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Electrical Properties of Titanate Nanostructure Films

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Abstract – We have prepared films based on titanate nanostructures and measured their electrical properties for temperatures (T) ranging from 25 to 300°C under different atmospheres. For T>100°C the conductivity presents a thermally activated behavior that can be attributed to electronic transport via hopping. For T<100°C, this behavior changes significantly and is affected by the presence of water molecules, providing evidence of protonic transport. The films also present significant response to H_2, indicating that they can be applied as gas sensors.

Hydrogen (or sodium) titanates nanostructures (TNS) such as tubes, fibers and sheets can be efficiently produced by treating TiO2 powders in alkaline solutions [1]. Although most of the work on these nanomaterials has been on their structural identification and control, recently several applications have been proposed, such as pollutant cleaning by ion exchange [2] and nano-composite polymeric electrolytes in fuel cells [3]. On the other hand, thin films of nanostructured/porous oxides have been used in several applications such as gas sensors, solar cell electrodes, hydrophobic coatings, etc. In this work, we have investigated the electrical properties of TNS films (TNT) films.

The TNS were produced by the reflux of commercial TiO_2 powder (anatase phase) in an aqueous NaOH solution. The resulting material was washed with DI water for neutralization. We avoided the use of acid in washing in order to preserve some of the Na cations within the titanate structure. The films were deposited by doctor-blading, by spreading a TNS based paste over the desired substrate. The as produced powder and films were characterized by scanning and transmission electron microscopies (SEM and TEM, respectively) and x-ray diffraction. A SEM picture of one of the produced films is shown in Fig.1.

Electrical measurements were performed on films deposited over oxidized silicon wafers whereby interdigitated gold contacts were previously evaporated. The temperature dependence of the electrical conductivity from 25 to 300°C was determined for films subjected to different atmospheres (dry N_2, N_2 + 1% H_2, and N_2 + 1.5% H_2O). The response of the films to different concentrations of H_2 and H_2O at room temperature was also evaluated. It is observed that for T > 100°C, the conductivity is thermally activated with similar activation energy (E_a~0,56 eV) for all atmospheres studied (see Fig.2). This behavior is attributed to electronic conduction and the E_a value obtained can be associated to hopping via surface traps states.

On the other hand, for T < 100°C, the linear dependences of the conductivity on the Arrhenius plot show clear deviations, especially for the measurements performed humid atmosphere. This result suggests that protonic transport mediated by physisorbed H_2O molecules in the TNS may become dominant at low T. Currently, we are performing impedance spectroscopic measurements in order to further elucidate the transport mechanism in such films. In addition, we have observed that the films present significant responses to variations of the concentration of H_2, even at low T, indicating that they can be used as gas sensors.

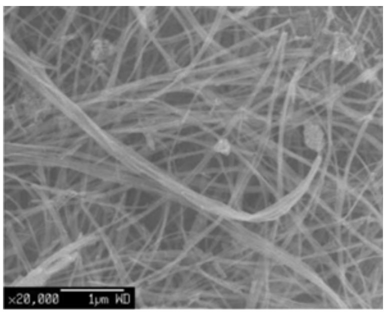

Figure 1: SEM picture of the TNS film.

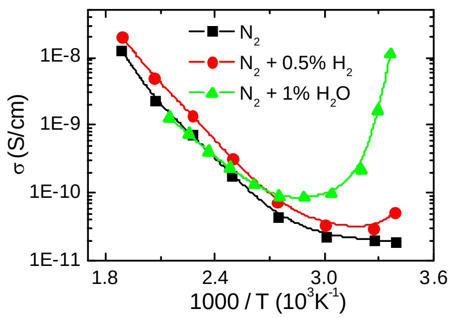

Figure 2: Arrhenius plot of the films conductivity measured under different atmospheres.

References

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