Electronically tuneable nanomaterials

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The properties of materials are typically controlled in a static manner by their microstructure. This implies control of the grain size, defect concentration, structure and metastability. As long as the microstructure does not change during the use of the material, the properties of the material are fixed, or irreversible. In contrast, in semiconducting materials, properties can be tuned by the application of an external field due to the space charge regions which extend far from the interfaces. In metallic systems, this effect cannot be observed unless the dimensions of the structures are in the nanometer regime. The reason for this different behaviour is the small spatial dimension of the space charge regions due to the effective screening of the induced charges by the conduction electrons.

In nanoporous metals and thin films exposed to appropriate electrolytes, it has been demonstrated that substantial changes of physical properties can be induced by the application of a potential between the nanostructured metal and a counter electrode. Examples of the changes of surface stresses and the electrical resistivity of thin Gold films and nanoporous Gold will be presented. A simple model is proposed based on the modification of the electron density distribution at the interface of the metal and the electrolyte. Effectively, the corresponding change of the effective thickness of the sample is the major cause of the observed resistivity change.

Additionally, a transparent conducting oxide, ITO, in a nanoparticulate form has been prepared from a dispersion using spin coating. The observed resistivity changes, i.e. the on/off ratio can be as large as 2.000, i.e. 200.000 %, between the different values of the control potential. Moreover, the device exhibits field effect transistor behavior identical to a conventional semiconductor, but in this case observed in a material with a large charge carrier density exhibiting metallic conductivity. The ITO dispersion can be deposited using established ink-jet techniques to prepare printable electronic devices. Additionally, the mobility is approx. 25 cm^2/Vs, i.e. much larger than most organic printable devices and, moreover, stable at ambient conditions. Studies of the tuneability of the conductivity, scanning tunnelling microscopy and spectroscopy in ITO thin films with various thicknesses have been used to understand the origin of the large changes of conductivity in these nanomaterials.