Supplemental Document

(1) Characterization of W–Ni–B thin film metallic glass (TFMG)

1. The high values for both H (20 GPa) and E_r (217 GPa) were obtained for W–Ni–B TFMG.
2. The crystallization temperature (T_x) is 860 ºC, which is much higher than those of conventional metallic glasses such as Zr-based metallic glasses (350–500 ºC).

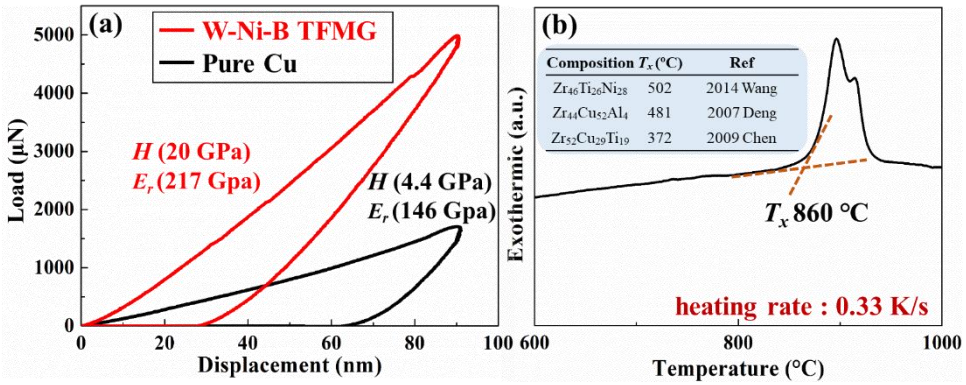


Fig. 1 (a) Load-displacement curves of the as-deposited W–Ni–B TFMG and Cu film measured by nanoindentation and (b) DSC measurement of the as-deposited W–Ni–B TFMG showing T_x of 860 °C.

(2) XRD interfacial diffusion analysis

1. The as-deposited W–Ni–B TFMG confirmed the amorphous structure.
2. No obvious Cu-silicide peak was observed after annealing below 900 ºC, demonstrating the good thermal stability of Cu/W–Ni–B/Si stacks.
3. Cu_3Si and WSi_2 phases were detected and no Cu peak could be observed after the sample was annealed at 950 ºC.

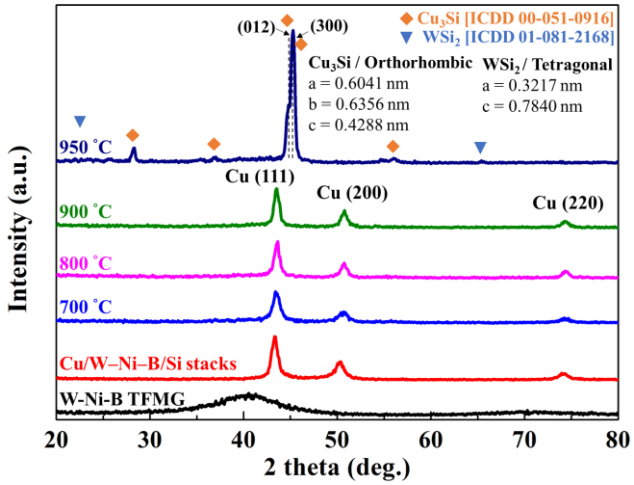
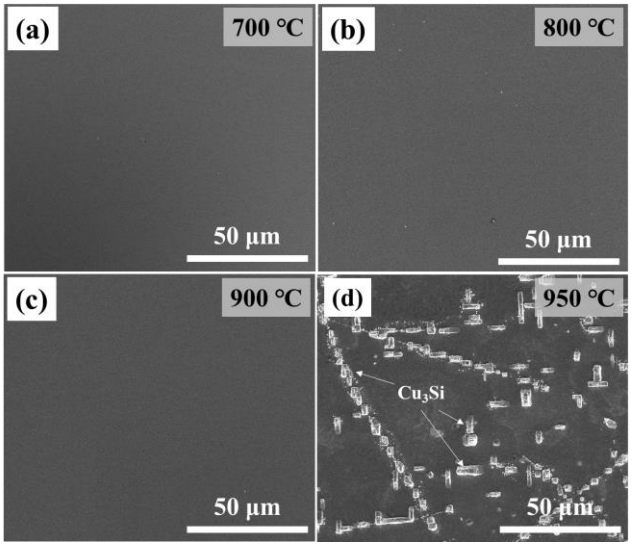


Fig. 2 XRD patterns of the as-deposited W–Ni–B TFMG and Cu/W–Ni–B/Si samples before and after annealing at different temperatures for 30 min.

(3) SEM observation of surface morphology

1. No visible contrast of the smooth surface, and no Cu–Si or W–Si intermetallic compounds could be observed on the surface for annealing below 900 ºC for 30 min.
2. Cu film was shattered into islands structure or slug-like feature on the surface and Cu_3Si compounds could be observed scattering on the surface of the sample after 950 ºC annealing.



(4) TEM interfacial diffusion analysis

1. Sharp interfaces between the barrier layer and adjacent Cu and Si layers could be observed and the Cu/W–Ni–B and W–Ni–B/Si interfaces remained free of IMCs up to 800 ºC annealing.
2. As the annealing temperature was elevated to 950 ºC, the Cu layer was severely consumed.

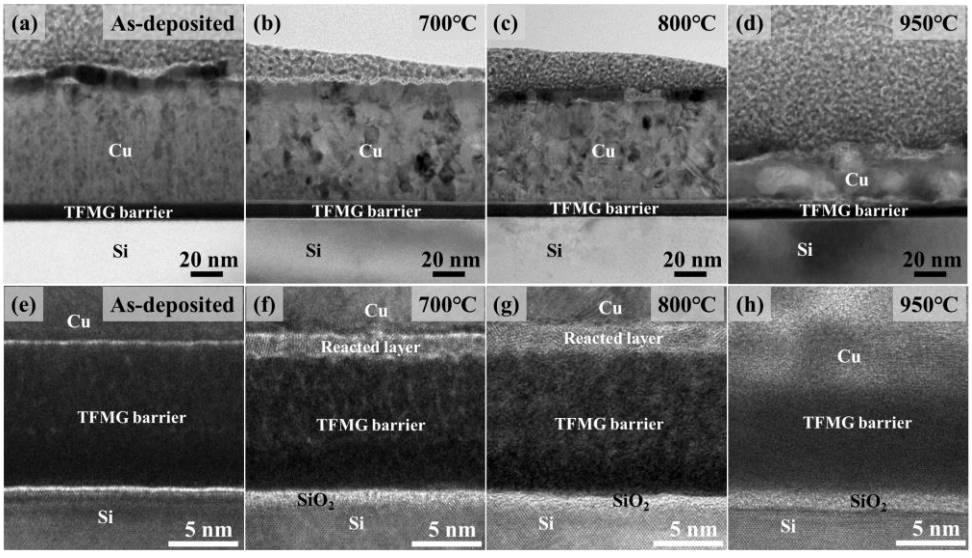


Fig. 4 TEM cross-sectional images of Cu/W–Ni–B/Si multilayered structures (a) in as-deposited state, and after annealing at (b) 700 °C, (c) 800 °C and (d) 950 °C for 30 min. HRTEM images of (e) as-deposited state and after annealing at (f) 700 °C, (g) 800 °C and (h) 950 °C for 30 min.