Deformation mechanism of amorphous/nanocrystalline multilayers thin films on polyimide substrates

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Abstract

The tensile behavior of the monolithic amorphous ZrCu and crystalline Cu thin films and the ZrCu/Cu multilayered thin films in different monolayer thicknesses has been investigated. The morphology of as-deposited thin film is composed of sphere domains, and between the domains would be stress-concentrated. The cracks vertical to the loading direction would propagate along the domains. The tensile moduli of monolithic amorphous ZrCu and crystalline Cu thin films are closed to results extracted from micro-compression. Based on the current results for the moduli of multilayered thin films obtained from the tensile tests, it is reliable and consistent with the theoretically rule of mixture prediction. As the monolayer thickness going down from 100 nm to 10 nm, the tensile moduli would not change too much. The ductility and maximum stress would be improved.

Experimental procedures

Cutting polyimide (50 μm) into suitable size

Cleanning polymer substrate by ultrasonic cleaning in isopropanol for 5 minutes

Sticking the polymer substrate on holder, then put on the 0.3-mm-thick 304 stainless mask

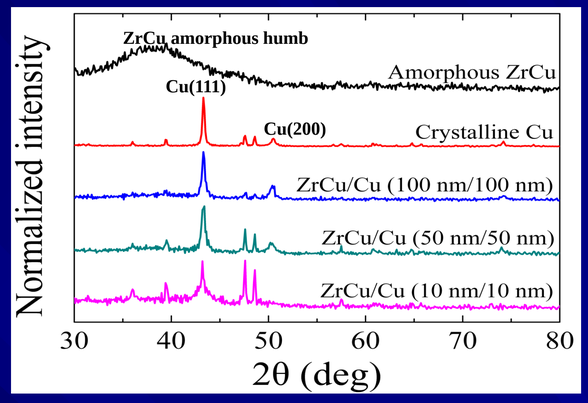
Depositing ZrCu/Cu multi-layer at the thickness of 1 μm in different thickness ratio

Observing the morphology by SEM

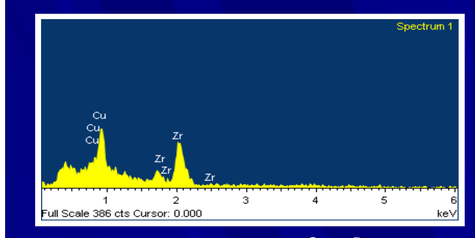
Confirming the crystal structure by XRD

Examining the mechanical property by Mini-Tester

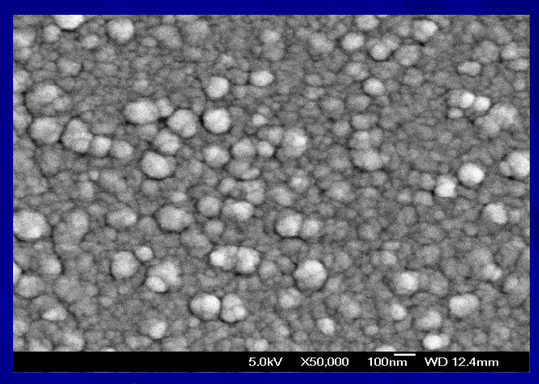
Examination of film properties



XRD pattern of the monolithic and multilayered thin films on the polyimide substrate.

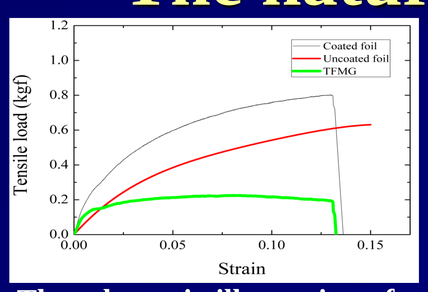


EDS pattern of the as-deposited amorphous $Zr_{46}Cu_{54}$ thin film on the silcon nitride substrate.

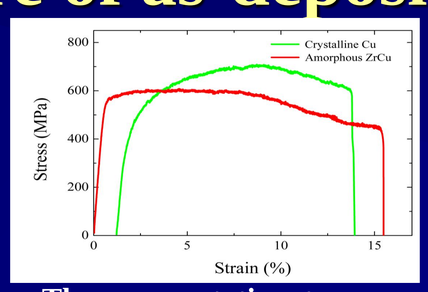


SEM surface morphology of the undeformed ZrCu/ Cu (100 nm/100 nm) multilayer sample

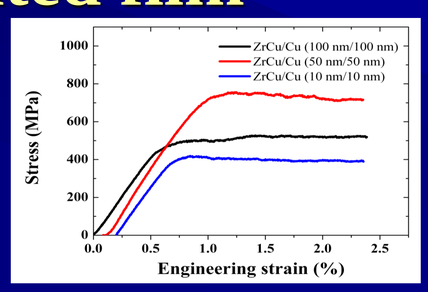
The nature of as-deposited film



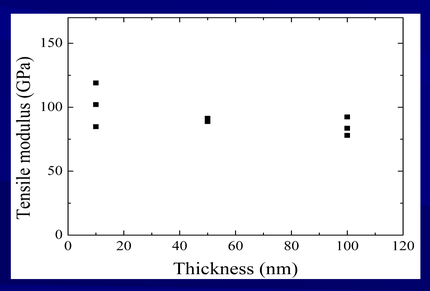
The schematic illustration of evaluating tensile test data.

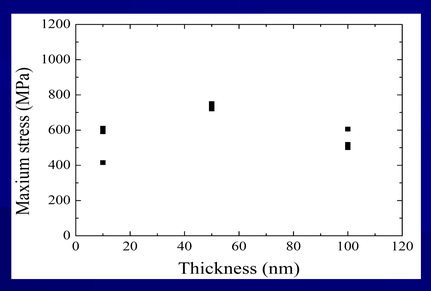


The representative stress-straincurve of monolithic thin films.



The representative stress-strain curve of ultilayered thin films.



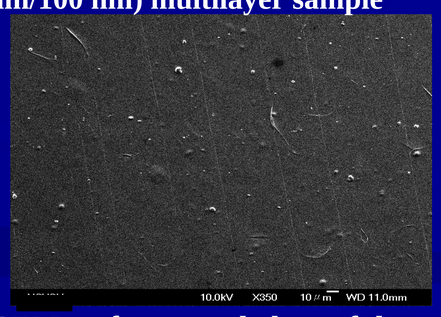


The schematic illustration of Young's moduli and maximum stress versus the thickness.

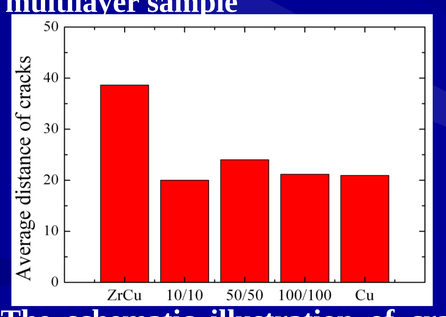
Results of deformed morphology

SEM surface morphology of the deformed ZrCu/Cu (100 nm/100 nm) multilayer sample

SEM surface morphology of the deformed ZrCu/Cu (50 nm/50 nm) multilayer sample



SEM surface morphology of the deformed ZrCu/Cu (10 nm/10 nm) multilayer sample



The schematic illustration of crack distances of the deformed thin films

Conclusions

From the SEM surface morphology observation, the as-deposited thin film is smooth under low magnification, but the sphere domains can also be observed under high magnification. XRD analysis shows the multilayered thin films are composed of amorphous and crystalline metals. The tensile moduli of monolithic amorphous ZrCu and crystalline Cu thin films are close to results from nano-compression, and the multilayered thin films deducting the fitted PI curve agree well with the theoretically rule of mixture prediction. The current study demonstrates that the nanolaminate of ZrCu/Cu (50/50 nm) can reach the highest maximum stress among all samples. Besides, There is no much difference in the moduli, ductility under the variant thickness conditions.