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THE DEPENDENCE OF RECOMBINATION KINETICS ON PHOTOEXCITATION DENSITY IN a-Si:H

D.R. Wake and N.M. Amer

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THE DEPENDENCE OF RECOMBINATION KINETICS ON PHOTOEXCITATION DENSITY IN a-Si:H

Douglas R. WAKE and Nabil M. AMER

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

Using pulsed excitation we observe a strong correlation between the recombination kinetics transition (monomolecular-to-bimolecular) and the optical absorption exponential (Urbach) edge. This correlation is observed over a wide range of Si dangling bond defect density in undoped, singly doped and compensated material. The results show that deep gap-states do not determine the excitation density at which the transition occurs. An important implication of these results is that deep gap-states do not play a major role in early recombination in a-Si:H.

1. INTRODUCTION

To evaluate the relative importance of the various centers which may be involved in the process of carrier recombination, we have investigated the effects of defects and dopants on the monomolecular-to-bimolecular transition in the recombination kinetics of a-Si:H using pulsed excitation. For this transition to be observed, the photoexcitation carrier density should exceed that which existed in the steady-state, prior to the pulse. An additional requirement is that the recombination time τ must be less than the duration of the excitation pulse. By combining nanosecond pulse excitation and the technique of photoinduced absorption we show that early recombination in a-Si:H is strongly related to the width of the exponential absorption (Urbach) edge E_o; thus ruling out the possibility that Si dangling bonds play an important role in early recombination.

2. RESULTS AND DISCUSSION

Photoexcitation was done with 2.2 eV, 4 nSec wide, 1μJ pulses. Details of the photoinduced absorption measurement have been published earlier.[1] The a-Si:H films were deposited by rf glow discharge technique.[2] Sample temperature was 10°K.

Fig. (1) is a plot of the critical excitation density (i.e., the density at which the mono-to-bimolecular transition occurs) as a function of the width of the exponential absorption edge. The undoped samples in this study covered a range of Si dangling bond defect density from $\sim 3\times10^{15}/cm^3$ at ~50 meV to

~$10^{18}/cm^3$ at ~85 meV. Over this range, the critical excitation density shifts by approximately an order of magnitude. Plotted on the same graph are a 10^{-4} boron-doped sample whose gap-states are vacant, and a 10^{-3} phosphorus-doped sample whose deep gap-states are doubly occupied due to the position of the Fermi level in the gap. Also shown are two compensated samples with Si dangling bond defect density of 10^{16} and $10^{17}/cm^3$.

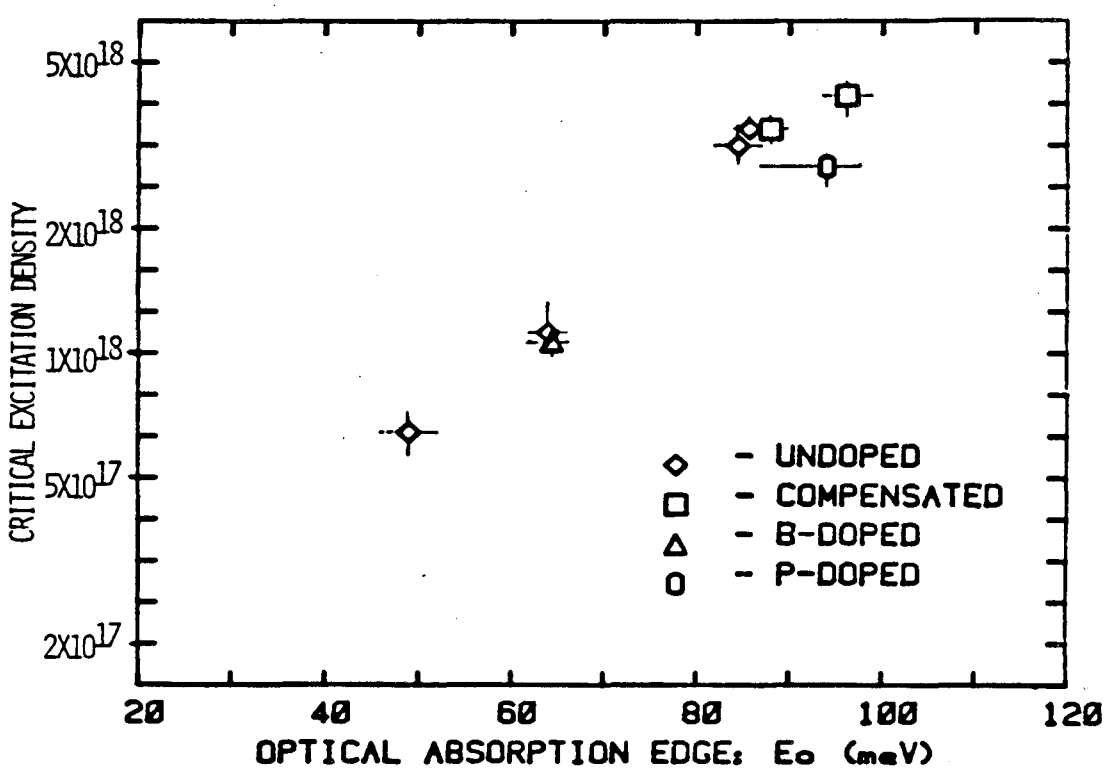

FIGURE 1
The Critical Transition Density Dependence on E_o.

Despite these disparate gap-state densities and occupancy factors, the data from these varied materials show a strong correlation between the critical excitation density and the width of the exponential bandtail which reflects the extent of structural disorder in the material. A significant consequence of the result is that deep gap-states do not play a major role in early recombination in a-Si:H.

To explain qualitatively the results presented here, one can invoke the concept of multiple trapping.[3,4] The recombination time can be written as[3]

$$\log \nu\tau = (E_o/k_B) \log(b_t N_t / b_r N_r)^{1/T}$$

where k_B is the Boltzman factor, ν is the attempt-to-escape frequency, N_t is the total bandtail trap density, b_t is their capture coefficient, N_r is the total number of possible recombination centers, b_r is their capture coefficient, and T is the temperature. This relationship shows a recombination time dependent both on the exponential edge slope E_o and on the total bandtail trap density N_t. Preliminary numerical modeling using the above equation yields qualitative agreement with the observed experimental results. Further work is in progress.

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