Subject: 3 Amorphous and Microcrystalline Silicon

MODIFICATION OF AMORPHOUS AND MICROCRYSTALLINE SILICON FILM PROPERTIES AFTER IRRADIATION WITH MeV AND GeV PROTONS

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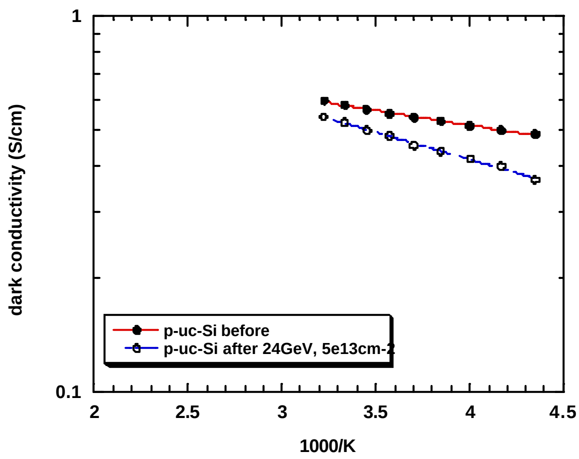
It is well known that the degree of crystallinity has a prominent influence on the stability of Silicon under proton irradiation. Amorphous silicon films are much more stable than mono- or polycrystalline silicon substrates or microcrystalline silicon thin films. In particular it has been shown, that in a micromorph tandem solar cell irradiated with protons in the lower MeV energy range only the microcrystalline diode showed a pronounced decrease in photocurrent after irradiation[1]. The proton irradiation induced damage in thick crystalline silicon samples has a maximum at beam energies between 1MeV and 4MeV and decreases for further increasing proton energies. However, irradiating an amorphous silicon/crystalline silicon heterojunction solar cell with a relatively dose of 24GeV, we observed a very strong drop in conversion efficiency with only minor recovery after sample annealing. In literature it has been reported [2], that the degradation of amorphous silicon is negligible for proton energies above 100MeV. In order to clarify to which extent also the thin film top layer of the hetero solar cell is affected by the proton irradiation, we exposed a variety of thin film silicon samples either to a 1.7MeV beam with a dose of $5 \cdot 10^{12}$ protons/cm^2 or to a 24GeV beam with a dose of $5 \cdot 10^{13}$ protons/cm^2.
The investigated intrinsic, p-type and n-type amorphous and microcrystalline silicon films have been deposited by conventional plasma deposition under variation of the silane / hydrogen gas phase ratio. Raman measurements have been done in order to determine the order of crystallinity obtained under various deposition conditions. We observed even at 24GeV a clear modification in the electrical characteristics of the films. Temperature dependent measurements of the dark current revealed in particular for all doped samples a significant increase of the activation energy, that might be explained by a decrease of the dopant efficiency, while for intrinsic a-Si:H layers the increasing activation energy is due to deep defect creation.

[1] J. Kündig, M. Götz, A. Shah, L. Gerlach and E. Fernandez, Solar Energy Mat. & Solar Cells, Vol 79 (2003), p. 425
[2] R. Brüggemann, J.P. Kleider, W. Bronner and I. Zrinscak, J. Non-Cryst. Solids, Vol 299-302 (2002), p.632

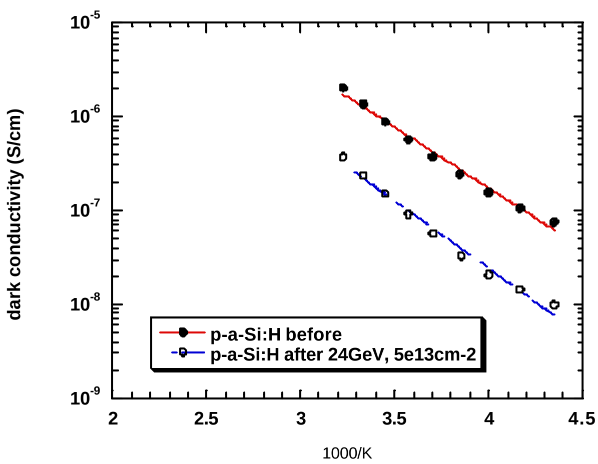
<u>Explanatory page 1</u>

Sample no	SiH4/H2 ratio	Plasma RF-frequency (MHz)	Activation energy of the dark conductivity (eV)
16	**2.40**	**100**	**0.26**
34	**5.25**	**100**	**0.32**
32	**6.40**	**100**	**0.42**
56	**50.00**	**13.65**	**0.89**

Table 1 Growth conditions and dark conductivity data, measured in coplanar geometry



a)



b)

Fig. 2 Temperature dependence of the dark conductivity of a) a p-type μc-Si and b) a p-type a-Si:H sample before irradiation and after irradiation with $5\cdot 10^{13}$ protons/ cm^2 at 24 GeV

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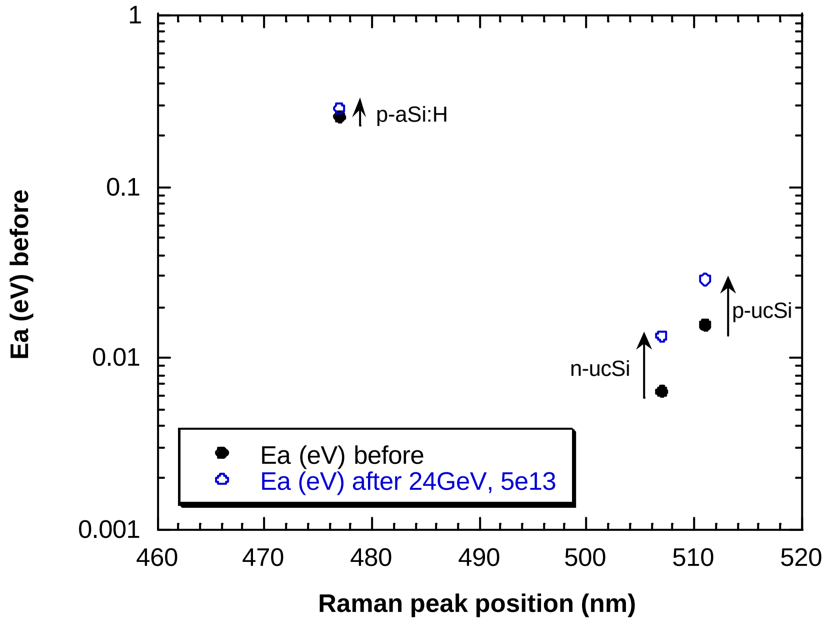

Fig. 3 Activation energy of the dark current of different types of amorphous and microcrystalline silicon films before irradiation (filled circles) and after irradiation (open circles) with $5 \cdot 10^{13}$ protons/ cm^2 at 24GeV

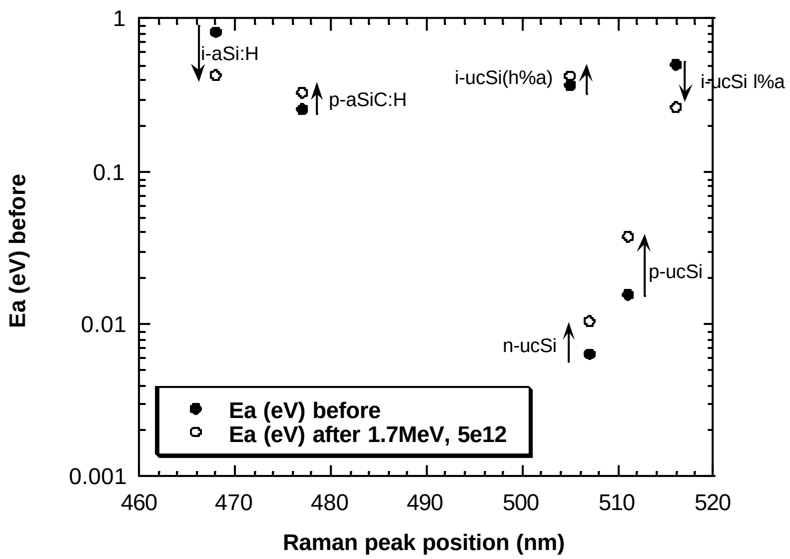

Fig. 4 Activation energy of the dark current of different types of amorphous and microcrystalline silicon films before irradiation (filled circles) and after irradiation (open circles) with $5 \cdot 10^{12}$ protons/ cm^2 at 1.7 MeV