Mechanical Response of Phase Separated Cu-V-Zr-Al Metallic Glasses Alloys

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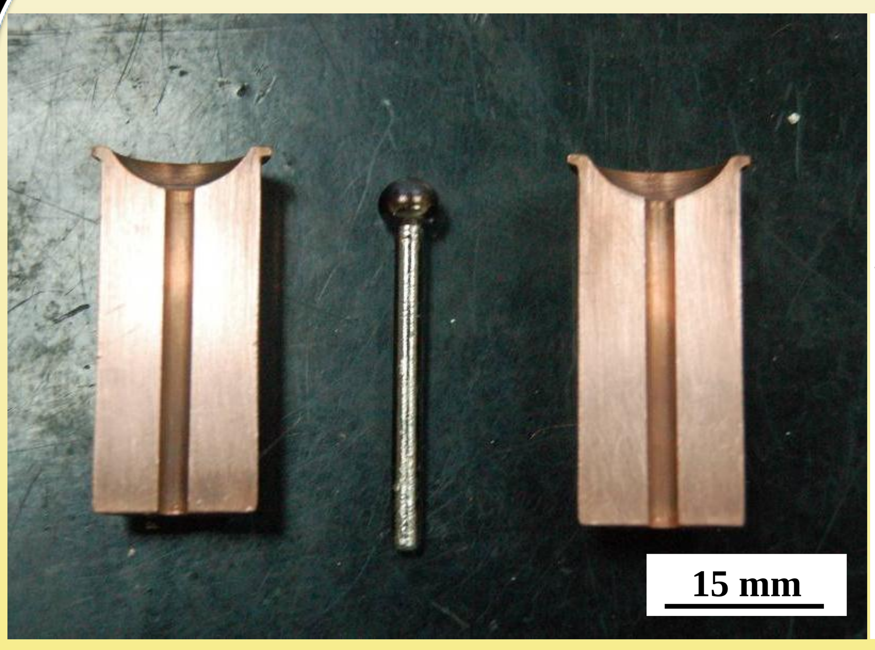
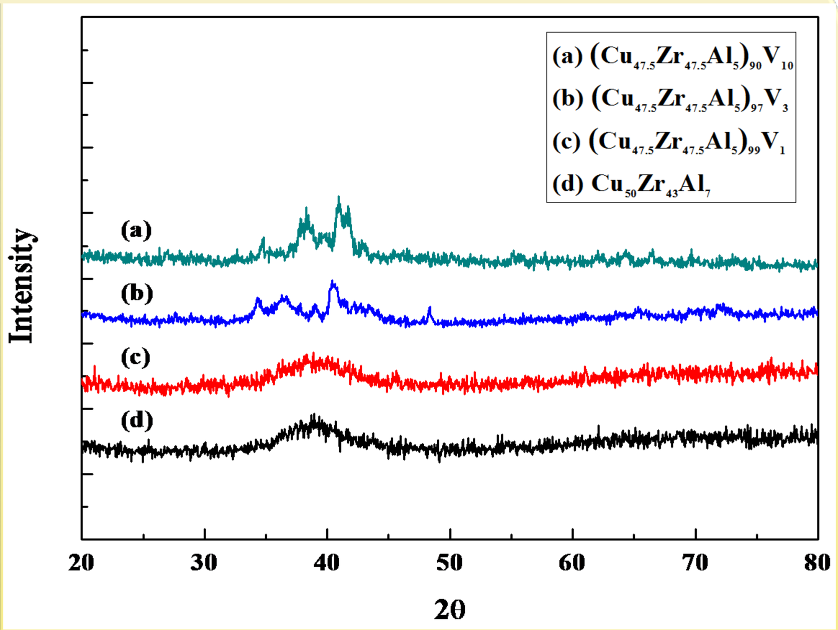
Abstract

The Cu-V-Zr-Al metallic glasses alloys were fabricated by suction casting method and tested under compression. Due to the positive heat of mixing between Cu and V, the alloy is able to proceed phase separation in the liquid state, and then rapidly quenched to form the Cu-rich and V-rich phases. Moreover, the micro-sized dendrite-like V-rich phase was formed when the V content is more than 3 at% in the alloy system. On the contrary, while the alloy consists of V less than 3 at%, nanoscaled compositional heterogeneities embedded within the monolithic glassy matrix would result in the Cu-V-Zr-Al alloys. When the V content is less than 3 at%, the cast rods of 2 mm diameter show apparent compressive plasticity enhancement in comparison with the base Cu-Zr-Al amorphous rods. However, the dendrite-like second phase shows harmful effects to the mechanical response since the precipitated V-Al compound phase is inherited with lower strength and worse plasticity.

Amorphous Natural

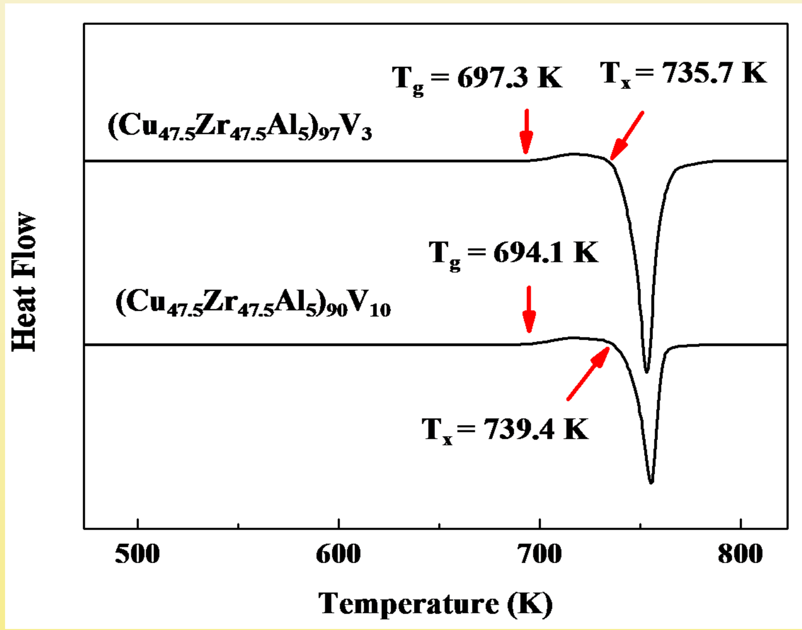


Appearance of sample and the cupper mold



X-ray patterns

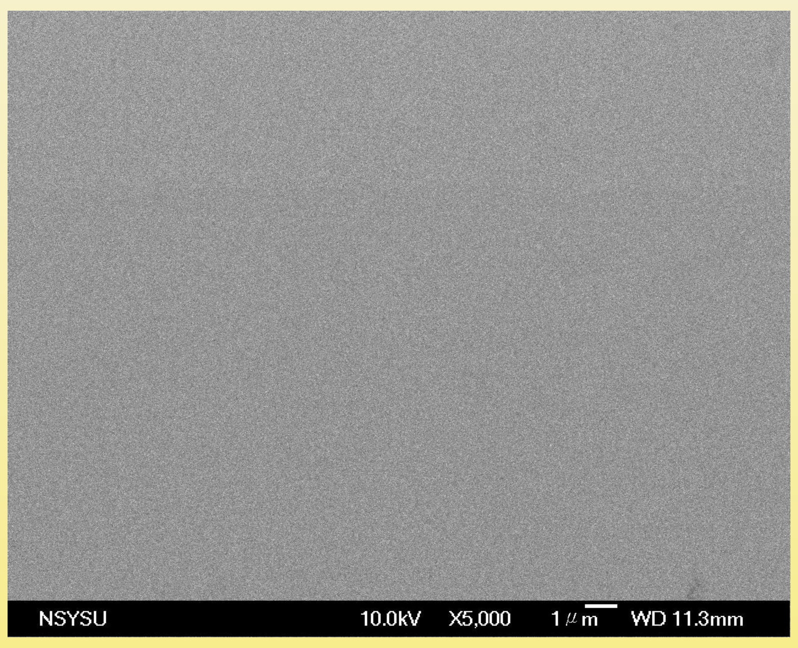
Differential Scanning Calorimeter Testing



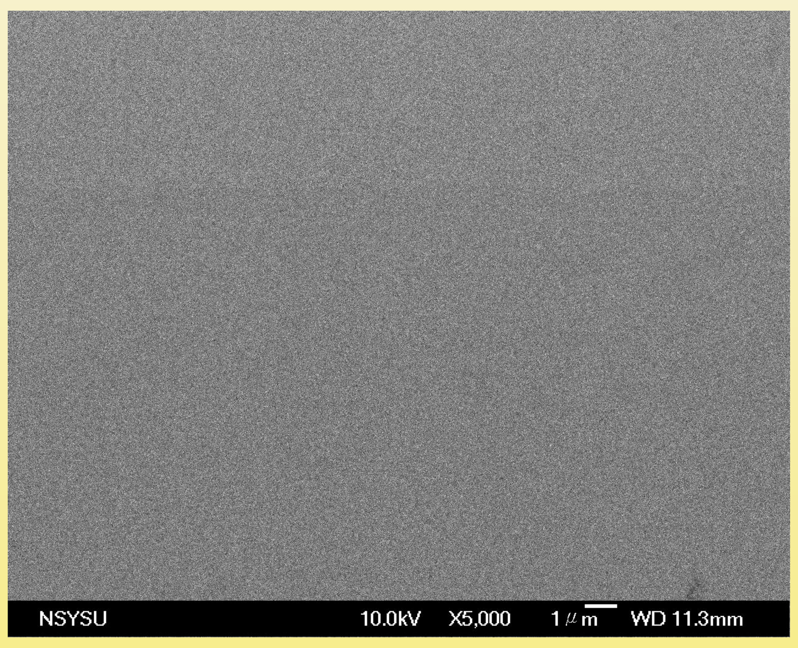
DSC curves

Since the XRD curves for the 2 mm cast rods with higher V contents possess characteristic crystalline peaks, it is necessary to confirm that there is still sufficient metallic glassy phase. DSC scans are conducted on the CuZrAlV alloys with 3 and 10% V. The results confirm the glass transition (Tg) and crystallization (Tx) temperatures in all samples. The DSC results suggest that there consist of an amorphous structure in the as-cast samples.

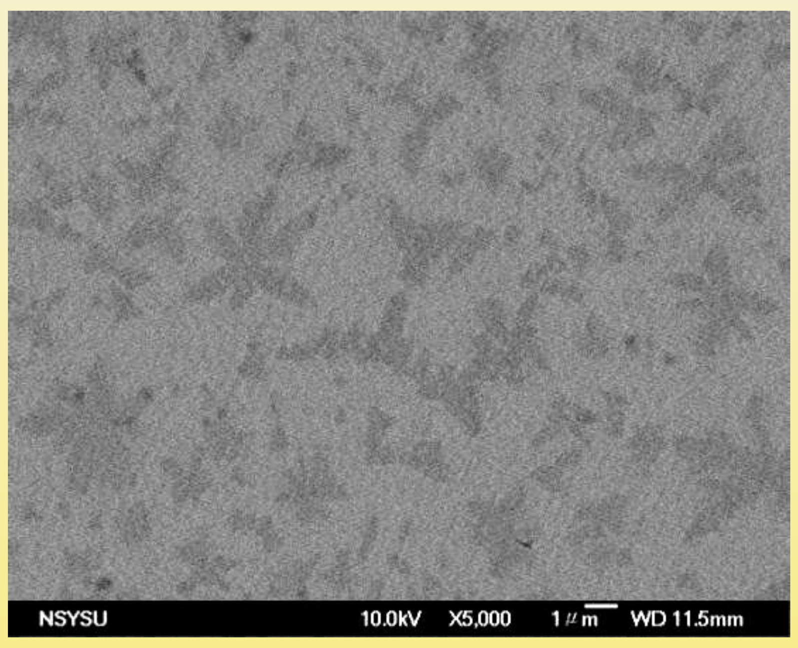
SEM/BEI Observations



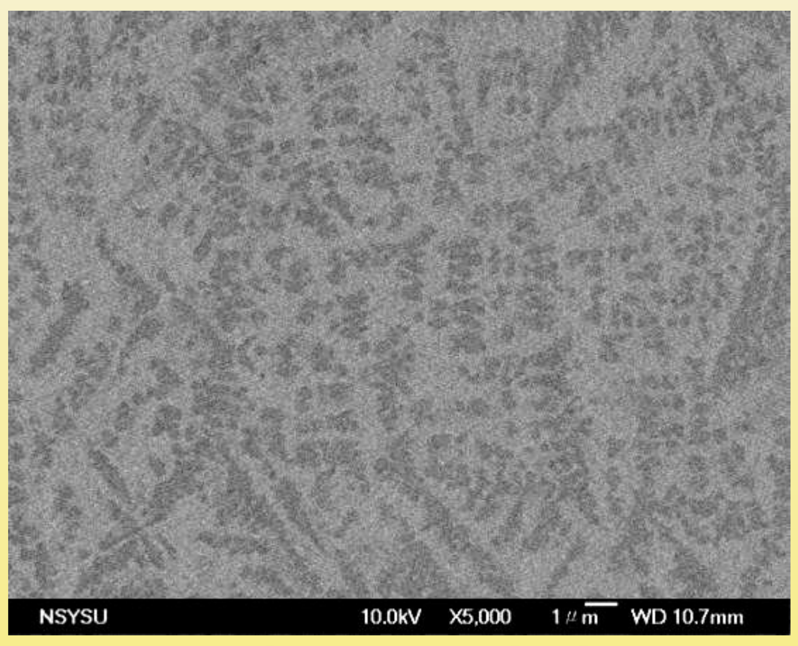
$Cu_{47.5}Zr_{47.5}Al_5$ sample



$(Cu_{47.5}Zr_{47.5}Al_5)_{99}V_1$ sample

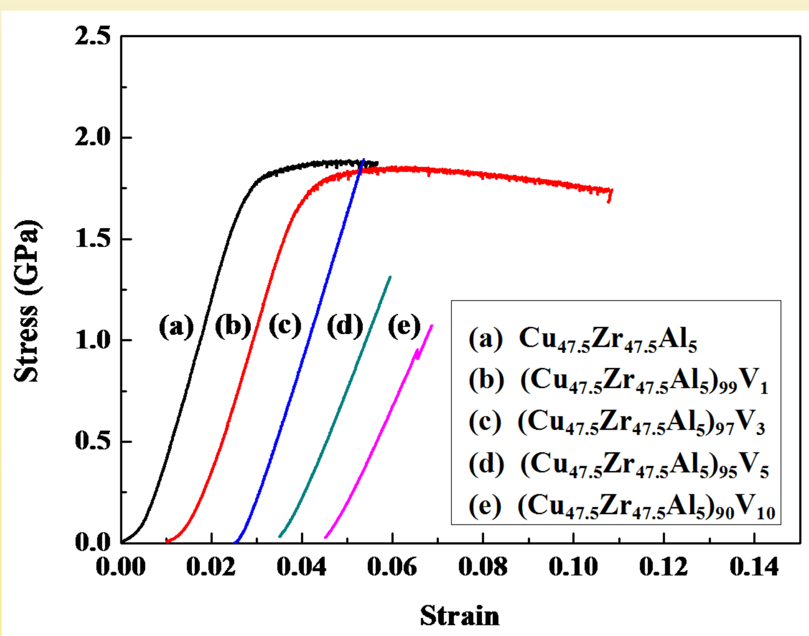


$(Cu_{47.5}Zr_{47.5}Al_5)_{97}V_3$ sample, there exists the V-Al rich dark domains and the Cu-Zr rich bright domains.



$(Cu_{47.5}Zr_{47.5}Al_5)_{90}V_{10}$ sample, there exists the V-Al rich dark domains and the Cu-Zr rich bright domains.

Compression Testing

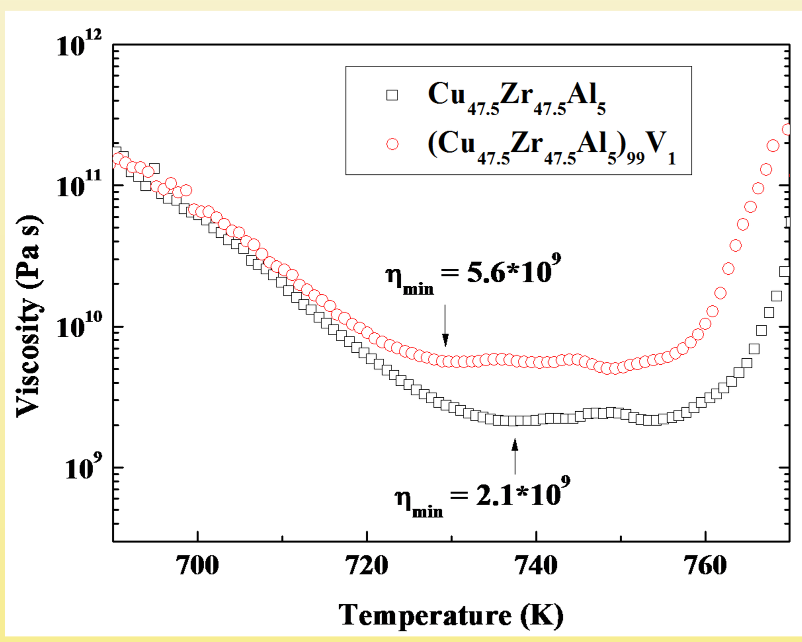


The compressive stress-strain curve of the Cu-based BMG.

The compression test results indicated that the $Cu_{47.5}Zr_{47.5}Al_5$ and $(Cu_{47.5}Zr_{47.5}Al_5)_{99}V_1$ alloys exhibited compressive plasticity. In particular, the compressive strain increased with a small V content (1 at.%), from 4.7% for $Cu_{47.5}Zr_{47.5}Al_5$ and 9.4% for $(Cu_{47.5}Zr_{47.5}Al_5)_{99}V_1$.

In contrast, the Cu-V-Zr-Al alloys with V content as 3 at%, 5 at% and 10 at% exhibited nearly zero plasticity, respectively. In addition, with a further increase of V content, the compressive fracture strength decreased, i.e., 1.89 GPa for 3at% V to 1.31 and 1.07 GPa for V content 5 at% and 10 at%

Thermomechanical Analysis

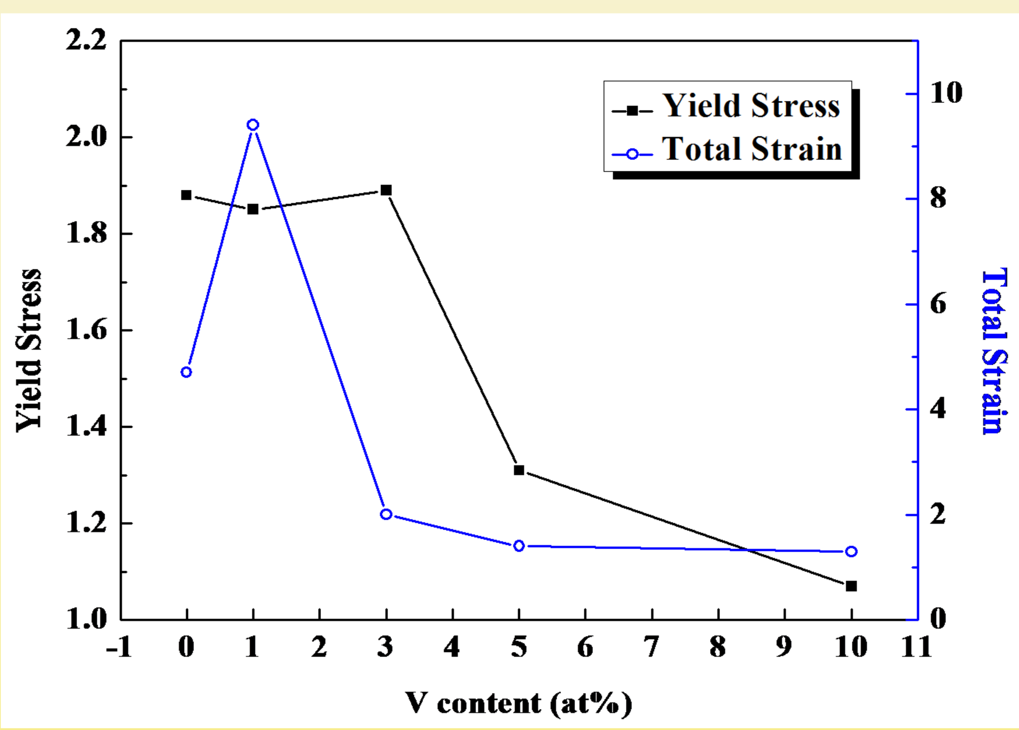


The TMA results of the as-cast $Cu_{47.5}Zr_{47.5}Al_5$ and $(Cu_{47.5}Zr_{47.5}Al_5)_{99}V_1$ cylindrical rods.

The result shows a large amount of viscosity is increased with a slight addition of high melting temperature V into the $Cu_{47.5}Zr_{47.5}Al_5$ BMG.

The huge difference of viscosity between these two compositions could not only cause by the sight composition difference. Therefore, it implies there would be a chemical inhomogeneity in composition of the $(Cu_{47.5}Zr_{47.5}Al_5)_{99}V_1$ BMG rod samples since the XRD and SEM/EDS results at the same time show a large tendency to bring out decomposition with sight V adding in the Cu-Zr-Al alloy system.

Summary



The summary of the yield stress and total strain with different V content of the Cu-based BMG/BMGC rods.

Conclusion

1. The addition of an alloying element having a positive heat of mixing with the constitutive element leads to the improvement of plasticity within a limited composition range.

2. Due to the positive heat of mixing between Cu and V, precipitated phase would occur with a slightly increasing V content (1 at% to 3 at%), implying that local chemical inhomogeneity would exist even in alloy compositions which solidify into a single amorphous phase from the liquid state (x=1).

3. The compressive strain increased from 4.7% for $Cu_{47.5}Zr_{47.5}Al_5$ to 9.4% for $(Cu_{47.5}Zr_{47.5}Al_5)_{99}V_1$ would be due to the chemical inhomogeneity which leaded by the addition of an element having a positive heat of mixing with the constitutive element, however, the plasticity only improved within a limited composition range.