Discovery of novel Bulk Metallic Glasses: Silver-base BMGs

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Overview

Using a new methodology of predicting specific compositions for glass forming ability [1], based on ternary elemental cluster selection, atomic packing efficiency, ab-initio calculations and liquidus lines, the synthesis of new metallic glasses are possible. In a world's first, use of this proposed composition selection model has lead to the discovery of the **first ever** silver-base Bulk Metallic Glasses (BMGs). Moreover, the discovery has generated interest in the development of high precision forming processes for these new materials.

Attraction

Initial testing has shown that Ag-base BMGs have near-similar electrical conductivity to pure silver, which has the highest electrical and thermal conductivity of all metals. These BMGs present a **cheaper alternative** to commercial silver components for use in electrical applications as well as anti-bacterial applications for medical use and water systems. Given the high reflectivity of Ag-base BMG surfaces, mirror applications for construction and aerospace applications are of interest.

Alloy Design Theory

Alloy compositions corresponding to efficiently-packed **ternary atomic clusters** were computed using a form of Miracle *et al*'s [2] coordination number formula for efficient atomic packing :

$$N = \frac{4\pi}{\pi(2-q)+(2q)\arccos\left\{\left(\sin\pi/q\right)\left[1-1/(R+1)^2\right]^{1/2}\right\}} \qquad (1)$$

Experimental Methodology

Figure 1: Alloy synthesis and analysis route

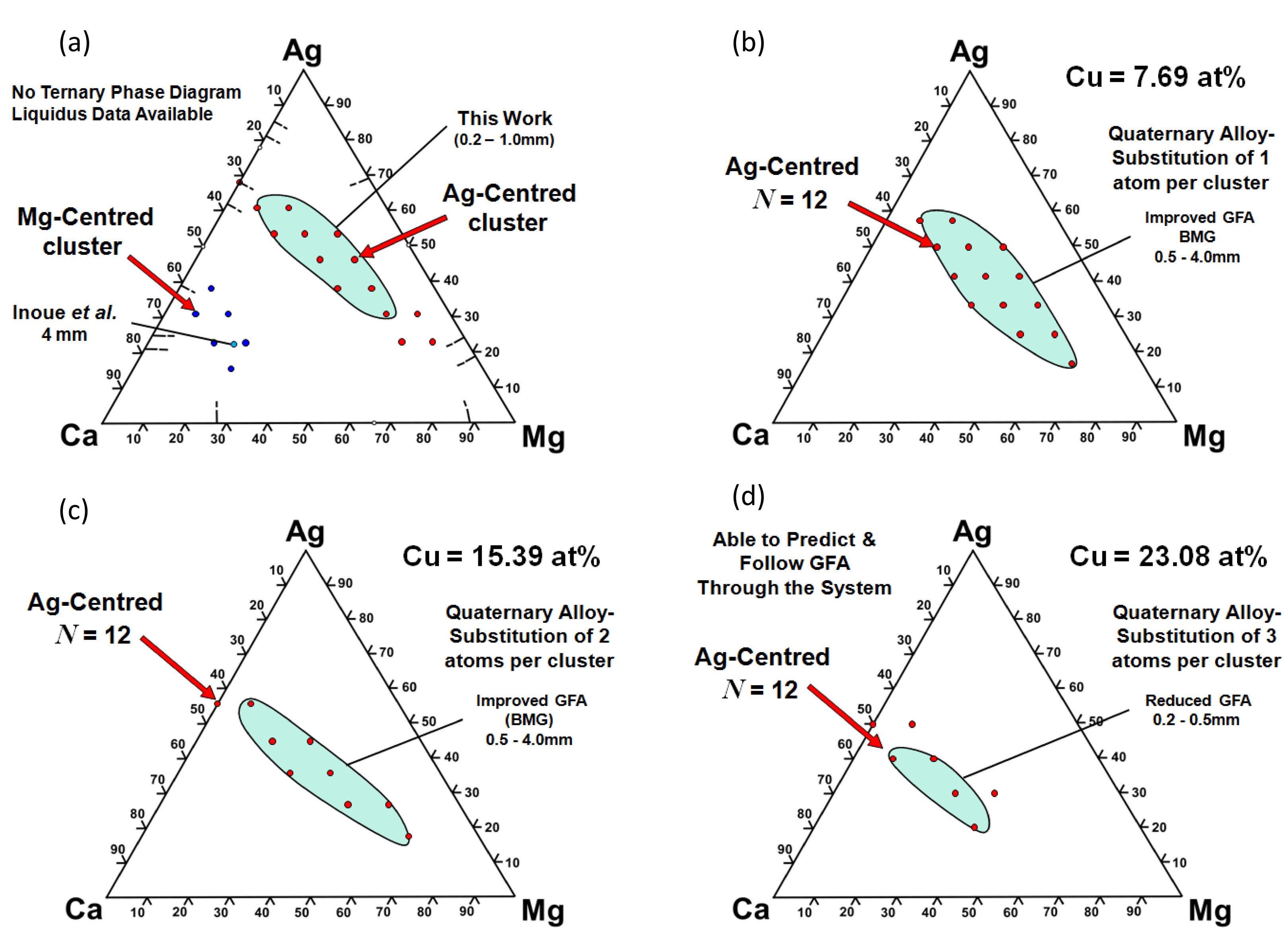

Figure 2: Representation of glass forming compositions with subsequent addition of Cu revealing the GFA within the Ag-Mg-Ca-Cu system, where Cu at.% : (a) 0 at.%, (b) 7.69 at.%, (c) 15.39 at.% and (d) 23.08 at.%.

Experimental Results

Successful attempts at conventional casting produced 9 Ag-base BMGs and over 20 more metallic glass specimens under 'bulk' size.

Amorphous Nature

Figure 3: 3.5 mm Ag-base BMG

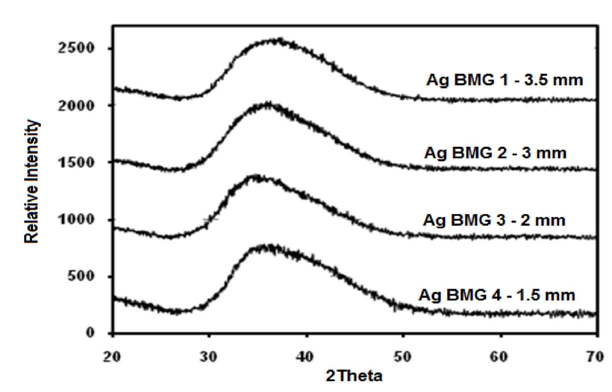

Figure 4: XRD spectra showing the amorphous nature of selected Ag-base BMGs

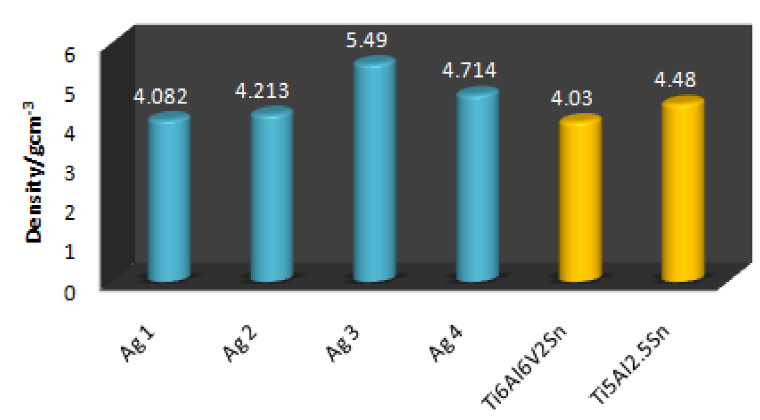

Figure 5: Light-weight BMG density comparable to that of Ti-alloys

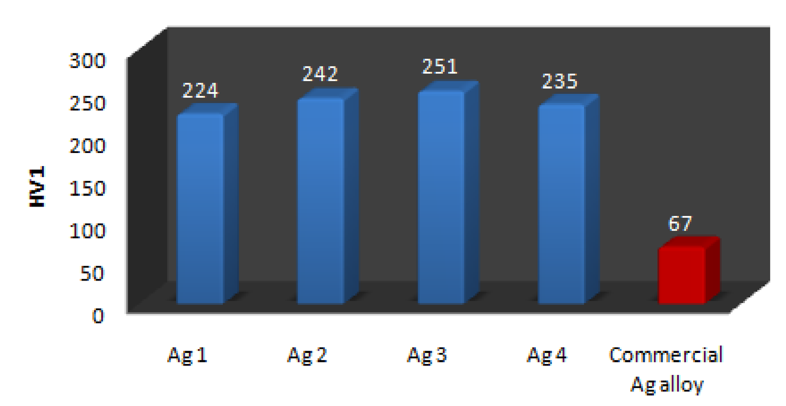

Figure 6: Higher hardness of BMGs compared to commercial Ag-alloy

Nanoformability and Surface Replication

- **Homogeneous properties** — Lack of crystalline structure
- **Superplastic deformation** — (Similar to thermoplastics) Wide supercooled liquid (SCL) region
- **Superplastic nanoforming** — Ability for submicron scale surface feature replication
- **High reflectivity** — For reflecting gratings and optical devices

Discussion and Conclusion

A general increase in Mg at.% at lower Ag content increases the glass forming ability (GFA). The glass forming region approaches the deep Ag-Mg eutectic at 75 at.% Mg. Increasing Mg at.% causes an increase in GFA as the atomic radius of Mg brings the overall cluster size to a point which increases the atomic packing efficiency (APE).

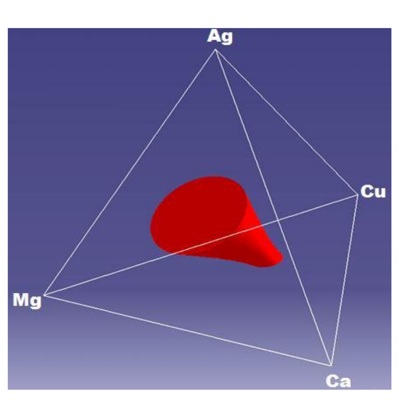

Figure 7: Representation of GFA path

Given the difficulty in obtaining metallic glass from Ag-base alloys it has been a success obtaining a number of **light-weight** Ag-base BMGs comprising of **low-cost** addition elements whilst using a conventional casting method. This reflects the confidence with which Ag-base BMGs can be produced.

References

[1] **K.J. Laws, K.F. Shamlaye, K. Wong, B. Gun, M. Ferry**, 7th Int. Symp. on Bulk Metallic Glasses. TMS Annual Meeting San Francisco, 2009.

[2] **D.B. Miracle, O.N. Senkov, W.S. Sanders, K.L. Kendig**, *Mat. Sci. Eng. A, 375–377* (2004)

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