EMCMRE-1
Marrakech-Morocco
November 21-25 2011
First Euro-Mediterranean Conference on Materials and Renewable Energies (EMCMRE-1) 21-25 November 2011

Film deposition and characterisation of p-doped microcrystalline silicon for silicon-heterojunction solar cells.

A. Casado[1], I. Torres[1], R. Barrio[1], J.D. Santos[1], J.J. Gandía[1], J. Carabe[1], G. Bianco[2], M. Losurdo[2], G. Bruno[2]*

[1]*CIEMAT, Madrid, Spain.*

[2]*IMIP, CNR, Bari, Italy.*

*E-mail: alberto.casado@ciemat.es

Abstract:

Microcrystalline silicon, μc-Si:H, is an interesting material for use in optoelectronic devices, such as sensors or solar cells. In particular, due to its high conductivities, good optical properties and stability in the presence of light, it has attracted much attention in the field of photovoltaics. In this field, μc-Si:H is a versatile material, since different variations on its properties make the material fit the needs of diverse solar cell technologies. For instance, a transparent and conductive material with a high energy gap might be included in p-i-n devices as the window layer. In the case of silicon-heterojunction (SHJ) solar cells, highly conductive μc-Si:H can be used wether as an emitter or as a rear contact to create a back surface field (BSF).

The goal in this study was to obtain a suitable p-doped microcrystalline silicon, μc-Si:H(p), material to be inserted as a BSF in our SHJ solar cells, which structure is a-Si:H(n)/c-Si(p)/μc-Si:H(p+). This leads to a p-p+ junction which may create a strong electrical field and help increase carrier collection at the rear side. No restrictions on transparency or gap energy are necessary, although high conductivity, that is, a high crystalline fraction and good doping efficiency is required.

The technique used for deposition was RF-PECVD (Radio-Frequency Plasma Enhanced Chemical Vapor Deposition), since it is widely used for low temperature, amorphous silicon deposition and for its capability to deposit over large areas [1]. First intention was to use an He-diluted silane plasma. Some advantages have been previously reported when using He-dilution [2, 3], in particular, the fact that high density plasmas can be obtained at low power, low pressure and low temperature or the possibility of depositing microcrystalline silicon onto transparent conductive oxides substrates that are chemically reduced by hydrogen plasmas. However, a small addition of H was found to be necessary in order to obtain high crystalline fractions. Trimethylboron was chosen as the doping gas, being a widely used dopant gas in photovoltaics. Different deposition conditions were explored, varying different parameters like pressure, RF-power or gas fluxes, among other, in order to optimise material properties.

Electrical, optical and structural properties of microcrystalline layers were analysed. Conductivity was measured in the dark and under controlled illumination conditions (Figure 1). Also the temperature dependence of the dark conductivity was measured and the activation energies calculated (see Figure 2). In addition, reflectance and transmittance, as well as ellipsometric spectroscopy (SE) and micro-Raman measurements were carried out to evaluate the optical constants, thicknesses and structural composition of the different films. A layer model was obtained from from fitting ellipsometric spectra of some samples, in order to understand the physical structure of the material. An example of this can be seen in Figure 3

Figures

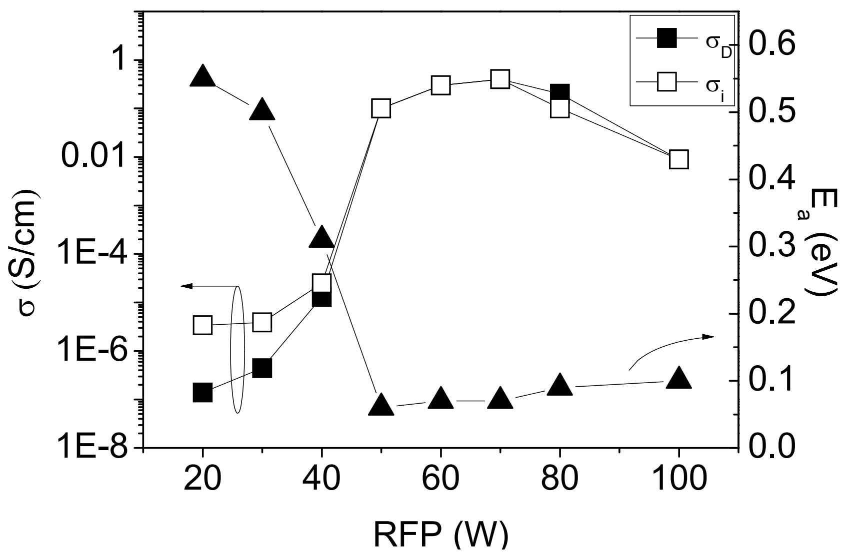

Figure 1. Conductivity under dark and illuminated conditions, σ_D and σ_i, respectively, for a series where RF-Power was varied. SE measurements and modelling for the sample with the maximum conductivity values (E210C) is presented in Figure 3.

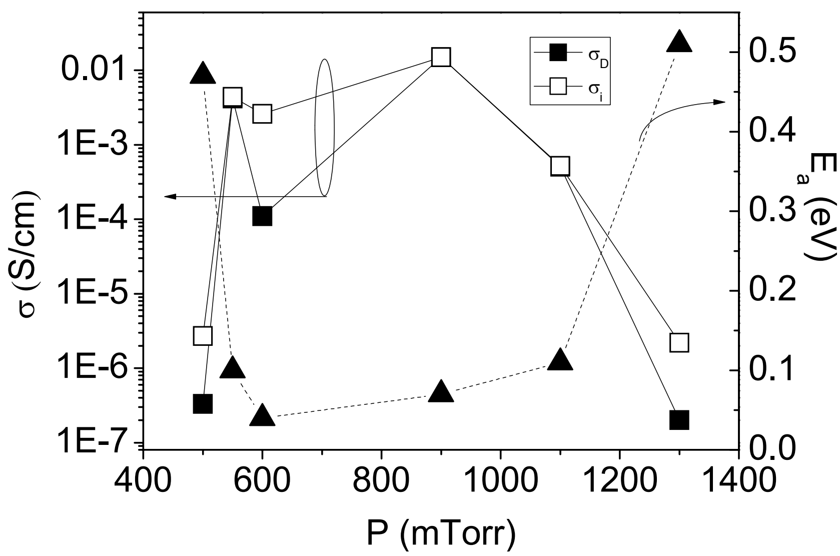

Figure 2. Activation energy, E_a, of a series of samples where the pressure of the chamber was varied.

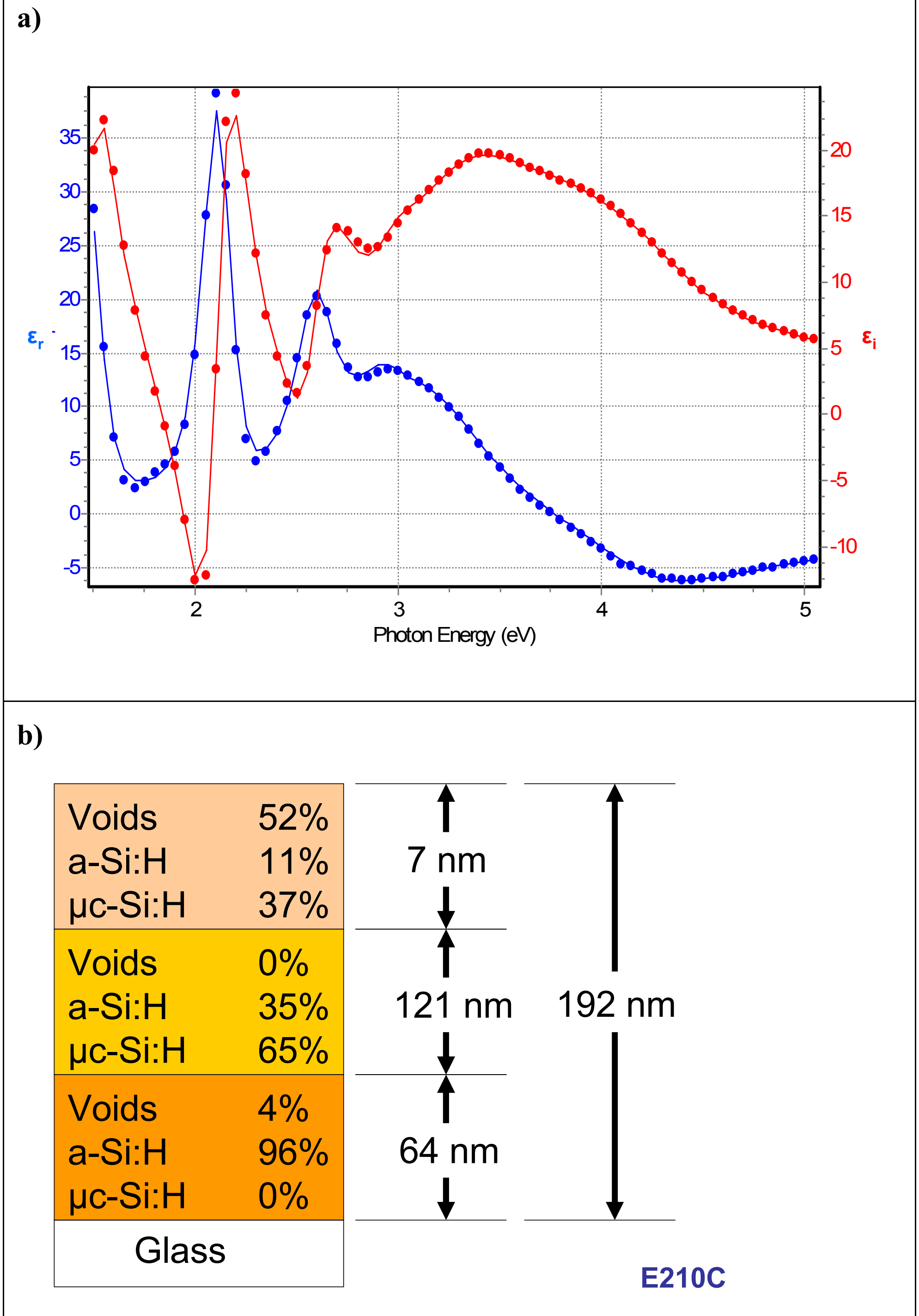

Figure 3. a) The imaginary and real part of the dielectric function obtained from SE spectra corresponding to sample E210C are shown. b) A three-layer structure, including three phases (voids, amorphous and microcrystalline silicon), was assumed for fitting the experimental SE spectra.

Sample E210C was prepared at RFP = 70 W and P = 550 mTorr. Conductivity values were $\sigma_D = \sigma_i = 4.0 \times 10^{-1}$ S/cm. Thickness calculated from reflectance and transmitance spectra was d = 229 nm, in accordance with results from SE.

Bibliography

1. R.E.I. Schropp y M. Zeman, *Amorphous and microcrystalline silicon solar cells*. 1998.
2. J. Cárabe, *et al.*, *Microstructure of thin films prepared by plasma-enhanced chemical vapour deposition of helium-diluted silane.* Applied Surface Science, 1999. 143(1-4): p. 11-15.
3. N. González, *et al.*, *Optoelectronic properties of doped layers for a-Si solar cells prepared using helium dilution.* Solar Energy Materials and Solar Cells, 1997. 45(2): p. 175-184.