Abstract for an Invited Paper
for the MAR09 Meeting of
The American Physical Society

Development and Applications of Bulk Metallic Glasses

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We realized, through detailed amorphous material investigations in the 1980's, that a number of metallic glassy alloys of multi-component La-, Mg- and Zr-based systems exhibit a large supercooled-liquid region prior to crystallization. The stabilization phenomenon of these supercooled liquid should enable us to fabricate, by slow cooling processes, bulk metallic glasses (BMGs) with critical diameters larger than several millimeters. Caltech's group also succeeded the fabrication of BMG in Zr-based alloy system in 1993. Since then, much attention has been paid to BMGs because of their novel characteristics in basic science and engineering aspects and new materials science and engineering fields have emerged for BMGs. Based on knowledge obtained thus far, we have successfully developed new BMGs with technologically-important transition metals, such as Zr-, Ti-, Fe-, Co-, Ni- and Cu-based alloys. Currently, the maximum diameter for glass formation reaches 30 mm for Zr- and Cu-based systems, 12 mm for Ti-based system, 18 mm for Fe-Co-based system and 20 mm for Ni-based system, even employing the copper mold casting technique. These large size BMGs possess nearly the same fundamental properties as those of the BMGs with smaller diameters. BMGs with diameters above 10 mm can be formed in Zr-Al-Ni-Cu system with Zr compositions higher than 65 at% and they exhibit excellent properties, such as high Poisson's ratio, high ductility, high fracture toughness, high fatigue strength and high stability of mechanical properties to annealing-induced embrittlement. The new Ti-based BMGs without allergic and toxic elements should exhibit good compatibility to bio-tissues. Applications of BMGs in Fe-, Co-, Ti- and Zr-based systems have advanced many devices including the following; choke coil, power inductor, electro magnetic shielding, magnetic and position sensors, micro-geared motor, pressure sensor, Coriolis flowmeter, surface coating layer, precise polishing medium, magnetic and structural parts in electric magnetic control-type spring drive watches, medical operation instruments and so forth. A. Inoue, Acta Mater., 48(2000), 279-306.