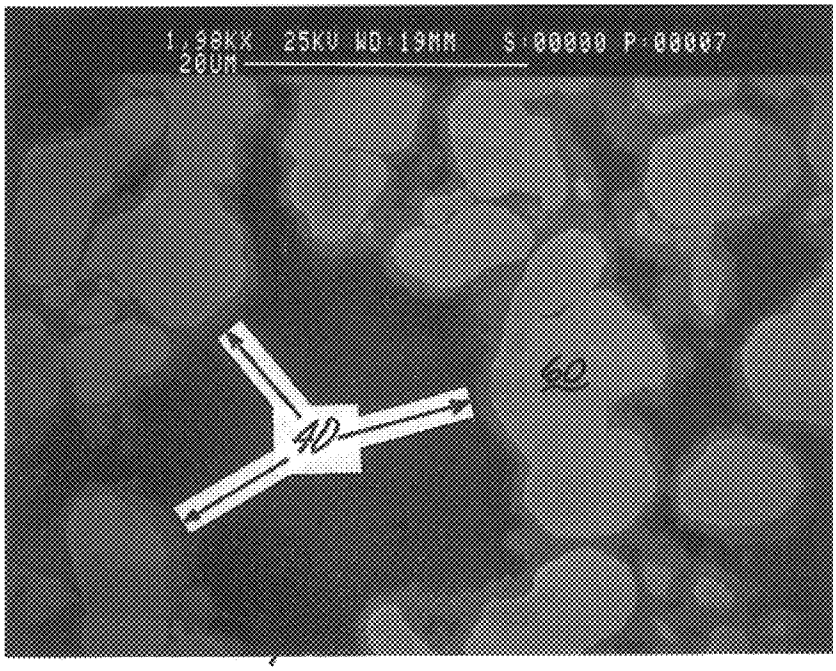



FIG. 1C

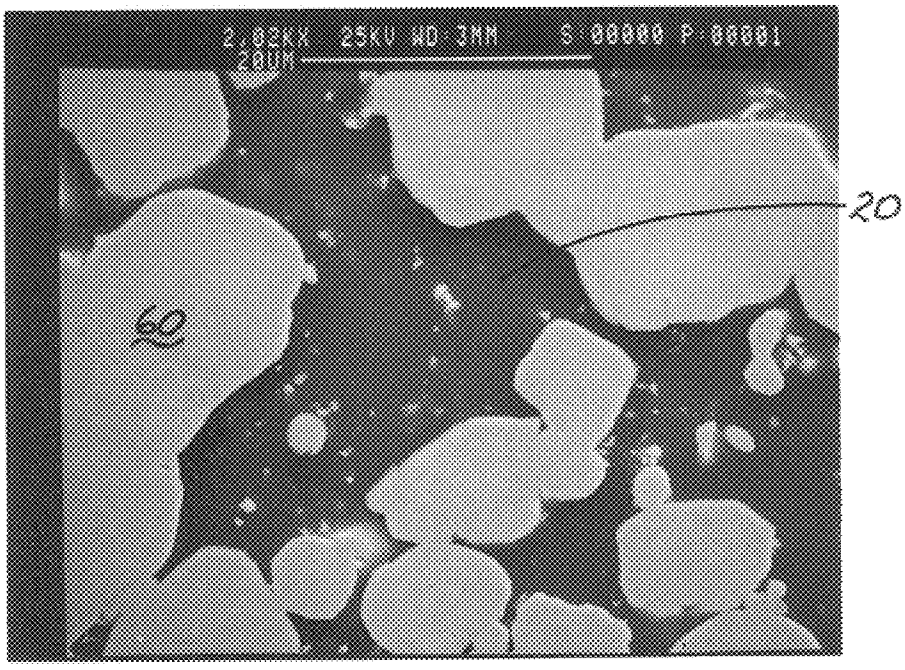



FIG. 2C

# METHOD OF MAKING UNREACTED METAL/ALUMINUM SPUTTER TARGET

## FIELD OF THE INVENTION

This invention relates generally to sputtering targets, and more specifically to methods of making high performance, high density sputtering targets composed of aluminum and a non-aluminum metal.

## BACKGROUND OF THE INVENTION

Sputtering targets are used in the formation of semiconductor substrates as a source of material to be deposited on the substrates. In some applications layers of alloys composed of one or more metals are deposited onto the surface of a substrate to improve performance and characteristics of individual products. For example, magnetron sputtering is a widely used method to deposit thin layers of aluminum and non-aluminum metal alloys onto flat and patterned substrates. The fabricated substrates are then used in the manufacture of products such as integrated circuits, memory storage devices, magnetic recording or reproducing apparatus, and ink-jet heads.

Metals to be deposited on a semiconductor substrate are removed from the sputtering target by a plasma. The quality of the resultant semiconductor substrate depends on the quality of the sputtering target supplying the material, which in turn depends on the quality of its fabrication. The fabrication of the sputtering target, in particular the target composition and structure, is important in achieving a high performance, high density substrate.

Improperly fabricated sputtering targets have several undesirable features such as low density, the presence of intermetallic compounds, and a non-uniform composition. Low density sputtering targets are undesirable because they cause outgassing during pumpdown, where air trapped in the target either increases the time for the desired level of vacuum to be reached, or prevents the necessary vacuum from being reached at all, thus reducing uptime of the target. Additionally, impurities in the air trapped in the target can contaminate the film. Intermetallic compounds are brittle and may result in sputtering target failure during fabrication or operation. A non-uniform composition of the sputtering target is undesirable because it reduces the substrate yield, since the non-uniform composition is reproduced on the film coating the substrate.

One method of solving the problem of improperly fabricated or nonhomogeneous sputtering targets, and hence the problem of reduced substrate yield, has been to use separate targets as sources for the aluminum and the non-aluminum metal. This method, however, is inefficient in that the sputtering targets must be mechanically rotated to average out the composition from each metal. Additionally, mechanical rotation has only been used when the non-aluminum metal was tantalum, thus its applicability to non-aluminum metals other than tantalum is unknown.

It would be advantageous to fabricate a sputtering target that is a homogeneous composition of an unreacted aluminum and non-aluminum metal and that contains greater than about 2% to 5% by weight of aluminum. This would be sufficient to allow formation of an aluminum layer around the non-aluminum metal. Therefore, a high quality, high performance, substantially uniform sputtering target, and an efficient method of fabricating such a target, is needed.

## SUMMARY OF THE INVENTION

To this end, the present invention provides a method of making a high performance, high density sputter target composed of a homogeneous mixture of aluminum and a non-aluminum metal.



The present invention also provides a sputter target formed by the method of the invention. Such a sputter target has high performance, high purity, and is a composition, structure and density that is substantially uniform across the body of the sputter target.

The present invention also provides a high performance, high density sputter target that is a hot pressed evacuated machined cylinder of a cold pressed blend of a non-aluminum metal powder and an aluminum powder.

According to one embodiment, a non-aluminum reactive metal such as titanium, tantalum, niobium, zirconium, iron or nickel, is fabricated into a powder by a hydride-dehydride process. In alternative embodiments, the powder may be fabricated by a sodium reduction process or an inert gas atomization process. The non-aluminum reactive metal powder may have a spheroidal, angular, or granular morphology. The non-aluminum metal powder is preferably between about 6 $\mu$m and about 300 $\mu$m, and is most preferably between about 6 $\mu$m and about 45 $\mu$m. An aluminum metal body is also fabricated into a powder by a mechanical comminution process or an inert-gas atomization process. The aluminum powder, which may have a spheroidal morphology, is preferably less than about 300 $\mu$m and is most preferably less than about 45 $\mu$m.

The non-aluminum and aluminum powders are blended with 1" long×0.5" wide cylinders of pure aluminum for at least 2 hours. A solvent such as alcohol or acetone, or a binder such as stearic acid or stearates may be added to the powders to enhance blending. The blend is subjected to cold pressing in either a uniaxial, biaxial or hydrostatic direction. In a preferred embodiment, the blended powders are subjected to cold isostatic pressing at a pressure of about 30 ksi to form a blank. The blanks are machined into a right cylinder, then the cylinder is subjected to hot pressing under a vacuum. Hot pressing is preferably performed at at least about $10^{-3}$ torr at a temperature less than 0.9 times the melting temperature in degrees Kelvin of aluminum (0.9 $T_m$ of aluminum) and at a pressure of at least about 5 ksi.

In an alternative embodiment, a non-aluminum reactive metal powder is blended with an aluminum powder. The blend is subjected to cold pressing and is then assembled into a mosaic. The mosaic is subjected to either hot isostatic pressing, vacuum hot pressing, inert gas hot pressing, or pressure-less sintering at a temperature below 0.9 $T_m$ of aluminum.

The unreacted non-aluminum metal/aluminum sputter target formed is a high performance, high density sputter target. It has a substantially uniform composition, structure and density across the body of the target and a non-aluminum metal average particle size of about 30 $\mu$m.

By virtue of the foregoing, there is thus provided a sputter target of aluminum and a non-aluminum reactive metal containing greater than about 2% to 5% by weight of aluminum and a method of making such a sputter target. These and other objects and advantages of the present invention shall be made apparent from the accompanying description thereof.

## BRIEF DESCRIPTION OF THE FIGURES

FIGS. **1**A, **1**B, and **1**C are a series of photomicrographs showing a sputter target made by an early unrefined method of the present invention.

FIGS. **2**A, **2**B, and **2**C are a series of photomicrographs showing a sputter target made by the method of the present invention.

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