Vibration Casting of AuSn and AuGe Sputtering Targets

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Abstract

The development of fine grain size in PVD sputtering targets has been shown to improve the processing performance of the target in the sputtering chamber. Fine grain size is most commonly developed in a metal through the introduction of mechanical work and the addition of heat to allow recrystallization of the metal into small grains. Some alloys due to their brittle nature are not able to be processed by traditional metal working techniques without experiencing cracking and material failure.

A novel approach to obtaining fine grain size in PVD sputtering targets for brittle materials has been developed. Gold-Tin (AuSn) and Gold-Germanium (AuGe) are two brittle alloys formed into targets used to deposit the solder layer on the device surface. Neither of these two alloys tolerate appreciable mechanical work. AuSn and AuGe are produced at near-eutectic composition leading to the formation of a heterogeneous microstructure. Traditional cast targets exhibit a large varying grain size and a large eutectic structure that is detrimental to the performance of the target. A method to introduce vibration energy during casting was developed. The energy of vibration is introduced into the molten metal leading to small grains being formed. The size of the grains formed is a function of both frequency and amplitude.

The vibrational manufacturing process develops sputtering targets that have a smaller grain size and more uniformly distribute the heterogeneous structure throughout the target. The vibrational casting process decreases the grain size from 5 mm to 0.5 mm and the eutectic structure by an order of magnitude. The smaller grain size targets produced by vibrational casting give improved performance in the chamber.

Introduction

Gold-Tin (AuSn) and Gold-Germanium (AuGe) sputtering targets are used by the microelectronics industry to deposit the solder onto thermal management packages and other devices for attachment to printed circuit boards. The development of a fine microstructure in PVD targets has been shown to improve the sputtering performance of the target. (Ref. 1)

In order to develop this fine microstructure in sputtering targets, the cast billet is typically thermomechanicaly processed by either cold or hot working to break up the cast grains. The subsequent heat treatment recrystallizes the grains. The object of this process is to recrystallize the grains without any additional grain growth.

Two solder alloys, 80%(by weight) Gold (Au) 20% Tin (Sn) and 87.5% Gold (Au) 12.5% Germanium Ge can not be made by these traditional methods. These alloys are very brittle due to their heterogeneous microstructure of the eutectic composition. They crack and break up when mechanically worked at cold temperatures. AuSn solder is successfully produced as strip by rolling the solder at an elevated temperature with small reductions between anneals. This method will not develop acceptable grain size due to the inability to achieve significant reductions.

Both alloys are produced at the eutectic composition. Figure 1 is the phase diagram of AuGe (Ref. 2). Figure 2 is the phase diagram of AuSn (Ref. 3).

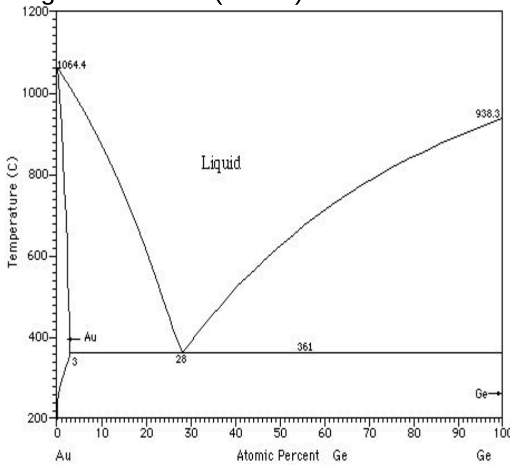

Figure 1. AuGe Phase Diagram (Ref. 2)

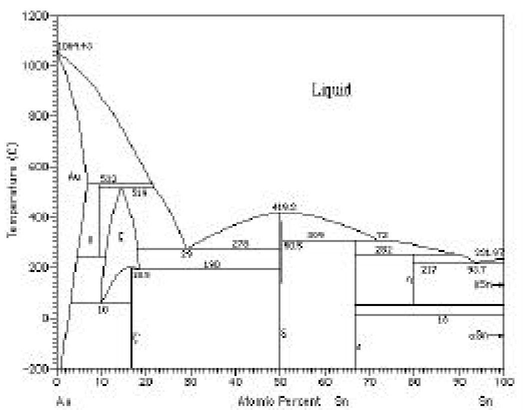

Figure 2. AuSn Phase Diagram (Ref. 3)

The introduction of vibrational energy into the casting process refines the resultant cast grain structure. The minimum grain size that can be achieved is determined by the dendrite arm spacing of the eutectic microstructure. The variation of the vibration frequency and amplitude affects the refinement of the grains. (Ref. 4).

Statically Cast Metals typically have a large variation in grain size and a large overall microstructure. Vibration casting has been extended to the production of AuSn and AuGe Sputtering targets. This method allows for fine grain sputtering targets which show an improved performance in use.

Experimental

AuSn and AuGe targets were produced both by traditional casting methods and vibrational casting methods. The targets were then examined to determine both the microstructure and grain size.

The targets were examined both visually and samples were prepared metallographically for microscopic identification before their use in the field. The targets were also examined after use.

Results

<u>AuSn</u>

A comparison was made between targets produced by standard casting techniques and the vibrational cast method. Figure 3. below shows an AuSn sputtering target after use. The brittleness of the target is indicated by the missing piece of the target.

Figure 3. AuSn Sputtering Target After Use

Figure 4 is a metallographic picture taken at 50 X of a regular cast AuSn target showing the large grain size. The specific picture is of a grain boundary.

In comparison, Figure 5 is a metallographic picture of the vibrationally cast AuSn target taken at a magnification of 50X. The microstructure an order of magnitude smaller after vibrational casting.

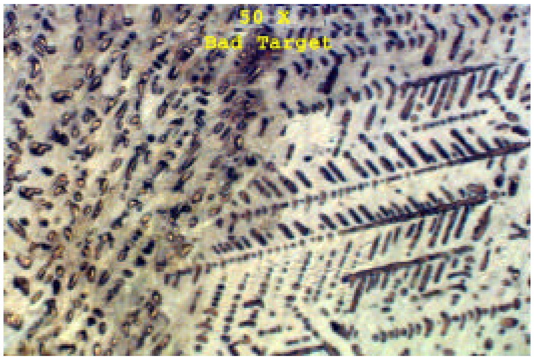

Figure 4. AuSn Regular Cast - 50X

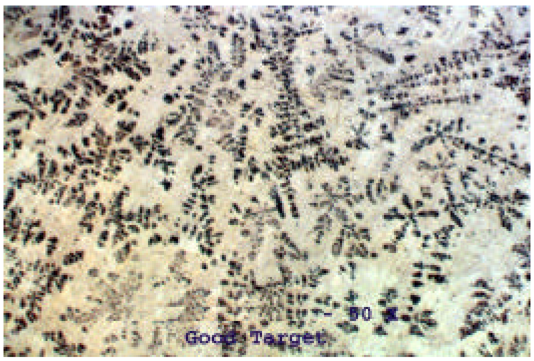

Figure 5. AuSn Vibration Cast - 50X

A comparison of the grains was also made at a magnification of 100 X. At this magnification you can clearly see the dendritic structure at the AuSn eutectic. The difference in the microstructure between the statically cast material (Figure 6) and the vibrationally cast material (Figure 7) is also apparent.

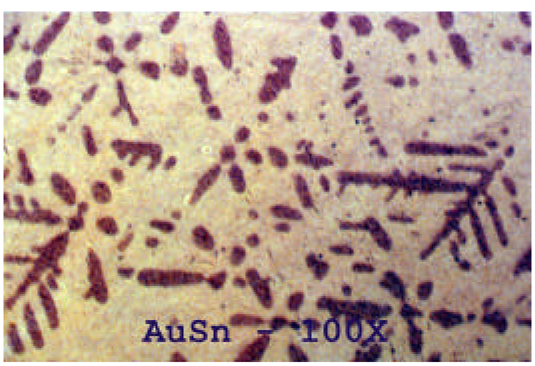

Figure 6. AuSn Static Cast - 100X

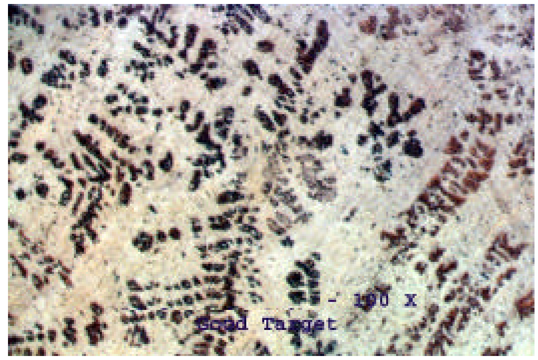

Figure 7. AuSn Vibration Cast - 100X

<u>AuGe</u>

Similar results were found with the AuGe sputtering targets. The microstructure of the AuGe eutectic composition responds to the vibrational energy to form a smaller grain size.

Figure 8 is a full view of an AuGe sputtering target after use displaying some of the large eutectic microstructure that resulted from a normal static cast.

Figure 8. AuGe Sputtering Target After Use

A metallographic examination of the AuGe microstructure at 50X magnification showed that the eutectic composition of the vibrationally cast target was an order of magnitude greater than the statically cast target. Figure 9 is the microstructure of the regularly static cast AuGe at a magnification of 50X.

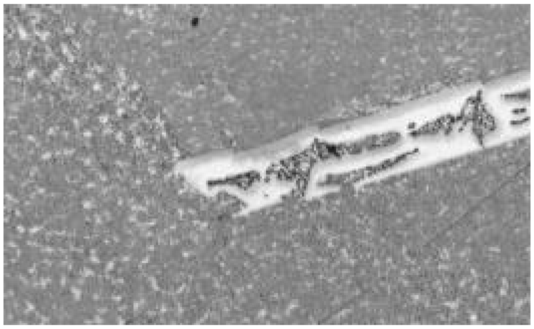

Figure 9. AuGe Regular Static Cast - 50 X

Figure 10 shows the improvement in the microstructure of the AuGe after vibration casting. The grain size is an order of magnitude smaller in the vibrationally cast target.

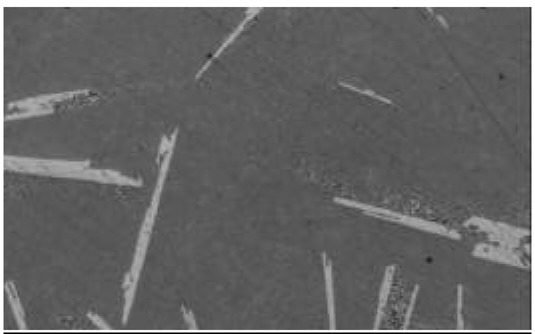

Figure 10. AuGe Vibration Cast - 50 X

Grain Size

The grain size on the AuSn and AuGe targets was measured to confirm the order of magnitude improvement as given in Table I.

Table I

	AuSn	**AuGe**
Regular Static Cast	5.0 mm	7.0 mm
Vibration Cast	0.5 mm	0.6 mm

Summary

At the eutectic compositions that AuSn and AuGe sputtering targets are produced, the material is too brittle for the microstructure to be developed by conventional metal working techniques. Vibrational casting is an effective method of effectively producing fine grain solder sputtering targets.

While traditional static cast targets have a mean grain size of 5-7 mm; the vibrational cast method produces a target with a fine grain size of 0.5-0.6 mm.

This order of magnitude improvement in the target has shown more consistent solder film deposition at our customers. The films deposited by these targets provide consistent solder properties in the microelectronic devices.

References

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