

XVII. ELECTRONIC PROPERTIES OF CHARGED CENTERS IN SiO_2 -LIKE GLASSES

Academic Research Staff

Prof. M.A. Kastner

Graduate Students

C.M. Gee

Joint Services Electronics Program (Contract DAAG29-78-C-0020)

Marc A. Kastner

Defects in amorphous (a-) SiO_2 are thought to result in deleterious optical and electronic effects. They may be responsible for limiting the transmission of optical fibers; they may be the origin surface states at Si- SiO_2 interfaces which trap charge carriers; they probably cause potential fluctuations which scatter mobile carriers moving near the Si- SiO_2 interface. Both of the latter effects seriously limit the performance of MOS devices.

A wide variety of techniques has been employed to study the defects in a- SiO_2 , and a great deal is known about them. However, the electronic structure and properties of the intrinsic defects are not yet well established. On the other hand, much progress has been made in developing detailed models for intrinsic defects in narrower band gap chalcogenide glasses (e.g., Se, As_2S_3 , As_xTe_y , etc.). The models have been successful in explaining Fermi-level pinning in the diamagnetic ground state and a wide variety of excited-state properties. The model of Kastner, Adler, and Fritzsche strongly emphasizes that the nature of the defects is a result of the special chemical bonding in materials containing two-fold-coordinated group VI elements. Therefore, it was proposed that defects similar to those in sulfides, selenides, and tellurides would be present in oxide glasses as well.

The most valuable probe of defects in semiconducting glasses has been photoluminescence (PL). The large PL Stokes shift and linewidth provided evidence for the strong electron-phonon coupling necessary to explain the effective attraction between electrons (Anderson's effective negative correlation energy). We therefore undertook a program solely under JSEP funding to study PL in a- SiO_2 .

(XVII. ELECTRONIC PROPERTIES OF CHARGED CENTERS IN SiO₂-LIKE GLASSES)

This program has recently had its first success. We were the first to observe intrinsic photoluminescence in a-SiO₂. The results have just been published [Phys. Rev. Letters 42, 1765 (1979)]. Although some features of the PL are different from those in sulfide and selenide glasses, these differences are quantitative rather than qualitative. We found that the PL spectra of SiO₂ and other glasses scale with band gap. Neutron irradiation increases the PL intensity and increases the optical absorption in the excited band to levels higher than could arise from impurities showing that the luminescence centers are intrinsic defects. The scaling of the PL and PLE spectra with band gap is strong evidence that the intrinsic defects in SiO₂ have structure similar to those in other chalcogenide glasses.

A second remarkable scaling was also discovered. The exponential decrease of PL quantum efficiency with temperature for all chalcogenide glasses indicates that the activation energies Δ for nonradiative processes must have a distribution of the form

$$g(\Delta) = e^{-\Delta/kT_0/kT_0}.$$

The spread of activation energies kT_0 is found to be proportional to the glass transition temperature T_g . Thus when temperature is normalized to T_g , the temperature dependence of the quantum efficiencies of different glasses superpose. Experiments are now under way to measure time-resolved PL spectra using a pulsed F₂ laser (10-nsec pulse, 1 MW, 1575 Å) as the excitation source.