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EFFECT OF DIRECTIONAL CRYSTALLIZATION RATE ON MICROTEXTURE OF Al-$CuAl_2$ EUTECTIC ALLOY

WPŁYW SZYBKOŚCI KRYSTALIZACJI KIERUNKOWEJ NA MIKROTEKSTURĘ EUTEKTYCZNEGO STOPU Al-$CuAl_2$

The effect of crystallization rate on the microstructure and the orientation relationship of (Al) and $CuAl_2$ phases in the eutectic alloy was investigated using a step-by-step beam scan on the computer controlled transmission electron microscope.

The microstructure of this alloy evolves from the approximately parallel lamellar structure into the eutectic colony structure depending on the rate of the crystallization.

On the basis of the measurement of the individual orientations in the sections perpendicular to the crystallization direction the orientation maps were constructed. The resulting data enabled to link the microstructure to the orientation relationships between (Al) and $CuAl_2$ phases and the preferred orientations.

The dominant orientation relationship identified in all analysed samples was (111)(Al)//($2\bar{1}1$)$CuAl_2$, [$\bar{1}10$](Al)//[120]$CuAl_2$. In the small irregular areas the appearance of other orientation relationships has been found.

Keywords: microtexture, orientation relationship, orientation microscopy

W pracy badano wpływ szybkości krystalizacji kierunkowej stopu eutektycznego Al-$CuAl_2$ na mikrostrukturę i relację orientacji faz (Al) i $CuAl_2$ w transmisyjnym mikroskopie elektronowym.

Mikrostruktura stopu zmienia się wraz z szybkością krystalizacji stopu od w przybliżeniu regularnej płytkowej do kolonii eutektycznych.

Na podstawie pomiarów pojedynczych orientacji w przekrojach prostopadłych do kierunku krystalizacji zostały utworzone mapy orientacji, na podstawie których określono wyróżnione orientacje obu faz.

Stwierdzono, że dominującą relacją orientacji faz jest (111)(Al)//($2\bar{1}1$)$CuAl_2$, [$\bar{1}10$](Al)//[120]$CuAl_2$.

1. Introduction

The properties of a crystalline material depend on the geometry of internal ordering. The description of a crystalline material requires its characteristics as a statistical distribution of its elements (crystallites) and their mutual correlations. When the texture is considered as an orientation distribution, the crystallites have distinguished orientations in relation to the directions and planes characteristic for the process of the material treatment which has influence on its functional properties. Modern experimental – analytical techniques (orientation microscopy) used for the analysis of the local texture (microtexture) of Al-$CuAl_2$ alloy allow a quantitative presentation of the problem.

2. Material

The paper presents the analysis of the microtexture of the Al-$CuAl_2$ eutectic alloy (containing 33.2 wt% of Cu and 66.8 wt% of Al) obtained in the process of directional crystallization by the B r i d g m a n method at various crystallization rates (a detailed description has been presented in the study [1]). This alloy belongs to the group of composites in situ. It is characterized by distinct crystallographic texture.

3. Microstructure analysis

The microstructure was analysed with respect to the morphology and the orientation characteristics. The orientation relationships between phases occurring on both

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sides of the interface and their orientations with respect to the crystallization direction were determined.

3.1. Morphology description

The paper presents the analysis of samples (the round rods with the diameter of about 3 mm) crystallizing at various rates: $v = 21 \cdot 10^{-5}$ cm/s, $v = 85 \cdot 10^{-5}$ cm/s, $v = 333 \cdot 10^{-5}$ cm/s. A change of the crystallization rate is followed by a modification in the microstructure of the alloy. Figures 1, 2, 3 show the cross sections of the analysed samples made in scanning electron microscope.

a) b)

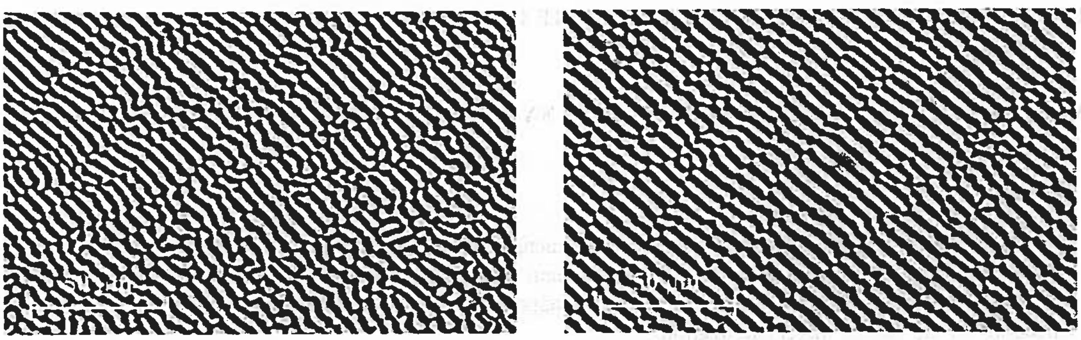


Fig. 1. Microstructure of the cross section of a sample crystallizing at $v = 21 \cdot 10^{-5}$ cm/s; a) near the sample edge, b) at the sample center; magnification 600x

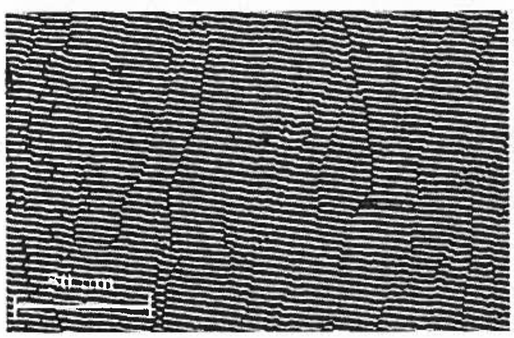


Fig. 2. Microstructure of the cross section of a sample crystallizing at $v = 85 \cdot 10^{-5}$ cm/s; magnification 600x

a) b)

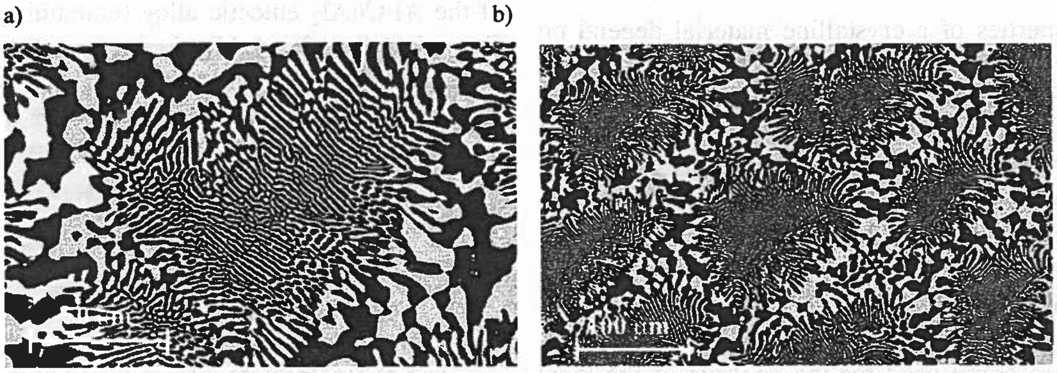


Fig. 3. Microstructure of the cross section of a sample crystallizing at $v = 333 \cdot 10^{-5}$ cm/s, a) magnification 600x, b) magnification 250x

The microstructure of a sample crystallizing at the rate $v = 21 \cdot 10^{-5}$ cm/s is composed of lamellae, about 3 μm thick, and near the sample edge the lamellae are arranged very irregularly (Fig. 1a). When moving towards the middle of the rod we can observe a regular arrangement of parallel lamellae of (Al) and $CuAl_2$ phases (Fig. 1b).

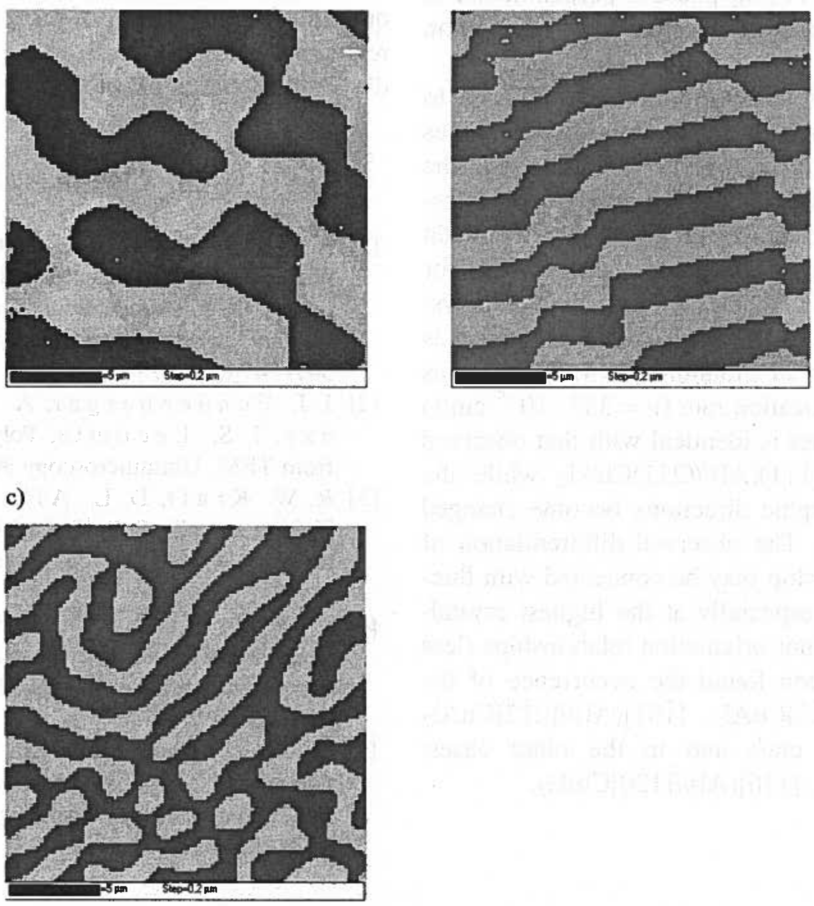
A similar microstructure is observed in the case of a sample crystallizing at the rate $v = 85 \cdot 10^{-5}$ cm/s, with the difference that the lamellae of the phases are parallel to each other on the whole cross section of the sample and their thickness is considerably smaller (about 1.7 μm) (Fig. 2).

A completely different microstructure is revealed in the case of a sample crystallizing at the rate $v = 333 \cdot 10^{-5}$ cm/s. It is composed of cells of similar size, in which the lamellae are deviated towards the cell boundaries (Fig. 3). It has been observed that only in the middle part of such complex cell the lamellae grow parallel to the crystallization direction, and in this area their thickness is about 1 μm. In the other places an apparent increase in the samples thickness due to their deviation towards the cell boundaries was observed.

3.2. Microtexture analysis

The microtexture of Al-$CuAl_2$ alloy was determined using the orientation microscopy. This method enables the measurement of large sets of single orientations in a transmission electron microscope through automatic indexing of the diffraction patterns (the Kikuchi lines) and determination of orientations in the analysed area at the given measurement step [2]. The diffraction patterns obtained using TEM were used to identify the orientations of lamellae of (Al) and $CuAl_2$ phases with respect to the crystallization direction and further on also the orientation relationship between the neighbouring lamellae of the phases (Fig. 4).

a) b)



c)

Fig. 4. Orientation maps constructed for samples crystallizing at the rates:
a) $v = 21 \cdot 10^{-5}$ cm/s, b) $v = 85 \cdot 10^{-5}$ cm/s, c) $= 333 \cdot 10^{-5}$ cm/s

For each of the three samples crystallizing at various rates the planes (hkl) perpendicular to the crystallization direction have been determined (Table 1).

TABLE

Orientation alterations depending on the crystallization rate

The crystallization rate [cm/s]	The planes perpendicular to the crystallization direction	
	(Al)	$CuAl_2$
$v = 21 \cdot 10^{-5}$	$(\bar{1}27)$	$(\bar{1}15)$
$v = 85 \cdot 10^{-5}$	$(\bar{1}\bar{1}2)$	$(\bar{2}14)$
$v = 333 \cdot 10^{-5}$	$(\bar{3}34)$	(201)

From the data listed in Table 1 it follows that the orientation of lamellae undergoes changes depending on the crystallization rate. It is connected with the deviation of the interface plane from a position parallel to the crystallization direction, which occurs at the rates: $v = 21 \cdot 10^{-5}$ cm/s and $v = 333 \cdot 10^{-5}$ cm/s. In the case of a sample crystallizing at $v = 85 \cdot 10^{-5}$ cm/s the interface plane is parallel to the crystallization direction and the direction $[\bar{1}10]$ in (Al) phase is perpendicular to crystallization direction, which results in the orientation $(\bar{1}\bar{1}2)$.

Further analysis of the orientation sets allowed to determine the distributions of the orientation differences and their local maxima. On the basis of these data the relations of the orientations of (Al) and $CuAl_2$ phases were determined. It has been found that the main orientation relationship of the phases (about 95%) for $v = 21 \cdot 10^{-5}$ cm/s and $v = 85 \cdot 10^{-5}$ cm/s is as follows: $(111)(Al)//(2\bar{1}1)CuAl_2$, $[\bar{1}10](Al)//[120]CuAl_2$ and it is analogous to that cited in literature [3, 4, 5], whereas for the greatest crystallization rate ($v = 333 \cdot 10^{-5}$ cm/s) the relation of the planes is identical with that observed in the earlier cases $(111)(Al)//(21\bar{1})CuAl_2$ while the coinciding crystallographic directions become changed $[\bar{2}11](Al)//[102]CuAl_2$. The observed differentiation of the orientation relationship may be connected with fluctuations of heat flow, especially at the highest crystallization rate. As the minor orientation relationships (less than 5%) there has been found the occurrence of the relation $(1\bar{1}1)(Al)//(1\bar{2}\bar{2})CuAl_2$, $[\bar{1}01](Al)//[2\bar{1}2]CuAl_2$ for $v = 333 \cdot 10^{-5}$ cm/s and in the other cases: $(1\bar{1}2)(Al)//(2\bar{1}2)CuAl_2$, $[110](Al)//[120]CuAl_2$.

4. Summary

A distinct dependence between the crystallization rate and the microstructure has been observed.

The morphology and the orientation characteristics are transformed depending on the crystallization rate.

The microstructure of Al-$CuAl_2$ eutectic alloy evolves from the local irregular structure into the approximately parallel lamellar eutectic in samples crystallizing at the rates $v = 21 \cdot 10^{-5}$ cm/s and $v = 85 \cdot 10^{-5}$ cm/s. The microstructure of the sample crystallizing at $v = 333 \cdot 10^{-5}$ cm/s is more complex; it consists of eutectic colonies.

The main and the minor orientation relationships remain constant for the lower crystallization rates, however the planes perpendicular to the direction of crystallization alter. In the sample crystallizing at $v = 333 \cdot 10^{-5}$ cm/s only the planes describing the main orientation relationship remain unchanged.

The modifications of planes perpendicular to the crystallization direction in (Al) and $CuAl_2$ phases (observed at the lowest and the highest rates) are the consequence of the deviation of the planes in the orientation relationship description from the location parallel to the direction of crystallization.

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