Tuning the properties of thin metal films via structural disorder

Crystalline order is typically considered a prerequisite for an ideal material. Disorder is thus commonly perceived as detrimental, even though it is a key advantage in important classes of materials such as metallic glasses. Typically, crystallinity and amorphicity in alloys are connected to specific stoichiometries, making the effects of structure and composition difficult to disentangle.

Here, we show that the level of disorder in thin films is tuneable and strongly affects materials properties. We make use of the versatile nature of pulsed laser deposition (PLD) to prepare crystalline and amorphous alloy layers of identical composition by growing thin films under two very different sets of conditions, close to and far from equilibrium. We study the structural, optical, and electronic properties as well as the surface chemistry of polycrystalline and amorphous films for two selected alloys: CuZr and HfMoNbTiZr.

Grazing-incidence X-ray diffraction measurements with a 2D detector demonstrate that HfMoNbTiZr films are amorphous for growth temperatures up to 800°C, above which crystallinity and strong preferences in orientation are observed. For CuZr, which is also amorphous when deposited at room temperature, 500°C is sufficient to induce crystallization. Tuning the level of structural disorder in these alloy layers strongly affects their electronic and optical properties as well as their surface chemistry. Transport measurements demonstrate a change from defect-dominated metallic conductivity to hopping conduction with increasing levels of disorder, while X-ray photoelectron spectroscopy shows remarkable structure-dependent differences in the oxidation of the alloy surfaces.

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