Thin and ultrathin conducting MoO_3 films on copper for technological application: a XAS study of electronic and structural properties

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Background

One of the main goals of modern accelerating devices is to achieve high RF fields, limiting at the same time the size of the accelerating structures. In order to accomplish these targets is necessary to reduce the overheating effects due to the RF and the electrical breakdowns that induce damages on the surface of any RF device. One of the possible solutions is to cover the inner metallic surface of a RF device with harder materials like a transition metal (TM) oxides. Molybdenum trioxide films growth on copper shown also a high work function that minimizes the field emission from the surface. Moreover ultrathin and relatively thin layers of MoO_3 are conductive still maintaining a high and constant value of the work function (~7 eV).

Methods

We setup a method to grow MoO_3 films using a dedicated evaporation HV chamber, optimized for the deposition technique and suitable to control different parameters of the pre and post-deposition. The setup allows to evaporate flat and cylindrical surfaces up to 200 mm in diameter. The MoO_3 films were deposited on Cu at different thickness from 30 nm to 1000 nm and different annealing treatments have been performed, all below the sublimation temperature of the molybdenum trioxide. Films have been characterized with different techniques. We performed transport experiments vs. temperature, morphological characterizations with AFM and STM, spectroscopic analysis using Raman and Auger methods. XRD and nano-indentation were also performed to characterize the amorphous and crystalline nature and the hardness of the films vs. annealing. Finally a set of samples was characterized at the B18 beamline at the Diamond Light Source at Oxford and at the B08 beamline at the ESRF synchrotron radiation in Grenoble, using fluorescence XAFS and ReflEXAFS techniques. The latter technique is particularly useful to investigate films since it can be tuned to investigate the surface, the interface or few layers just below the surface.

Results

Since XAS spectroscopy is a technique that, in addition to the local structure, probes the local and partial empty density of states around the photo-absorber, experiments performed at the K-edge of Mo excite the transitions from the 1s core level probing the p-projected empty density of states at the Mo site. The Mo K-edge spectra of these films show tiny changes of the empty density of states of *p* character, which however probes the different number of occupied electrons and the hybridization in these films. The presence of a small shift points out also a concurrent shift of the Fermi level, a parameter that can be correlated to the transport properties in these metallic/semiconducting films. Results will be discussed as function of the thickness, the thermal annealing of the substrate, the ratio of the different valence state and the electrical properties of the interface between the copper metal and the oxide layers.

Conclusions

Nowadays an increasing interest is devoted to metallic molybdenum oxides due to their high mechanical resistance, good electrical conductivity, and low field emission. These oxides are complex nanophase systems where molybdenum may exist in several oxidation states: Mo^{4+}, Mo^{5+} and Mo^{6+} and whose properties can be tuned for different technological applications by changing the substrate and/or the treatment after the evaporation. By using X-ray absorption spectroscopy, we can control the presence of insulating or metallic phases and correlate the electronic properties with the transport properties of ultra thin and thin films.