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An electron backscattered diffraction analysis on microstructure of continuous unidirectional solidification Cu–2.5%Sn alloy

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An electron backscattered diffraction analysis on microstructure of continuous unidirectional solidification Cu–2.5%Sn alloy

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Abstract. A Cu–2.5%Sn alloy was fabricated by continuous unidirectional solidification (CUS). The EBSD was used to analyse the microstructure of CSU Cu–2.5%Sn alloy. The results show that the alloy is composed of coarse columnar grains, which grow along the direction of [001] and [101], and the average diameter of the columnar grains is about 470 μm. Most of grain boundaries between the columnar grains are small-angle and the rest are high-angle grain boundaries. It is also found that the CUS Cu–2.5%Sn alloy has strong {110} <110> texture and cubic texture.

1. Introduction

The columnar grain structure can be obtained by continuous unidirectional solidification (CUS). In the process, the columnar grain grows along the opposite direction of the heat flow. The growth direction of columnar grain has an important influence on mechanical properties of the alloy [1, 2]. At the same time, the texture direction also has an effect on the performance of the plastic processing [3]. For observation of columnar grain orientation, the traditional method mainly relies on comprehensive analysis of XRD, optical microscope, scanning electron microscope (SEM) and transmission electron microscope (TEM) etc. technology. Then the possible solidification mode can be deduced by using these results [4-6]. For example, TEM is used to analyze the pattern of diffraction patterns and obtain grain orientation information. TEM technology has the advantages of high spatial resolution of microanalysis. However, it takes a long time for sample preparation [7]. On the contrary, electron back scattering diffraction (EBSD) or oriented imaging microscopy (OIM), based on SEM, has developed very quickly as a new technology [8-11]. EBSD technology has SEM features, can be used for large block samples, and has ability to analyze crystallographic data. Furthermore, EBSD technology has become increasingly popular as the most powerful tool for measuring of grain orientation, orientation difference, phase, strain and grain size.

In this study, Cu–Sn alloy with Sn content of 2.5% (mass percentage) was fabricated by CUS, and the electron backscatter diffraction (EBSD) was used to analyze the microstructure of CUS Cu–2.5%Sn alloy, which included the grain orientation, texture, and the grain boundaries.

2. Experimental

2.1. CUS Cu–2.5%Sn experiment

In this paper, Cu–2.5%Sn alloy was used as raw materials, and the experiments were performed using the CUS technology. The method and technology for alloy fabrication were described in elsewhere [12]. The Main process parameters are as follows: the mold temperature of 1080 °C, the melt temperature control at 1200 °C continuous casting speed of 10 mm/min. an alloy with a diameter of 10 mm can be continuously pulled out by traction wheels.

2.2. EBSD experiment

The continuous unidirectional solidification Cu–2.5%Sn alloy was cut along the axial direction. Then the surface of the sample was polished and cut with sandpaper. Finally, the surface of the profile was subjected to electrolytic corrosion. The microstructure was observed by field emission scanning electron microscopy and use of EBSD function.

3. Results and Discussion

Fig. 1 is the microstructure of CUS Cu–2.5%Sn alloy. From the figure, it can be seen that the CUS Cu–2.5%Sn alloy is mainly composed of column grains, and the average diameter of the column grains is approximately 470 μm. The columnar grains of different colors in the figure represent the different Euler angles.

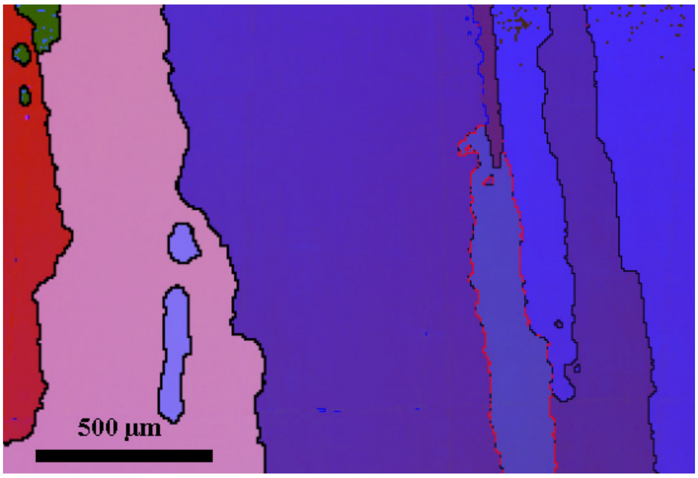

Figure 1. Microstructure of CUS Cu–2.5%Sn alloy

The microstructures mentioned above are analyzed by inverse pole map, and the results are shown in Fig. 2. As can be seen from the figure, it has higher density in [001] and [101] directions and lower density in [111] directions, which means that the orientation of the grains in Fig. 1 is mainly in the [001] and [101] directions. Copper alloy has faster growth direction in [001] and [101] directions [13, 14]. During CUS, the alloy grows mainly in the opposite direction of heat flow. In the experiment, the direction of heat flow is almost vertical downward. Therefore, columnar grains grow upward. In the process of columnar grains growth, the grains that grow faster with [001] and [101] directions gradually eliminate the grains with the other directions of slower growth, resulting in higher grain density in both directions.

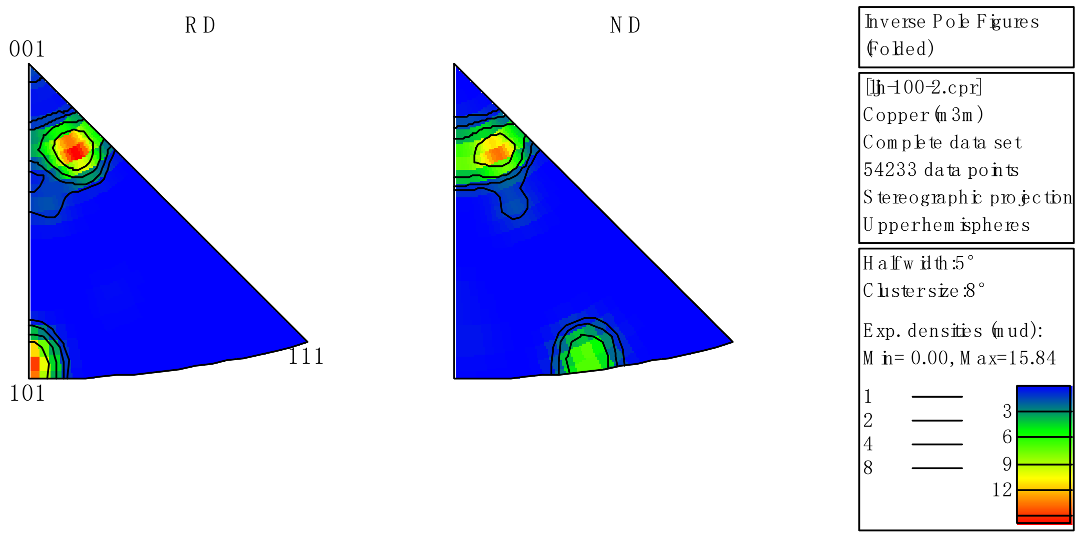

Figure 2. Inverse pole diagram of CUS Cu–2.5%Sn alloy

Fig. 3 is a texture analysis of CUS Cu–2.5%Sn alloy, with different colours representing different structural organizations. The cyan in the picture represents cubic texture, and the yellow represents {110} <110> texture. It can be seen that the two occupy 18.7% and 45.3%, respectively, as shown in Fig. 3(b). The other colours represent other texture, for example, the green columnar grains belong to {110} <100> textures, which is not the main texture of CUS Cu–2.5%Sn alloy because of their smaller volume fraction.

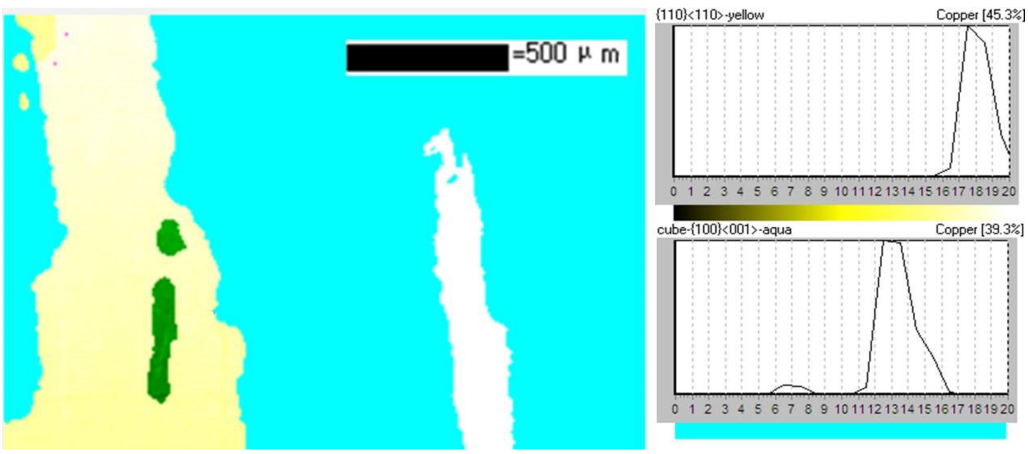

Figure 3. Schematic diagram of weave composition for CUS Cu–2.5%Sn alloy

The above results indicate that the Cu–2.5%Sn alloy fabricated by CUS has strong texture characteristics. Compared with the normal solidification alloy, the grain growth has a significant direction. These results are basically consistent with the grain growth direction which is mentioned above.

Fig. 4 is the grain boundary angle levels of CUS Cu–2.5%Sn alloy. It can be seen that the angle between the columnar grains ranges from 5° to 55°. It indicates that there is a high-angle grain boundary (>15°) between columnar grains and small-angle grain boundary (⩽15°). When the growth direction of columnar grains is basically same, a small-angle grain boundary can be formed. For example, in Fig. 1, the columnar grains on the left are roughly the same color, indicating that the Euler angles are not very different and have the same texture (the cyan region in Fig. 3). As a result, the two angles are basically 5°~9°. Similarly, when the growth direction of columnar grains is quite different, a high-angle grain boundary can be formed. For instance, in Fig. 3, the columnar grains with yellow colour do not belong to the same texture as the other columnar grains, so there exists high-angle grain boundaries. It is much higher than the other green and cyan columnar grains, which is between 20° ~55°, as shown in Fig. 4.

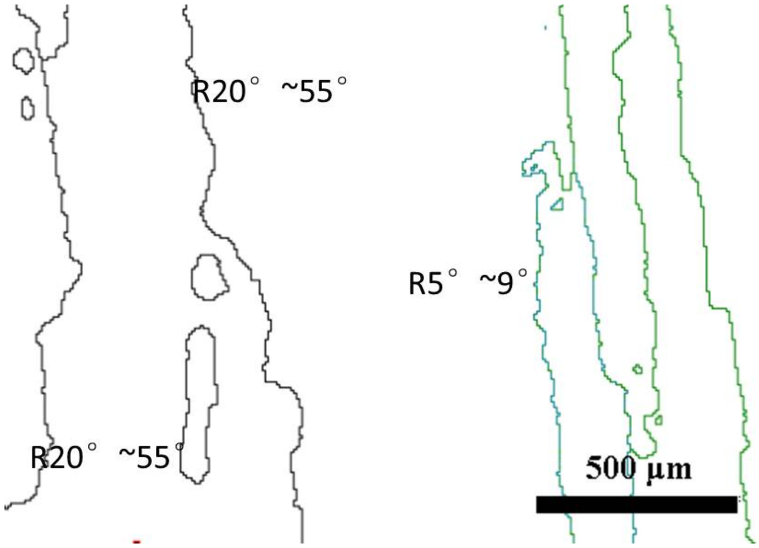

Figure. 4 Boundary angle levels of CUS Cu–2.5%Sn alloy

In CUS process, mold temperature is controlled near the liquidus of the alloy. At the same time, the solidified alloy is forced to cool at the mold exit. Therefore, there exists a strong heat flow from top to bottom of the mold, which forms the unidirectional solidification condition. Grains begin to grow along the opposite direction of heat flow. However, the crystallographic plane, which parallel to the direction of heat flow, has rapid growth speed, and grows up to form columnar grain. The columnar grains with rapid growth gradually eliminate the ones with slow growth. Spatially, the direction of heat flow is basically parallel to [001]. Therefore, the [001] and [101] direction of columnar grains have priority growth and gradually forms columnar grain growing along a single direction.

4. Conclusions

Cu–2.5%Sn alloy was prepared by CUS technology, and the EBSD was used to investigate the microstructure of alloy. The following conclusions are obtained.

1) CUS Cu–2.5%Sn alloy is mainly composed of coarse columnar grain and the growth direction of columnar grains is mainly [001] direction and [101] direction.

2) There are both large angle and small angle boundary between the columnar grains.

3) CUS Cu–2.5%Sn alloy has strong {110} <110> texture and cubic texture.

Acknowledgments

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