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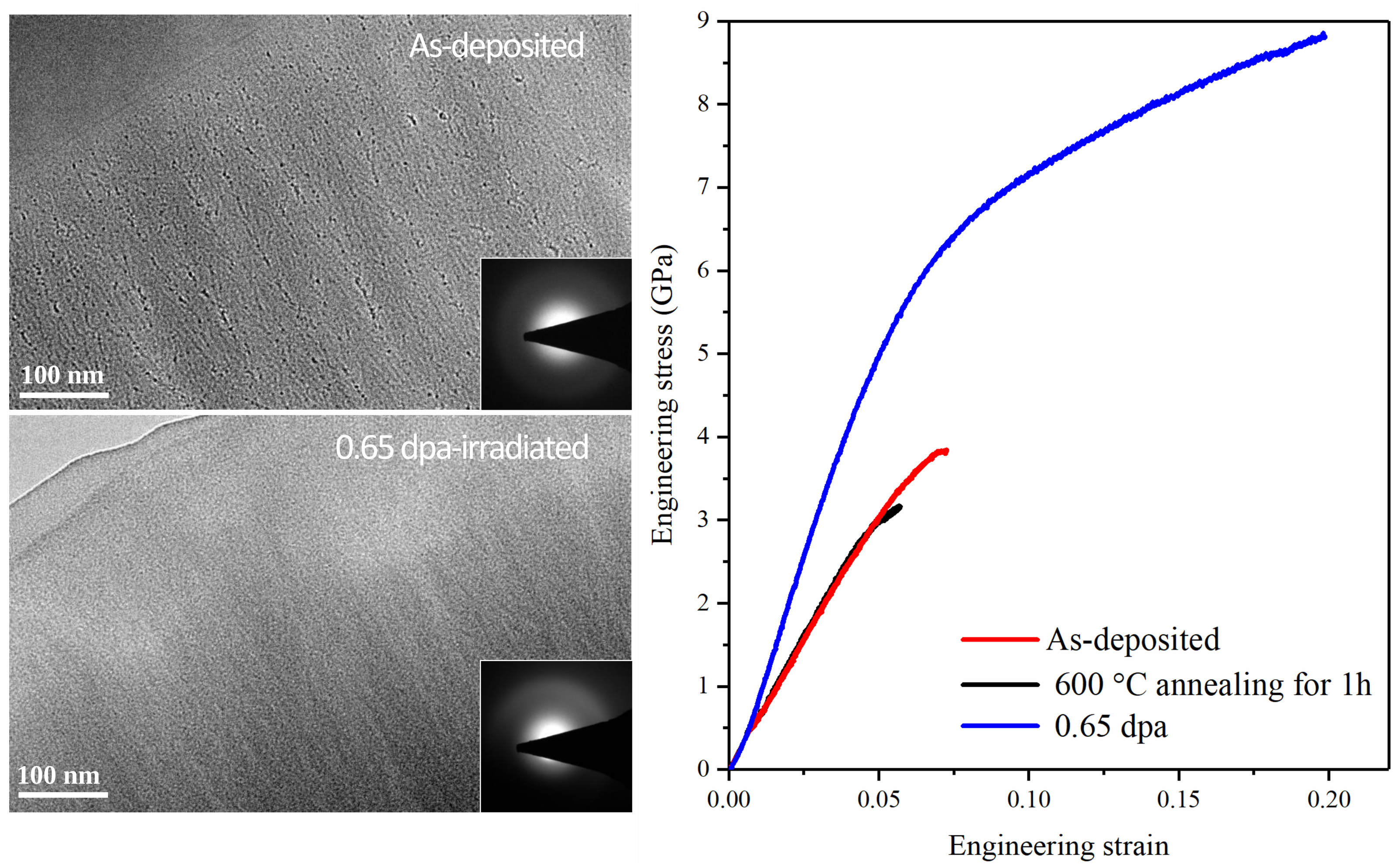
Strength and plasticity of amorphous ceramic composites

Dongyue Xie, Kaisheng Ming, Qing Su, Chao Gu, Michael Nastasi, Jian Wang

Strong, ductile, and irradiation tolerant structural materials are in urgent demand for improving the safety and efficiency of advanced nuclear reactors. Amorphous ceramics could be promising candidates for high irradiation tolerance due to thermal stability and lack of crystal defects. However, they are very brittle due to plastic flow instability. Here, we realized enhanced plasticity of amorphous ceramics through compositional and microstructural engineering. Three amorphous ceramic materials, amorphous silicon oxycarbide (SiOC), Fe-SiOC and Cu-SiOC composites, were fabricated by magnetron sputtering. We investigated their strength and plasticity by using in-situ scanning electron microscope micro-compression tests.

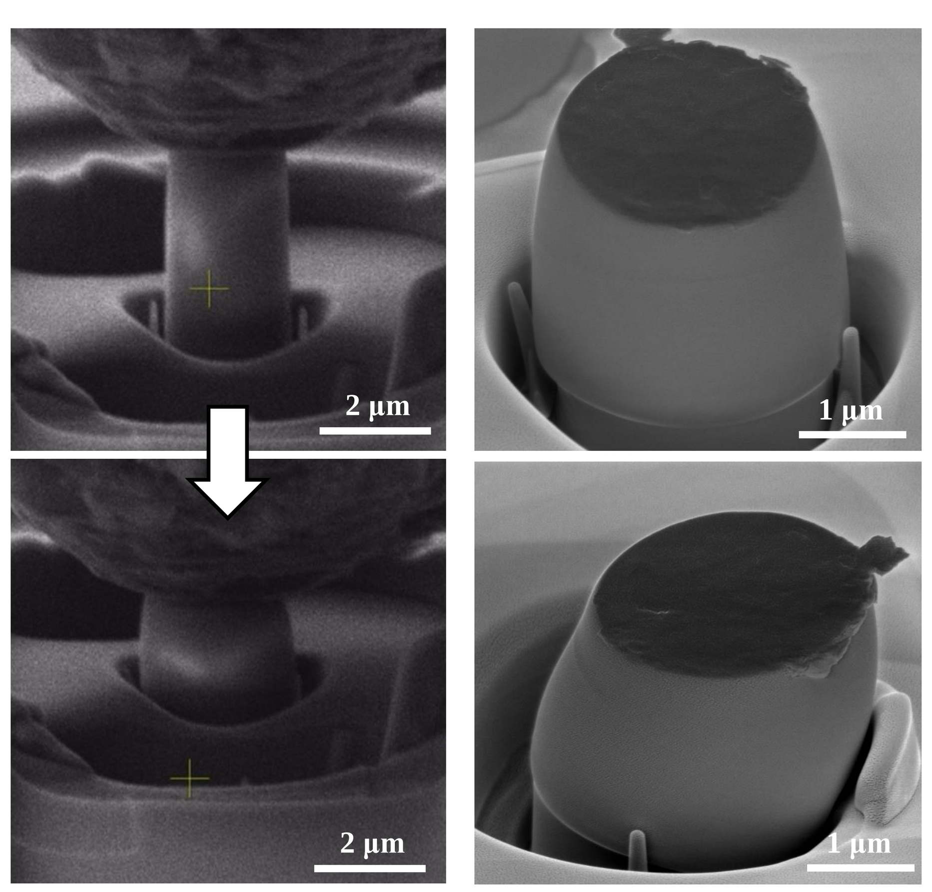
Amorphous SiOC ceramics

Amorphous SiOC ceramics are a group of superior radiation-tolerant materials suitable for applications in reactor-like harsh environments due to their exceptional thermal stability and irradiation resistance.



As-deposited SiOC films exhibit catastrophic failure due to microstructural heterogeneities associated with the formation of voids during deposition. Ion irradiation unifies microstructure accompanied with eliminating the voids, resulting in a simultaneous increase in strength and plasticity.

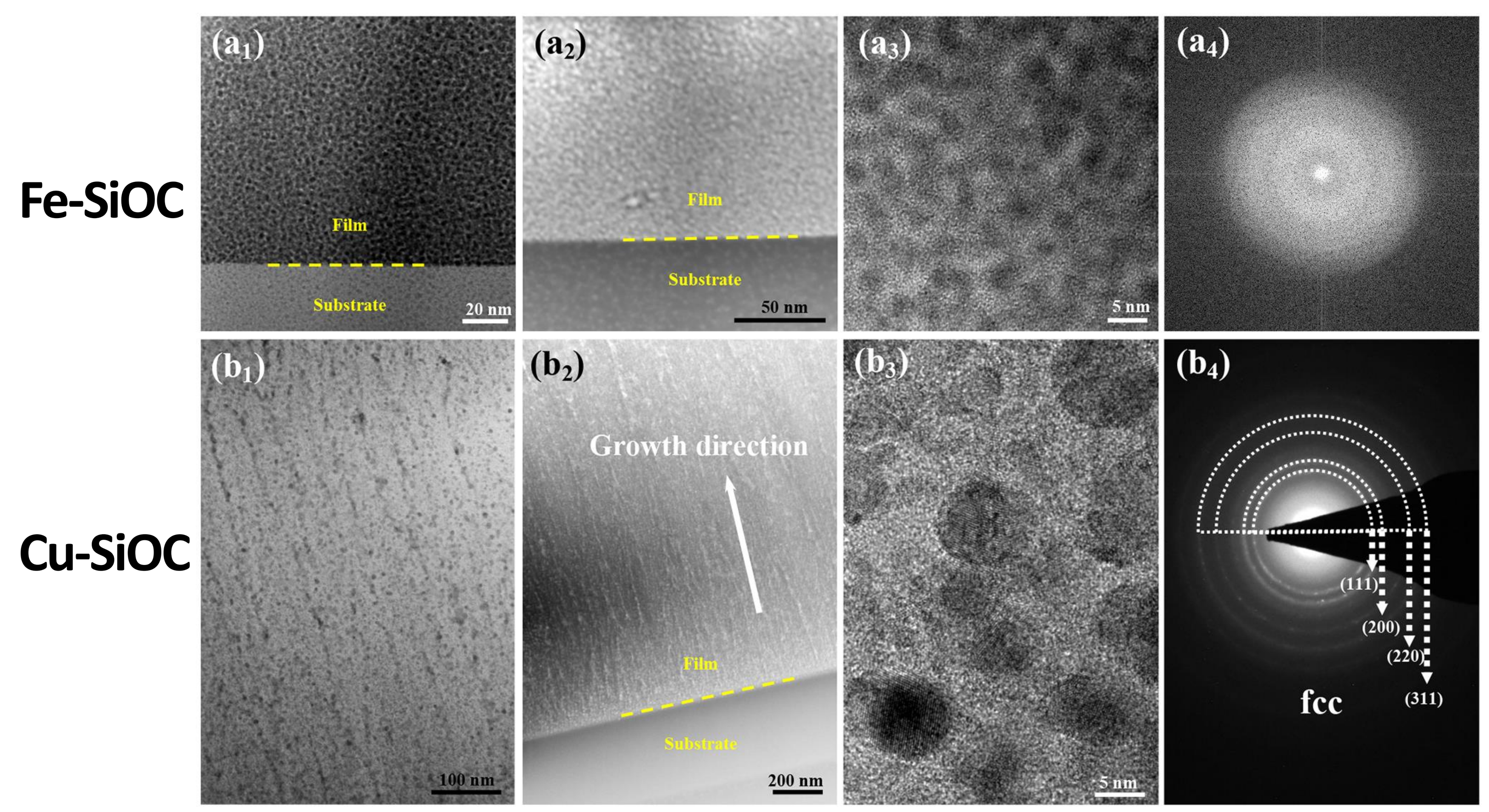
In-situ SEM compression test shows that microstructural homogeneous amorphous SiOC ceramic exhibits intrinsically high strength and plasticity, making them promising as structural engineering materials.



Amorphous metal-SiOC composites

Designing and engineering **amorphous ceramic composites (ACCs)** for extreme conditions through tailoring three-dimensional nanosized heterogeneities. ACCs are designed with spatially distributed nanosized heterogeneities in amorphous ceramic matrix. Nanosized heterogeneities can take one of three structures including amorphous metal-rich ceramic nanoclusters, metallic nanoparticles and intermetallic nanoparticles.

Nanosized heterogeneities in as-deposited ACCs

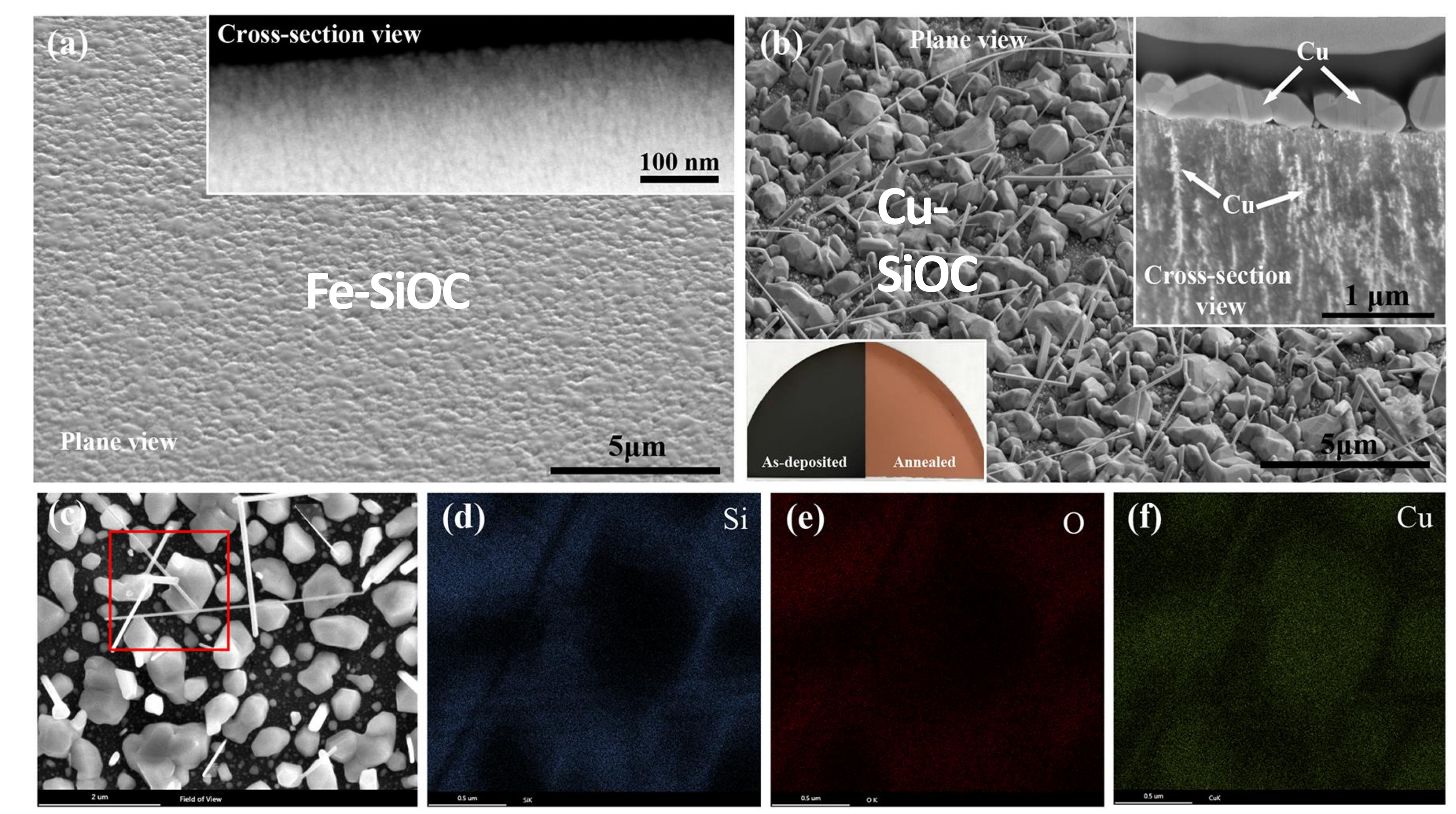


As-deposited Fe 22 at.% -SiOC: Fe-rich nanoclusters

As-deposited Cu 21 at.% -SiOC: Crystalline Cu nanoparticles

Annealing: 800 °C/1h →

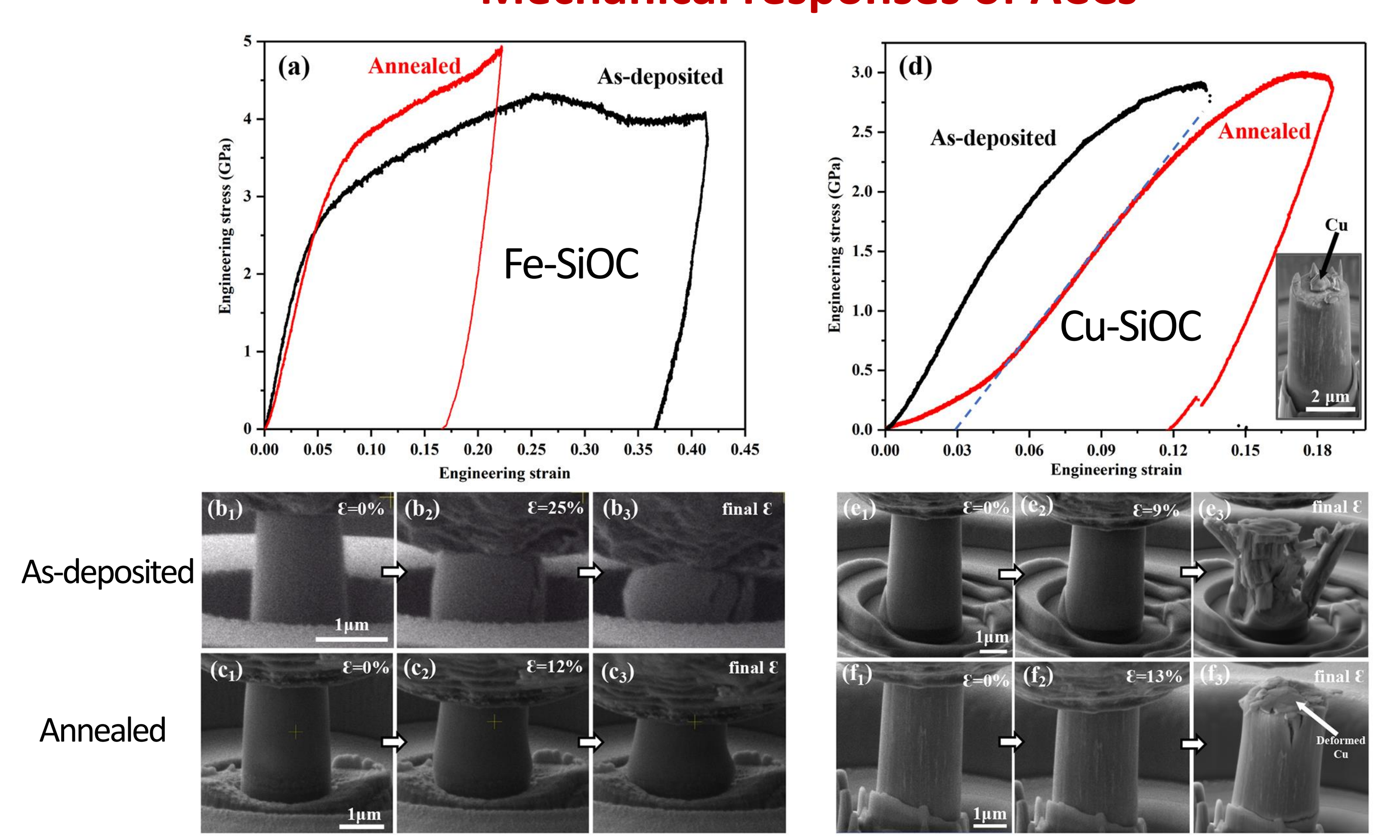
Thermal stability

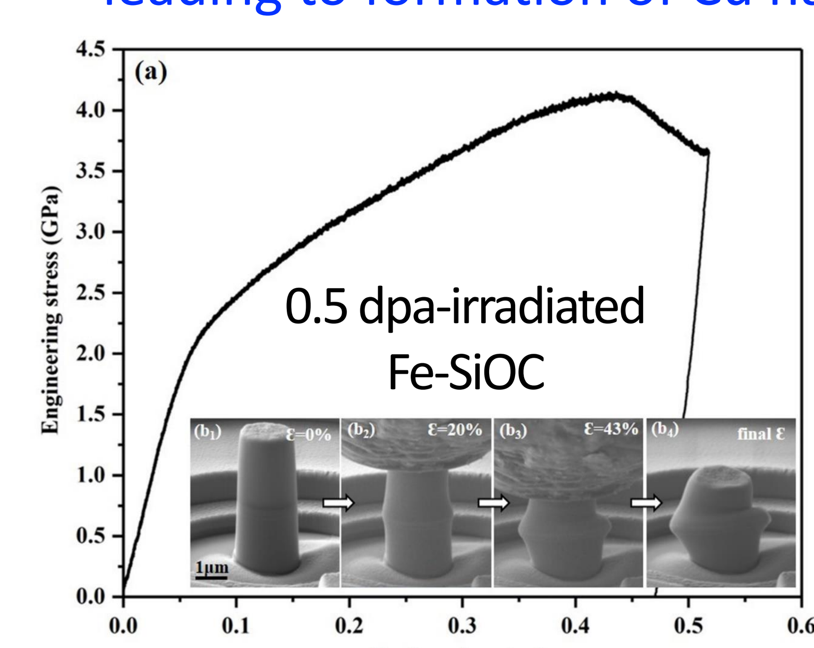


Annealed Fe 22 at.% -SiOC: Fe-rich nanoclusters

Annealed Cu 21 at.% -SiOC: Cu atoms diffuse to film surface leading to formation of Cu nanoparticles and whiskers.

Mechanical responses of ACCs





These findings suggest that metal constituents play a crucial role in developing microstructure and determining properties of metal-amorphous composites.

The Fe-SiOC composite exhibits high strength and plasticity associated with strain hardening, as well as good thermal stability and irradiation tolerance. In contrast, the Cu-SiOC composite displays a very low plasticity and poor thermal stability.

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