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Technology of obtaining REM-containing master alloy for silumins modification

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Abstract. The technology of producing ligatures containing rear earth metals (REM) for modification of silumins has been developed. The optimum content ratio of yttrium, cerium and lanthanum 2: 1: 0.5 (15-20 wt.% Y, 7-10 wt.% Ce, 3.5-5.0 wt.% La) for the synthesis of REM aluminides has been established. The peculiarities of the REM aluminides synthesis is studied using the methods of optical and electron microscopy and X-ray microanalysis, followed by the identification of the structural components of the Al-REM alloy. The microstructure of the master alloy is proved to consists of: REM aluminides (yttrium-containing and cerium-containing), metal base (Al), Al eutectic + REM aluminide and α + Si.

1 Introduction

There are very few publications on the development of compositions of master alloys from rare-earth metals for the silumins modification [1–4]. In the majority of works aluminum master alloys containing Ti, C, B, Ca, REM, P, and others are used [5].

Today Ce, La, Nd, Y etc. metals as well as mischmetals and transition metals or REM master alloys are widely used for modifying aluminum alloys, silumins in particular [6-19]. For example, the modification of the alloy Al-20 wt.% Si [7] with cerium (0.3-1.0 wt.%) contributes to the transformation of primary silicon of a large star-like shape to a small block shape, and the eutectic silicon of a needle-shape to a thin fibrous shape. In this case, the tensile strength σb and relative elongation δ are increased by 68% and 53.7%, respectively. The combined effect of Ce and Pr (0.6 wt.%) [8], Ce and La (2.0 wt.%) in A356 and A413 alloys with and without strontium [10-11], mischmetals based on La, Y and other alloys in Al-21 wt.% Si [12-14] and ligatures from Ce and Mn [16] significantly change the silumin fractography and its mechanical properties.

The literature review provides no information on the problem of technology development of the Al-Y-Ce-La master alloy synthesis. In this regard the present work gives a detailed identification of the structural components of this master alloy and determines their micro- and nanohardness values.

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2 Research methods

Aluminum of A95 grade was superheated to 900°C in the pure argon atmosphere and pure yttrium, cerium and lanthanum were introduced in the ratio - 2: 1: 0.5 (wt.%: 15-20 Y; 7-10 Ce; 3.5-5.0 La) [1,2].

Micro X-ray spectral analysis was performed to determine the content of elements on an analytical research complex based on FE-SEM Hitachi Su-70 (Japan) with attachments for energy dispersive (Thermo Scientific Ultra Dry) and wave X-ray microscopic analysis.

The microhardness test was carried out according to the standard procedure on a Vickers instrument of Shimadzu HMV-G brand [20]. Nanohardness was measured on an Integra Prima atomic force microscope [21]. Local analysis was carried out on 3-5 points of sample sections, and the average chemical composition of the structural components - α-solid solution, eutectic and intermetallic compounds $Al_xSi_yFe_zREM_v$ - was determined.

3 Results and discussion

Table 1 shows the stoichiometry of the synthesized aluminides (yttrium-containing and cerium-containing) in Al-Y-Ce-La master alloy.

According to the state diagrams, yttrium forms Al3Y aluminide, but cerium and lanthanum - $Al_{11}Ce_3$ and $Al_{11}La_3$ (respectively $Al_{3.66}Ce$ and $Al_{3.66}La$). The synthesized REM aluminide containing yttrium corresponds to the formula $Al_{3,11}REM$, but the standard one according to the state diagram - Al_3Y. The discrepancy between these values is insignificant (0.11 at.% Al).

Table 1. Stoichiometry of REM aluminide.

Aluminide REM	Element composition, at.%					
	Y	Ce	La	∑REM	Metal base	Eutectic
Yttrium-containing REM	17.2	5.38	1.71	24.29	Al, 100%	95Al; 1,82Y; 0.75 La 0.81Ce; ∑REM=3.38 Impurities: 1.0-1.77 Fe; 0-0.68Si
	$Al_{75,71}$ REM $_{24,29}$=$Al_{3,11}$REM					
cerium-containing REM	6.44	8.62	6.26	21.32	Al, 100%	93.23Al; 1.26Y; 0.3 La; 0.45Ce; ∑REM=2.01 Impurities: 1.0-1.77 Fe; 0-0.68Si
	$Al_{78.68}REM_{21.32}$=$Al_{3.69}$REM					

The resulting cerium-containing REM aluminide has a stoichiometry of $Al_{3,69}REM$, slightly different from $Al_{3,66}REM$. The discrepancy in stoichiometry is 0.03 at.% Al. From table 1 it follows that Al, Fe, Si and REM are present in the eutectic in certain amounts, the estimated structure of the eutectic corresponds to: Al+$Al_{3,66}$Р3М+Al_3Y+Si+$FeAl_3$. The iron-silicon compounds of variable composition $Al_xSi_yFe_z$ are also supposed to present.

The results of microhardness measurements showed that the yttrium-containing REM aluminide has a higher microhardness value (on the average 6547 MPa) than the microhardness of cerium-containing REM aluminide (the average 4695 MPa). The microhardness of pure aluminide is 254 MPa, and the microhardness of eutectic (Al + REM aluminide) is 423 MPa.

Fig. 1 shows the microstructure and location points of nanohardness measurement of structural components Al-Ce-La-Y of master alloy

It was established that nanohardness value of cerium-containing REM aluminide is 8560 MPa. Nanohardness of yttrium-containing REM aluminide is 9627 MPa. Accordingly, the nanohardness - and microhardness of yttrium-containing REM aluminide is significantly higher than that of cerium-containing REM aluminide. The average value of aluminum nanohardness corresponds to 1500 MPa. The average nanohardness value of the eutectic is 4650 MPa.

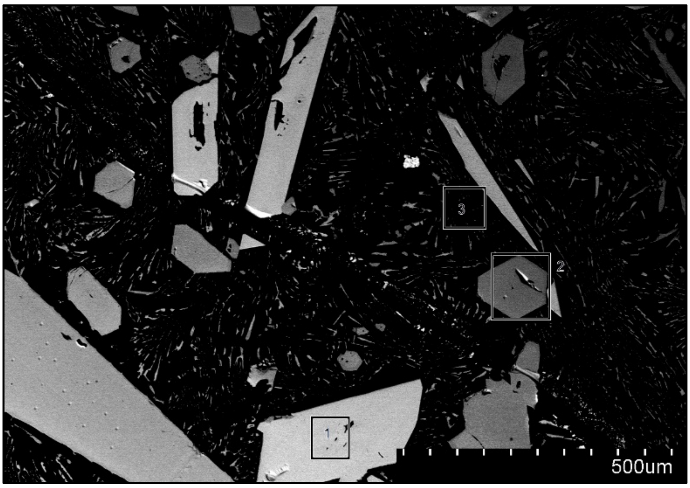

Fig. 1. Microstructure and location points of nanohardness measurement of Al-Ce-La-Y structural components of master alloy: 1- light crystal of REM aluminide (cerium-containing); 2 - darker crystal of REM aluminide (yttrium-containing); 3 - eutectic (Al + REM aluminide of variable concentration).

4 Conclusions

Micro X-ray analysis identified the structural components of the synthesized master alloy Al-Y-Ce-La:

- metal base consists of pure aluminum and eutectic ($Al+Al_xREM_y$); microhardness of pure aluminum is 254 MPa, and nanohardness - 1500 MPa;
- yttrium-containing REM aluminide has the Al3Y stoichiometry ; microhardness is 6547 MPa, and nanohardness is 9627 MPa;
- cerium-containing REM aluminide has the stoichiometry $Al_{11}REM = Al_{3.66}REM$ ($Al_{3.66}Ce$, $Al_{3.66}La$); Microhardness - 4695 MPa, and nanohardness - 8560 MPa.

1) The increase in the addition of master alloy up to 0.5 wt.% contributes to the grinding of structural components - α-solid solution and eutectic, and to crystallization of highly solid complex-doped aluminide $Al_xSi_yFe_z$ with and without REM (in the original alloy).
2) Structural components of the AK7ch alloy are identified at the addition of the increasing amount of Al-Y-Ce-La master alloy (α-Si solid solution in aluminum, α+Si eutectic and complex-doped REM aluminides - $Al_xSi_yFe_z$ and $Al_xSi_yFe_zREM_v$).
3) Regularities of changes in the element solubility and microhardness values of the structural components depending on the addition amount of master alloy Al-Y-Ce-La are revealed. Correlations between the silicon solubility in the α-solid solution and its microhardness are found. The hardness of the HB alloy is stated to depend on the values of microhardness of the α-solid solution and eutectic.

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