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Chemical, Structural and Mechanical Optimization of Zr-Based Bulk Metallic Glass for Biomedical Applications

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Abstract : Due to interesting compromise between mechanical and corrosion properties, Zr-based BMGs are attractive for biomedical applications. However, the enhancement of their glass forming ability (GFA) is often achieved by addition of toxic elements like Ni or Be, which is of course a problem for such applications. Consequently, the development of Ni-free Be-free Zr-based BMGs is of great interest. We have developed a Zr-based (Ni and Be-free) amorphous metallic alloy with an elastic limit twice the one of Ti-6Al-4V. The Zr56Co28Al16 composition exhibits a yield strength close to 2 GPa and low Young's modulus (close to 90 GPa) [1-2]. In this work, we investigated Niobium (Nb) addition through substitution of Zr up to 8 at%. Cobalt substitution has already been reported [3], but we chose Zr substitution to preserve the glass forming ability. In this case, we show that the glass forming ability for 5 mm diameters rods is maintained up to 3 at% of Nb substitution using suction casting in cooper moulds. Concerning the thermal stability, we measure a strong compositional dependence on the glass transition (Tg). Using DSC analysis (heating rate 20 K/min), we show that the Tg rises from 752 K for 0 at% of Nb to 759 K for 3 at% of Nb. Yet, the thermal range between Tg and the crystallisation temperature (Tx) remains almost unchanged from 33 K to 35 K. Uniaxial compression tests on 2 mm diameter pillars and 3 points bending (3PB) tests on 1 mm thick plates are performed to study the Nb addition on the mechanical properties and the plastic behaviour. With these tests, an optimal Nb concentration is found, improving both plasticity and fatigue resistance. Through interpretations of DSC measurements, an attempt is made to correlate the modifications of the mechanical properties with the structural changes. The optimized chemical, structural and mechanical properties through Nb addition are encouraging to develop the potential of this BMG alloy for biomedical applications. For this purpose, we performed polarisation, immersion and cytotoxicity tests. The figure illustrates the polarisation response of Zr56Co28Al16, Zr54Co28Al16Nb2 and TA6V as a reference after 2h of open circuit potential. The results show that the substitution of Zr by a small amount of Nb significantly improves the corrosion resistance of the alloy.

Keywords : metallic glasses, amorphous metal, medical, mechanical resistance, biocompatibility
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