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Authors
Skumanich, A.
Amer, N.M.

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A. Skumanich and N.M. Amer

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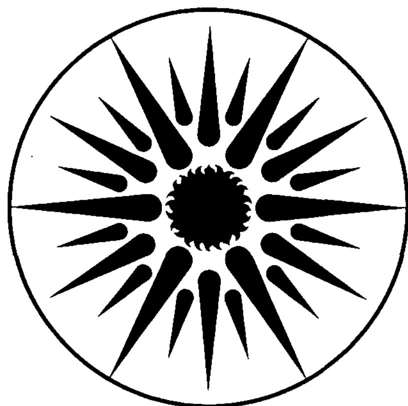

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OPTICAL PROPERTIES AND CORRELATION ENERGY OF DEFECTS IN a-Ge:H

Andrew SKUMANICH* and Nabil M. AMER

Applied Physics and Laser Spectroscopy Group, Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720, USA

Gap-state optical absorption of undoped and doped a-Ge:H has been measured using photothermal deflection spectroscopy. We show that the absorption is due to Ge dangling bond defects whose energy lies ~0.5 eV below the conduction band. We determine the correlation energy of the defect to be ~0.1 eV. Unlike a-Si:H, gap-state absorption of a-Ge:H shows little or no change after intense illumination.

1. INTRODUCTION

The optical absorption spectra of defect states provide information on the energy level and the density of defects in amorphous semiconductors. Using the sensitive technique of photothermal deflection spectroscopy[1] to detect these weakly absorbing states, it has been shown[2] that in the case of a-Si:H the absorption is due to Si dangling bond defects. The energy level of the defect was determined (~1.25 eV below the conduction band), and the defect density was found to depend on the deposition parameters and the level of doping.[2] By extending this type of investigation to other tetrahedrally-bonded semiconductors, a better understanding of defects in this class of materials should emerge. We have measured the gap-state absorption of undoped and doped a-Ge:H. We determined that the absorption is due to Ge dangling bond defects. The defect energy level lies ~0.5 eV below the conduction band, and its correlation energy is estimated to be ~0.1 eV. Illumination appears to be much less efficient in creating defects than is the case for a-Si:H.

2. RESULTS AND DISCUSSION

The samples were deposited by the glow-discharge technique.[3] Details of the photothermal deflection spectroscopy technique are described in Ref. 1.

In Fig. (1) we present the absorption spectra of undoped and singly-doped a-Ge:H. As can be seen, significant sub-gap absorption is observed. In the case of the doped material, the magnitude of the absorption increases as the dopant concentration rises. Also, the slope of the exponential absorption

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(Urbach) edge increases with increasing dopant concentration.

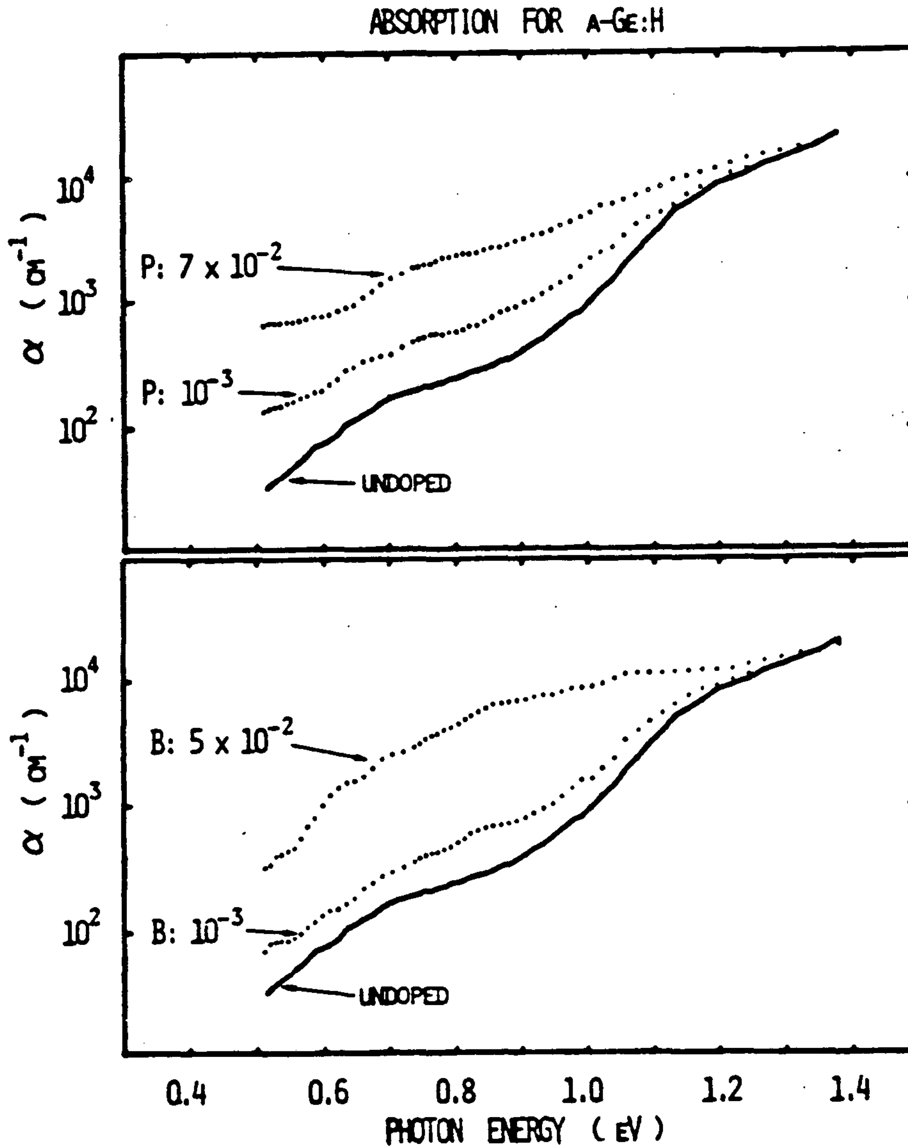

FIGURE 1
The gap-state absorption of doped and undoped a-Ge:H.

Previous work[2] has shown that the magnitude of gap-state absorption in a-Si:H is a measure of dangling bond defect density (N_s). Employing the same procedure for a-Ge:H, we determined the density of defects in undoped material to be ~$2x10^{17}/cm^3$. This value is in good agreement with the ESR measurements of Stutzmann et al.[4], indicating that the absorption is due to a Ge dangling bond. In heavily doped material, the defect density is as high as ~$6x10^{18}$ defects/cm^3. When compared with a-Si:H, for similar levels of doping, the number of defects is roughly the same. However, for the undoped case, the

defect density in a-Ge:H is an order of magnitude higher than in a-Si:H, and the Urbach edge is broader.

In addition to measuring the defect density, optical absorption measurements enable the determination of the energy position of the defect. For a-Ge:H, the defect lies at ~0.5 eV below the conduction band. Furthermore, the correlation energy of the defect (U) can also be measured by comparing the singly and doubly occupied dangling bonds in undoped and doped material. U is found to be ~0.1 eV, which agrees with the value reported in Ref. 4. This value is significantly smaller than the ~0.35-0.4 eV reported for the Si dangling bond defect.[5,6] A possible explanation for this striking dissimilarity is the weaker degree of localization in the case of a-Ge:H as compared with a-Si:H (correlation lengths of 11Å and 4Å for a-Ge:H and a-Si:H, respectively).

Finally, preliminary results indicate that the sub-gap absorption spectra were imperceptibly affected by illumination with unfilered light from a quartz halogen lamp (~1 W/cm^2 for 1.5 hrs.). The implication of this result is that unlike the case of a-Si:H, intense illumination is much less efficient in creating defects in a-Ge:H.

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