

Single Crystal Thin Film Mechanical Behavior Measured with Nanoindentation

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One of the most common methods to measure the elastic modulus and hardness of thin films is to use nanoindentation and the well-known “10% rule of thumb” is utilized. The 10% rule of thumb has evolved to the understanding that elastic modulus and hardness can be taken at 10% of the film thickness with no or little influence from the substrate, even though only hardness was stated in the original Bückle paper. While this guideline may hold true for some film-substrate systems and film thicknesses (greater than 1000 nm), it cannot and should not, be applied universally. It will be shown on single crystalline copper films on sapphire, grown by thermal evaporation (50, 100, and 300 nm thick) that the hardness can be evaluated but the elastic modulus cannot be properly measured when compared to bulk single crystal copper. It will be demonstrated that the elastic modulus is a long range property that is substantially influenced by the substrate even at indentations of 10% of the thickness. For example, using the initial Hertzian elastic portion of the load-displacement curve before a pop-in occurs does not allow for the elastic modulus of copper to be measured. The findings reveal that the 10% rule should not be applied to evaluating the elastic modulus of thin films and hardness can be measured for some film system up to 50% of the film thickness.