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Formation of amorphous-nanocrystalline structures in the conditions of stepped quenching of melts (SQM)

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The results of the calculation analysis of the formation processes of the volume-amorphized alloy $Mg_{65}Cu_{25}Y_{10}$ structure obtained by the method SQM, are presented. The thermal regime of the used method includes 3 stages: (1) – rapid cooling of the preheated melt to a temperature T_h which is close to the glass transition temperature T_g ($T_h = T_g + (30 – 100)$ K); (2) is the isothermal exposure at T_h for a given time period t_h; (3) is the final quenching operation from T_h to room temperature. In the conditions of stepped quenching, the mass crystallization occurs at deep melt supercoolings which respects to the melting point and corresponds to close to the maximum values of the nucleation frequency (~ 10^{17}–10^{18} $m^{-3}\cdot s^{-1}$) and negligible (~ 10^{-10}–10^{-9} $m\cdot s^{-1}$) values of the crystals growth rate. Such combination of kinetic parameters of crystallization gives the perspective of creating primary nanocrystalline structures. It is also obvious that by interrupting of isothermal crystallization, it is possible to obtain amorphous-nanocrystalline composites (ANCs) with different relations of structural components.

According to results of the performed studies, at isothermal exposure temperature T_h = 475 K (T_g + 50 K), the fraction of the crystallized volume x = 0,1 is formed over a time interval of t_h = 350 s. During this time ~ $9\cdot10^{19}$ crystals per unit volume are generated. The final average size of these crystals is 64 nm. At the final stage of SQM, the liquid part of the volume (1-x) solidifies without crystallization with forming an amorphous ANC matrix. With increasing of the isothermal stage duration to t_h =585 s, the volume fraction of the crystals increases to 50%, and their total number and average sizes reaches the values N=$1{,}3\cdot10^{20}$ m^{-3}, $\bar{R}$ = 97 nm. In the third variant of calculations the parameters t_h, N, $\bar{R}$, corresponding to the value x = 0,9, were determined. It is shown that the ANC structure with the crystalline phase predominance (90%) is formed during 950 s and characterized by increased values of bulk density (~$1{,}5\cdot10^{20}$ m^{-3}) and average sizes (~ 110 nm) of crystals.

The results of calculations confirm the principal possibility of using the SQM to obtaining a wide range of ANC-structures of the $Mg_{65}Cu_{25}Y_{10}$ alloy.