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Optimization of a-SiC:H p-type material for p-i-n solar cells

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Abstract:

The a-SiC:H p-doped is widely used in the fabrication of optoelectronic devices. This material is especially interesting for the development of front emitters in amorphous silicon p-i-n solar cells. Since some of its properties as the energy gap or the activation energy can be adjusted, short-circuit current and open circuit voltage of the photovoltaic device can be improved. For this reason, the a-SiC:H p-type optimization becomes an essential step for the production of such solar cells.

In this process, it is necessary to find the concentration of methane (CH_4), and doping gas, which allows optimizing the optical transmittance and electrical conductivity of the material. As an example, an excess of methane in the plasma could lead to a high density of voids within the structure, deteriorating electrical conductivity [1]. On the other hand, a dopant excess could produce a high density of defects within the bandgap, leading to an increase of the optical absorption [2].

These effect give rise to competition between the optical and electrical properties, and they are an example of the complex chemical structure of a-SiC:H p-type. Nowadays, it is still necessary to study these alloys in order to better understand how to improve their quality. Proof of this is the many existing studies, some of them very recent [3] [4]. In this sense, this work tries to give additional information on the influence of the deposition conditions on the optoelectronic and structural characteristics.

To do this, different a-SiC:H p-type film series has been prepared in PECVD reactor at 13.56 MHz. Transmittance-reflectance measurements have been used for optical characterization, while the electrical properties have been determined using electrical conductivity measurements as a function temperature. This characterization has been complemented and correlated with the structural analysis of the material, combining FTIR and XPS spectroscopy.

In particular, the methane concentration effect $C_{METHANE}=[CH_4]/[CH_4]+[SiH_4]$, as well as the doping concentration effect $R=[Doping\ gas]/[SiH_4]$, has been studied in detail. In both cases, diborane (B_2H_6) and trimethylboron ($B(CH_3)_3$) have been used as doping gases in order to compare their effect on the alloy properties. This study has allowed determining the optimum deposition conditions for the development of p-i-n solar cells with each doping gas.

In addition, the effect of the substrate temperature on the optoelectronic and structural properties of a-SiC:H p-type has been analyzed. Since this deposition parameter has an enormous impact on the quality of the grown material, this study has provided essential information for the development of solar cells onto low-cost plastic substrates. The obtained results allow the identification of the problems associated with the reduction of the mobility of chemical species in these alloys. A re-optimization of material properties have been achieved based on the adjustment of the stoichiometry of the plasma.

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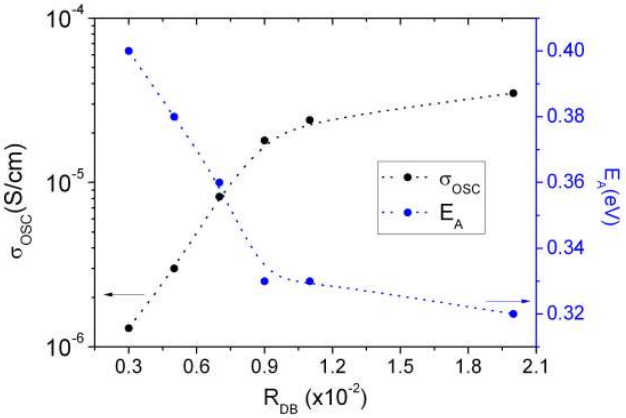
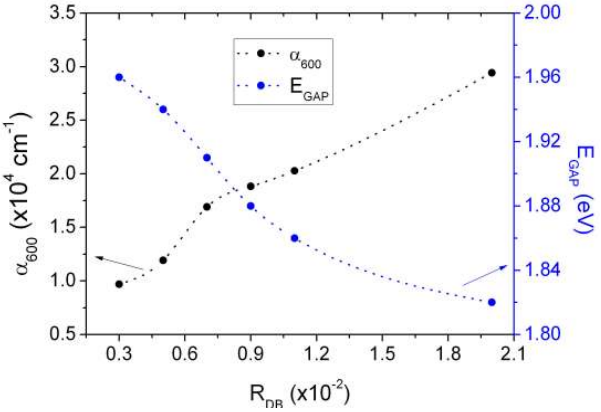
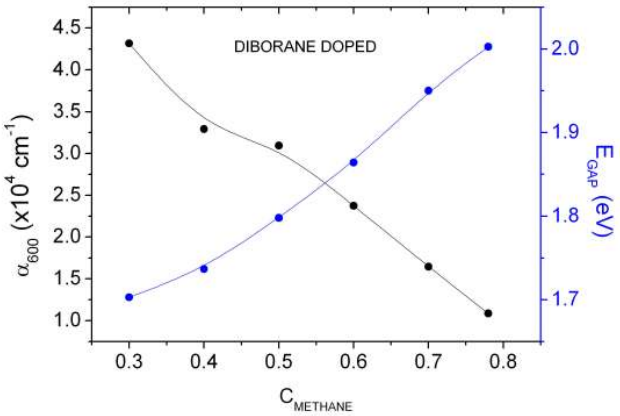
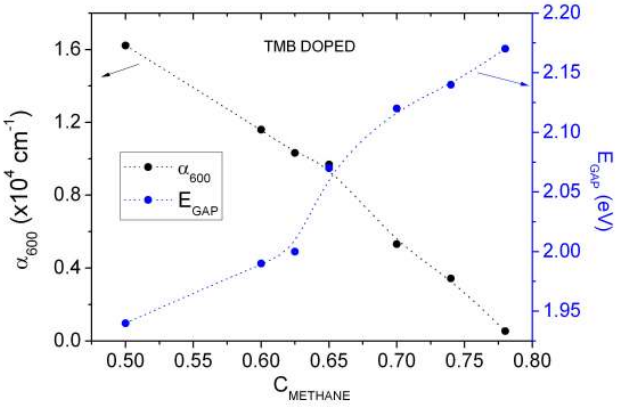
Explanatory pages



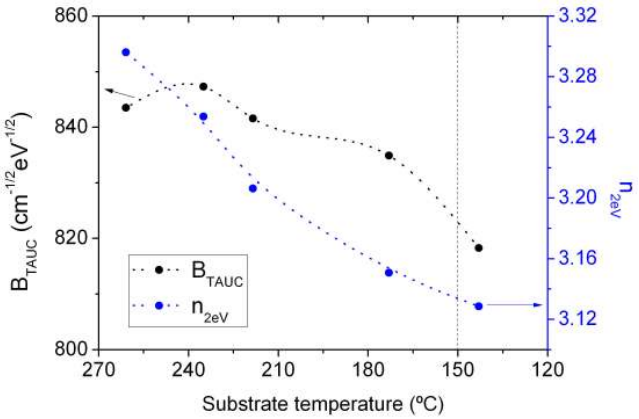


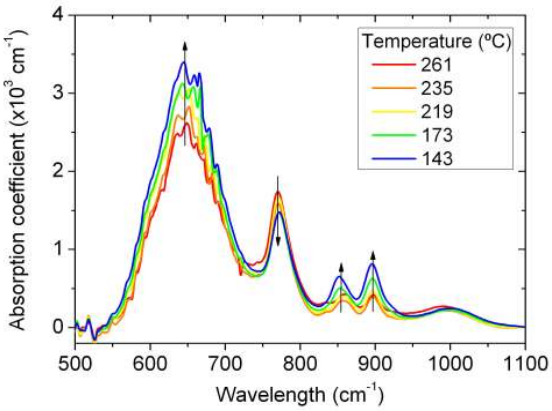
The electrical properties of a-SiC:H p-type can be improved by increasing the flow of doping gas. However, in the case of diborane (DB), there is a saturation point for R_{DB}= 0.01%. For such high doping concentrations, the optical transmission is insufficient for the solar cells development.





The gap energy can be increased by means of the modification the concentration of methane gas in the plasma. Thus, the optical properties degradation associated to the boron incorporation can be minimized. In the case of trimethylboron doping, better optical properties can be obtained, probably as a consequence of a lower density of defects.





At lower deposition temperatures, an increase in structural disorder and a loss of density in the material is extracted from the evolution of the Tauc slope parameter and the refraction index. This result is in good agreement with the increase of the Si-H2 and Si-H3 bonds densities obtained from FTIR measurements. As a consequence, the electrical characteristics show a strong deterioration.

References

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