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Microinhomogeneity of Liquid Alloys: Microscopy characterization and new production methods.

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The modern notions on the structure of liquid metals and alloys are surveyed. It is shown that several types of microinhomogeneity and microheterogeneity of liquid metallic solutions can exist. Varying their composition and pre-history, the temperature and the pressure or influencing them with various external impacts, one can change their structural state. At subsequent cooling with appropriate rate, these changes can be conserved down to liquidus and influence the structure and properties of solidified alloy. Various techniques were used to analyze the microstructure of the solidified alloys, including scanning electron microscopy, transmission electron microscopy and energy X-ray spectroscopy. Same examples of the alloys were treated by new technology and reviewed. These alloys are characterized by multiphase amorphous or crystalline structure. It is shown that such optimized thermal treatment of melts is efficient for both rapidly quenched metallic materials (amorphous ribbons, bulk amorphous alloys and glass coated microwires) or alloys produced by sand or chill casting technology.

In molten metals and alloys, the strong interaction of constituent particles substantially limits their relative positions; the resulting correlation is referred to as the local order, or short-range order. Metallic melts belong to systems with a strong interaction of particles. So, one expects the local order to be strong and close to a crystalline local arrangement. The structure of binary and multi-component molten alloys can be considered as a mixture of clusters based on different atoms and immersed into liquid predominant component. For example, the structure of Fe-B melts is usually presented as B-based clusters surrounded by the Fe matrix [1]. Therefore the liquid metallic solution is inhomogeneous at microscopic scale, i.e. microinhomogeneous. The clusters enriched with different components, do not have distinct interface with surrounding melt: their local composition and local structure change with distance from a central atom gradually and coincide with composition and structure of matrix at a distance of 10-20 Å. The following types of microinhomogeneity and microheterogeneity of liquid metallic solutions appear and analyzed:
-the short-range inhomogeneity which is caused by various kinds of the local order and can be changed by means of clusters volume fractions transformations or polymorphous transitions inside the clusters;
-the middle-range fractal inhomogeneity which is caused by the existence of two or more types of atomic interactions and can be changed by means of metalloid chains evolution: their elongation, joining to nets, coagulation to globules etc.;
-the nano-scaled colloid microheterogeneity which is caused by pre-history of the melt and can be changed by means of disperse particles volume fraction, size and composition transformations.

The use of Fe-base amorphous materials like METGLAS 2605SA1, 2605CA1 for air gap chokes, C-cores and other high frequency components is quite traditional now. These amorphous alloys have saturation induction over 1.5T, and their cost is comparatively low. The challenge is to decrease the watt losses at high frequencies while maintaining the advantages of high saturation induction and low cost. Using technology described below developed a new Fe-based alloy. This alloy has approximately the same saturation induction as the above-mentioned METGLAS products, but it features considerably lower watt losses at high frequency. The main idea of the development was a hypothesis [2-4] that the domains movement is dependent on the amorphous microstructure of alloys. The new MULTIAM amorphous alloy is characterized by multiphase amorphous structure. The alloy microstructure consists of several amorphous regions having 50-300 nm dimensions with sharply expressed boundaries. These regions are different in compositions. The first (main) diffusion halo (Selected aria diffraction method, TEM) has internal structure and consists of two rings. The microdiffraction feature also demonstrates the presence of segregations in the amorphous structure. Dark field TEM analysis of alloy shows that their dimensions are of 1-3 nm. Thus, the structure features of the new MULTIAM alloy (layering, boundaries in the amorphous state, segregations etc.) allow us to suppose that the reduction of domens size takes place.

The important industrial applications of Al-based amorphous alloys are related to their excellent mechanical properties. We also studied the effect of the melt microheterogeneity (melt thermal treatment) on the structure and properties of crystalline Al-based alloys. After the system transition to the state of true solution, considerable over-saturation of the solid solution, shift of the eutectic point to the region of larger concentration of the second component, appearance of quasi-eutectic structure in samples with the hypereutectic composition, fragmentation of eutectic phases and initial crystals, and change of their morphology, were observed. Some reversible structural changes of melt were observed as well: abrupt changes of volume fraction, size and composition of disperse particles; local order transformations inside the particles and in surrounding melt, fractal inhomogeneity transformations. Their effects can be conserved at high enough cooling rate only.

Recent developments give rise to the appearance of new promising soft magnetic material in the field of industrial high frequency applications. Now, many excellent solutions may be found for modern miniature HF components, electronic article surveillance markers and other products.
We believe that in the future, the thermal treatment of initial melts becomes such a necessary stage of every technological process involving rough materials melting, as thermal treatment of solidified alloys today.

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