Mechanical characteristics of Mg-Cu-Zr thin film metallic glasses

S. Y. Kuan, H. S. Chou, J. C. Huang*
Department of Materials and Optoelectronic Science, Center for Nanoscience and Nanotechnology,
National Sun Yat-Sen University, Kaohsiung 804, Taiwan, ROC
NSC 98-2221-E-110-035-MY3

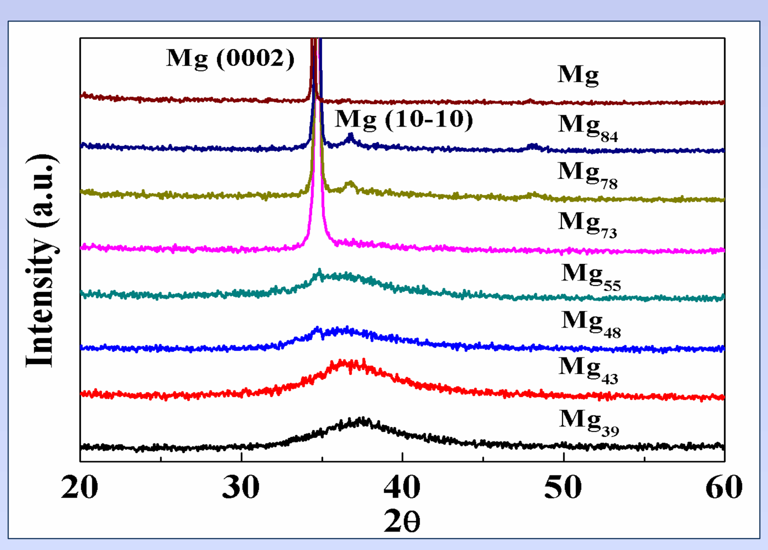
Abstract

For improving the ductility of metallic glasses, nanocrystals within the amorphous matrix are frequently intentionally added. In this study, the MgCuZr thin film metallic glasses (TFMGs) with a positive mixing heat between Mg and Zr are fabricated via co-sputtering in an attempt to separate the pure Mg nano-particles. The microstructure and mechanical properties of the sputtered MgCuZr thin films and their FIB-machined micropillars are examined as a function of Mg content from 39 to 100 at%. From the nanoindentation and micropillar load-displacement curves, the Mg-rich metallic glass composites exhibit smoother nature and more ductile behavior. Meanwhile, due to strong (0002) basal texture, the Mg-rich thin films and micropillars possess strong modulus (~80 GPa), hardness (~3.5 GPa), and yield stress (~1.5 GPa), coupled with much ductile behavior. All of these would allow promising applications in micro-electro-mechanical systems.

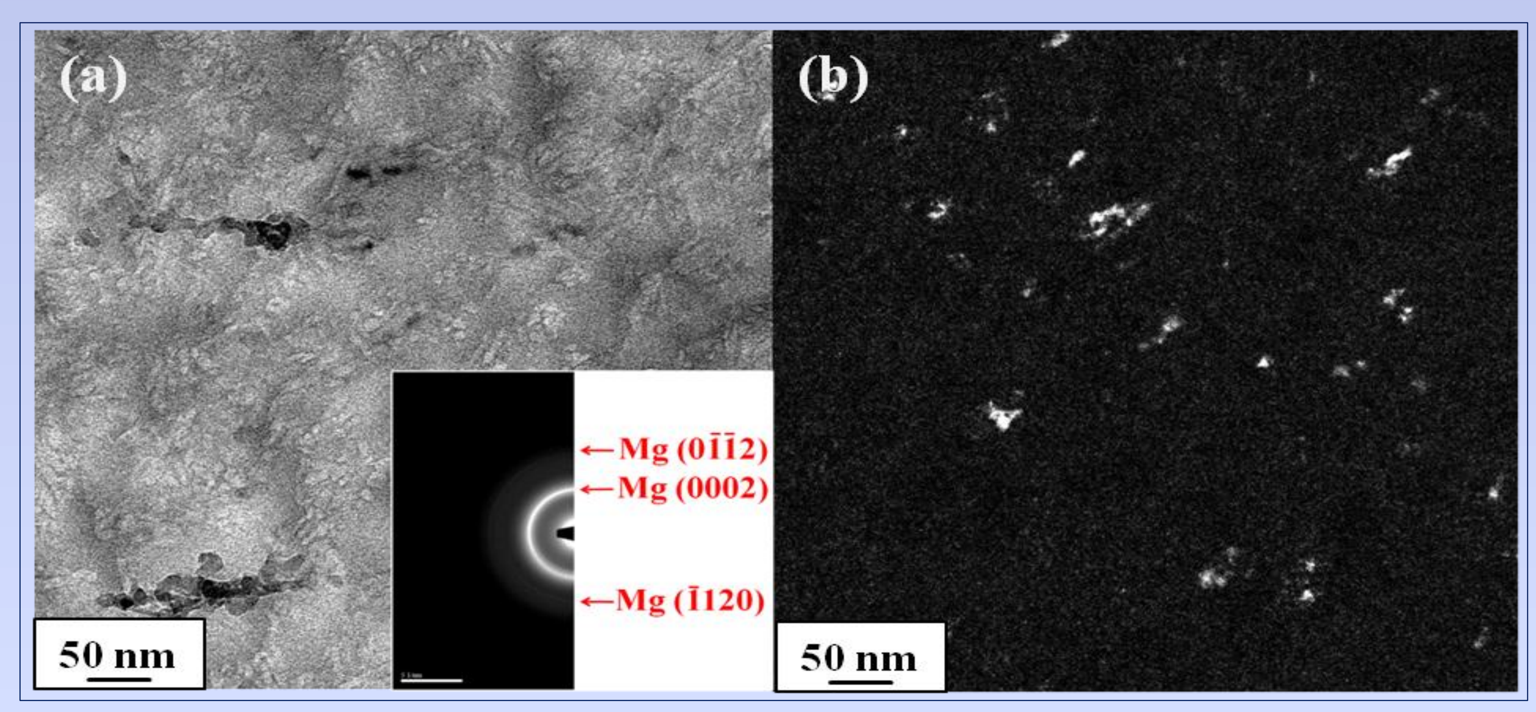
Experiment process

- **Structure characterization** → **XRD analysis**, **TEM analysis**
- **Mechanical properties** → **Nanoindentation**
- **Deformation mechanism** → **Microcompression**

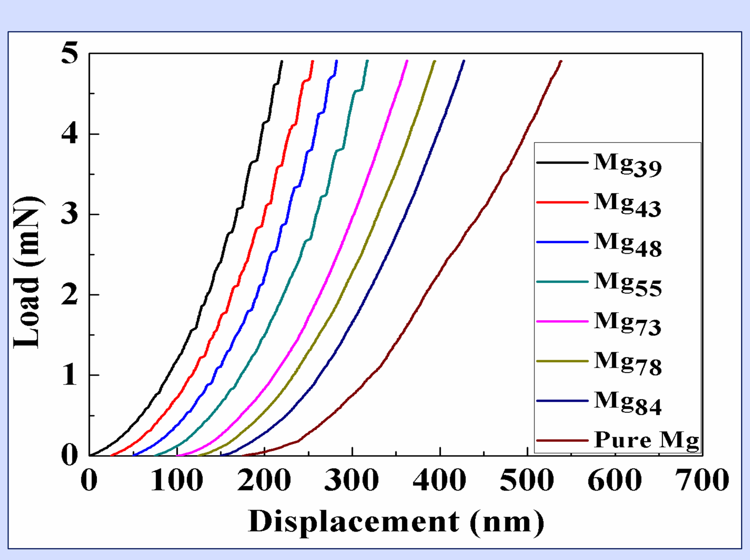
XRD analysis

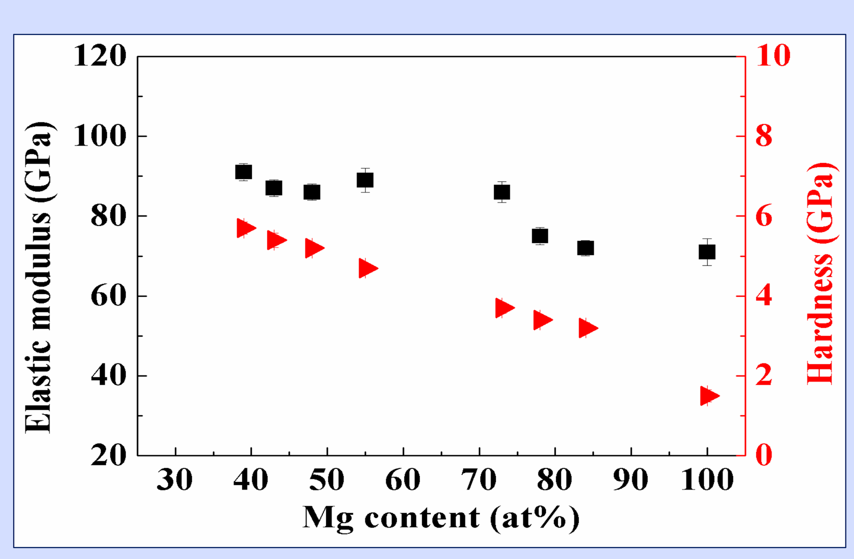


TEM analysis

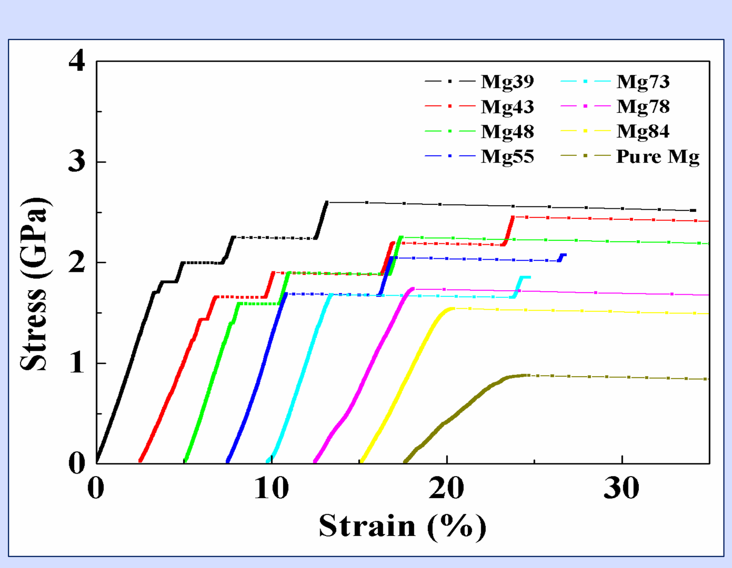


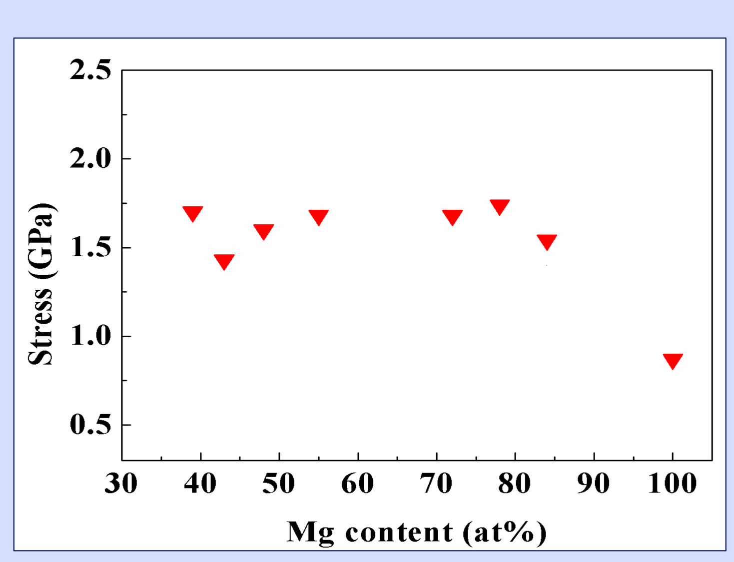
Nanoindentation



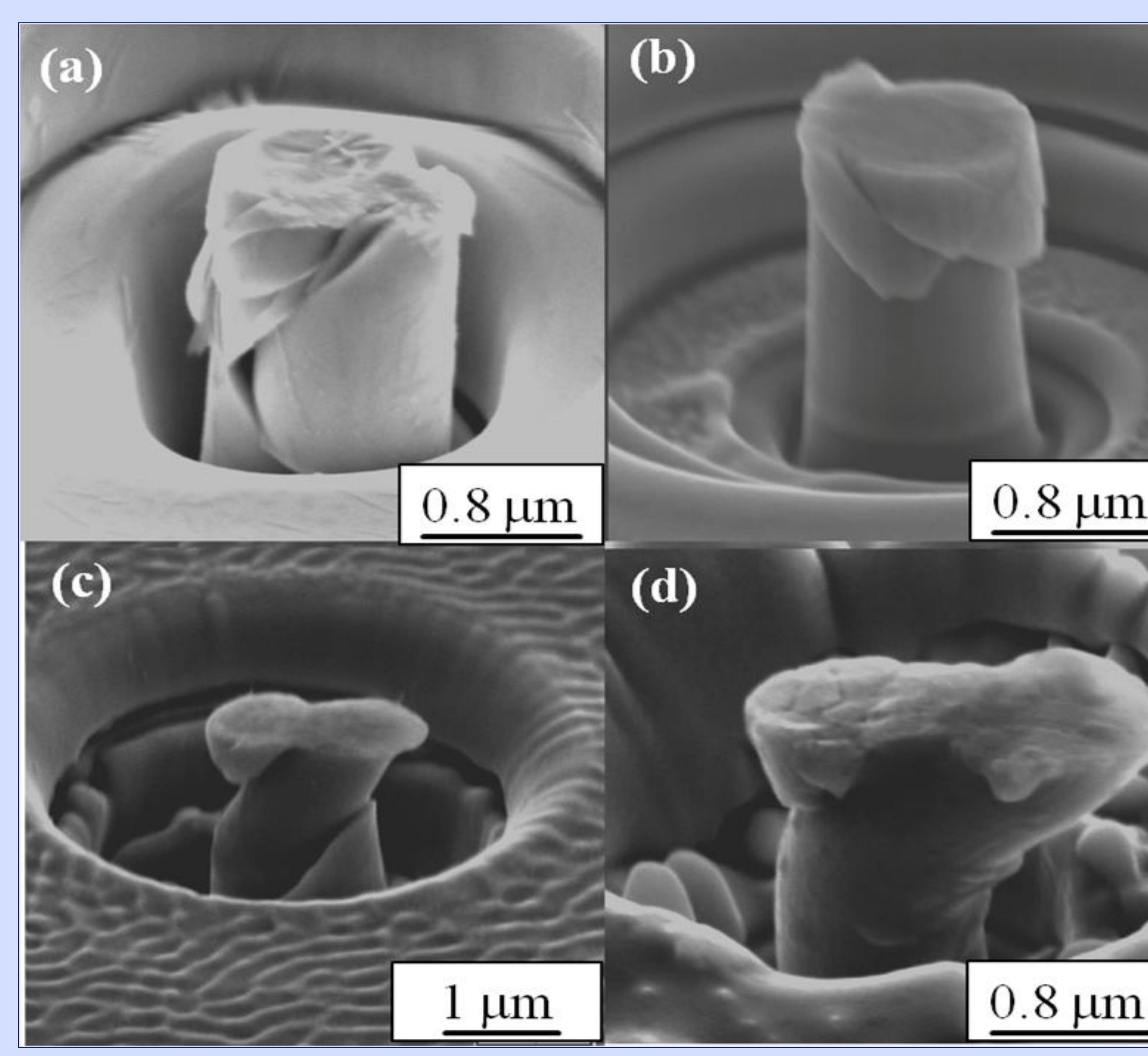


Microcompression





Defoemed pillars



Conclusions

The microstructure and mechanical properties of the sputtered MgCuZr thin films and their FIB-machined micropillars are examined as a function of Mg content from 39 to 100 at%. Due to the positive heat of mixing between Mg and Zr, the pure Mg crystalline phase would be separated out from the amorphous matrix. According to XRD and TEM results, the separated nanocrystalline Mg phase (50-100 nm in size) possesses a strong (0002) basal plane texture. Because the c-axis of separated Mg phase is parallel to the micropillar axis as well as the loading direction, the applied compression load is hard to activate the basal dislocation slip in the beginning. As the result, the yield stresses of Mg73, Mg78 and Mg84 do not decrease with increasing Mg content, still maintaining a high stress level around 1.5 GPa. In contrast, due to the complex 3D stress states under nanoindentaiton, the non-basal slip can be easily activated from the beginning, thus the hardness decreases appreciably with increasing Mg content.