Web Summary Report

January 2015 – December 2015

Phase V

In the fifth stage of the project the studies were focused on the growth and characterization of multifunctional zinc oxide thin films (Part B). Nd doped ZnO thin films were grown and their physical properties were studied with twofold strategy, having a "passive" and an "active" functionality for applications.

These studies have continued those carried out in the previous phase, where the optical properties have been investigated as function of growth conditions.

The resistivity of the films, the carrier concentration and mobility were determined by Hall measurements. A wide range of electrical properties of the films were obtained and correlated to the composition, crystalline structure and optical properties. The resistivity of the Nd-doped ZnO thin films varies between 10^{-4} Ω cm and 4 x 10^{-2} Ω cm as a function of growth pressure and substrate temperature. The measurements showed that the electron density measured in the Nd-doped ZnO films is often higher than the critical density and thus a metallic behavior is expected for these films. Thus by varying growth conditions, the films can be tuned to have either metallic or semiconductor characteristic, always with a good optical transmittance in the visible range.

The resistivity measurements as a function of temperature showed that a low-temperature metal-insulator transition in the 98 - 140 K range appears in Nd-doped ZnO films grown under low oxygen pressure. The presence of a metal-insulator transition in these films is due to the high density of carriers (metallic behavior) and to the structural disorder present in the films (scattering of the carriers). The increase of the resistivity below the metal-insulator transition critical temperature was interpreted in the frame of the quantum corrections to the conductivity to the semi-classical Boltzmann approach. For the films grown under high oxygen pressure and high substrate temperature the variation of resistivity was too high to be interpreted in the frame of the quantum corrections to the conductivity model and the variable-range hopping model was used.

Resistivities as low as $6x10^{-4}$ Ω cm and 90 % optical transmittance in the visible range and different near infrared transmittance are obtained with around 1.0-1.5 at.% Nd doping, and growth temperature around 500°C. A wide domain of conditions leads to the formation of films presenting a metallic behaviour at room temperature. Such films appear thus as an alternative candidate to replace ITO in photovoltaic applications, in particularly for relatively high temperature growth of multi-junction solar cells.

Details about results obtained in this Phase can be found in following papers presented in the Dissemination section.

Dissemination

M Nistor, E Millon, C Cachoncinlle, W Seiler, N Jedrecy, C Hebert and J Perrière, J. Phys. D: Appl. Phys. **48** (2015) 195103 and in 5 communications at international conferences.

In conclusion the objectives of Phase V were realized, resulting multifunctional zinc oxide thin films for applications.