An Optical and Photoelectrochemical Characterization of Tin and Indium Nitride Thin Film Electrodes

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Indium nitride (InN) and tin nitride (SnN_x) thin films were produced with reactive d.c. magnetron sputtering technique. The films were optically and photoelectrochemically characterized and the energetic positions of the two semiconductor's band edges were determined with respect to the NHE. A spectroscopic bandgap determination of InN showed that the film had an indirect bandgap of 1.4 eV and a direct bandgap of 1.8 eV. The optical spectra of SnN_x indicated a bandgap energy of approximately 1.4 eV. All nitride films showed photoresponse in 0.1 M KI (aq.) electrolyte at an irradiation intensity of 1000 Wm^{-2}.

Various semiconductor materials, like Si, $GaInP_2$, InP and TiO_2, have been designed and tested for solar cell and photoelectrochemical (PEC) cell applications. Here we report about two nitrides, indium nitride (InN) and tin nitride (SnN_x), which were produced by d.c. magnetron sputtering and optically and photoelectrochemically characterized. Little is reported about nitrides for solar energy purposes. However, Turner *et al* made a photoelectrochemical investigation of gallium nitride, GaN. They showed that the material was photoactive in a photoelectrochemical cell. The band edge positions of GaN were situated so that electrolysis of water was possible without an external bias. However, GaN is a wide bandgap semiconductor with a bandgap around 3.4 eV and only a small fraction of the incoming solar irradiation can be utilized in the photolysis. InN could be a more suitable nitride since it bandgap energy was found to be around 1.4 eV. Another interesting nitride semiconductor is tin nitride with a bandgap also around 1.4 eV.

The present contribution is a first report from our initial attempt to synthesize and photoelectrochemical study these interesting semiconductor materials. The photoelectrochemical characterization of the sputtered nitride films strongly indicated the possibilities to use photoactive electrodes based on single layers or combinations of indium- and tin nitride for solar energy purposes. This is due to several reasons:

1. The position of their valence and conduction band edges (see fig. 1.) makes them interesting for solar energy storage via photooxidation of water in a PEC cell.
2. They are also interesting for solar electricity generation, due to the favorable band gap energies of these semiconductors. The peak efficiency for solar energy conversion occurs for a bandgap in the range 0.9 to 1.6 eV, so both the sputtered InN and SnN_x and combinations of those are of interest. This is valid also for solid state devices based on indium and tin nitride.
3. They are interesting due to the expected low cost of the materials; this is true especially for SnN_x since tin and nitrogen are abundant and available substances.

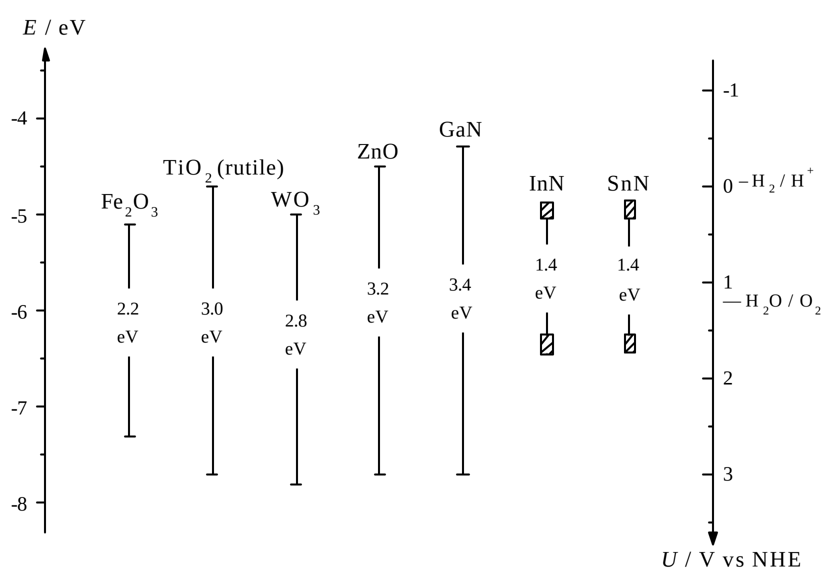

Fig. 1. Position of energy bands of InN and SnN_x (and a few other common semiconductors) at pH 1 with respect to the electrochemical scale. The standard electrode potentials of hydrogen and oxygen are also shown for reference.