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AMORPHIZATION AND NANOSTRUCTURE SYNTHESIS IN Al ALLOYS

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The recent innovations in metallic glasses have led to new alloy classes that may be vitrified and a re-examination of the commonly used criteria for glass formation and stability. The new alloy classes are usually at least ternary systems and often higher order that can be grouped into two general categories. In one case large, bulk volumes may be slowly cooled to the glassy state which signifies a nucleation controlled synthesis. The other important case is represented by Al and Fe based glasses that have been synthesized mainly by rapid solidification processes such as melt spinning. These glasses are often called marginal glass formers and are synthesized under growth controlled kinetic conditions. With marginal glass forming alloys the termination of the amorphous state upon heating is often characterized by a primary crystallization reaction that represents the partial crystallization into a high number density of Al nanocrystals dispersed within a residual amorphous matrix. For structural applications, partially devitrified glasses with a microstructure of Al nanocrystals (15-20 nm in diameter) with a number density in the range of $10^{21} - 10^{22} \text{ m}^{-3}$ dispersed in an amorphous matrix have demonstrated specific strengths that are almost three times that for steel. Alternatively other approaches have demonstrated that by suitable alloying it is possible to inoculate the primary crystallization reaction to increase the density of primary nanocrystals by about an order of magnitude and to influence the crystallization pathway. At the same time the results from alternate synthesis strategies involving intense cold rolling reveal that the primary crystallization reaction can be bypassed during deformation alloying of elemental multilayers or enhanced during deformation bonding of amorphous ribbons. These developments represent a valuable level of microstructure control. The kinetics analysis of the crystallization behavior under different processing treatments provides insight into the origin of the dispersed nanocrystal and amorphous matrix microstructures and an effective assessment of the overall stability.

NANO ICOSAHEDRAL QUASICRYSTALS IN Zr-BASED GLASSY ALLOYS

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Recently, a number of bulk glassy alloys with extremely high glass-forming ability (GFA) were found in Zr-based multicomponent alloy systems. They have attracted much attention in the aspects of the scientific interests in a high stability of glassy state. More recently, it is found that an icosahedral quasicrystalline phase is formed as a primary precipitation phase from a glassy state by addition of 5 or 10 at% of noble metal such as Ag, Pd, Au and Pt in the Zr₆₅Al_{17.5}Ni₁₀Cu_{17.5} glassy alloy. The icosahedral phase has an extremely small grain size in the diameter below 50 nm. The nucleation rate of the icosahedral phase increases significantly and grain growth rate decreases with an addition of noble metal. It is the main reason for the formation of a nano icosahedral structure in the Zr-based glassy alloys. The precipitation of the icosahedral phase implies that the glassy alloys include randomly oriented icosahedral configurations.

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Investigation of the crystallization process is of important for understanding the mechanisms of phase transformation far from equilibrium, for evaluating the glass forming ability of the melts and thermal stability of metallic glasses, and for producing controlled ultrafine microstructures. This process is sensitive to external influence, e.g., applied pressure and annealing temperature. The issue of the pressure effect on crystallization of metallic glasses, which is of interest from a fundamental viewpoint, and also with respect to the applicability of these materials by deformation in supercooled liquid region, will be first addressed in my talk. I present experimental results of the enhancement of crystallization temperature in $Zr_{41.2}Ti_{13.8}Cu_{12.5}Ni_{10}Be_{22.5}$ and $Pd_{40}Cu_{30}Ni_{10}P_{20}$ bulk glasses under pressure, while in $Al_{89}La_6Ni_5$ glassy alloy it first decreases with pressure and then increases at pressure higher than 1 GPa. The model of competing processes of the thermodynamic potential barrier of nucleation and the diffusion activation energy under pressure will be introduced. In the second part of my talk, experimental observations of the time-dependent nucleation process in a $Pd_{43}Cu_{27}Ni_{10}P_{20}$ undercooled melt and in a $Zr_{65}Cu_{7.5}Al_{7.5}Ni_{10}Ag_{10}$ glassy alloy will be presented. Such data reveal that transient nucleation exists during crystallization of glassy alloys. The nucleation-derived phase transformations (e.g., liquid-to-solid, amorphous-to-crystalline, and crystalline-to-crystalline transformations) in systems, including metallic, ceramic, polymer, bio-systems, could be governed by time-dependent nucleation in undercooled liquids.

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Text: The effects of annealing under pressures of 1.1 GPa and 0.1 MPa on the primary crystallization behaviour of α -Al and micro-hardness have been investigated for as-quenched Al₈₇Ni₇Gd₆ metallic glass. Thermal stability and microstructural changes have been analyzed by XRD, DSC and TEM. The first exothermic peak temperature ($T_{p,1}$) was shifted toward lower temperatures, indicating that pressurization promotes primary crystallization. The metallic glass annealed at 1.1 GPa also exhibited an increase in microhardness. The effects of superimposed pressure at different annealing temperatures on microstructural evolution have been quantified in terms of volume fraction of α -Al, microhardness, and tensile properties.