

Increasing the Ductility of Freestanding Metallic Thin Films – Insights from in situ TEM and in situ AFM Nanomechanical Testing

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Freestanding metallic thin films are generally thought to be very brittle and little is known about their ability to accommodate large strains under certain circumstances. New insights are provided by investigations on 30-200 nm thick PVD gold and silver films by means of in-situ tensile tests in a TEM and in-situ bulge tests in an AFM.

The bulge tests reveal that the low toughness of the films derives from the limited expansion of the fracture process zone, which limits the plastic energy dissipation. In-situ tensile testing in the TEM suggests that grain boundary mediated deformation mechanisms can significantly increase the tolerance of the samples to small cracks and lead to a ductility well above 10% plastic strain. These high ductility values measured on TEM samples are in sharp opposition to the behavior of larger samples, which typically fail around 1% strain. This is likely a statistical size effect, associated with the much larger surface of the bulge samples and the higher probability that they contain critical defects. As avoiding these defects is hardly achievable in practice, a promising strategy consists in improving the resistance of the films to crack nucleation and propagation. Using the bulge test technique, it was found that introducing grain boundaries and maximizing the material strength is key to optimizing the fracture toughness of freestanding metallic films.

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