STUDIES ON THE PHOTOINDUCED ELECTRONIC AND DIELECTRIC PROCESSES IN INORGANIC PHOTOCONDUCTING SYSTEMS.

BY

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PREFACE

The changes brought about in the electrical properties of semiconductors under the action of radiations form the basis of many opto-electronic devices. Much of the work in this area has been on single crystals. However, due to the ease and economy in the fabrication technique of large area opto-electronic devices, the photoconducting binder layer systems have gained importance in recent years. An understanding of the electronic and dielectric processes of these composite systems becomes necessary for their effective technological applications, as the single crystal data is not always extendable to binder layer systems. The present thesis is devoted to this cause.

In the first chapter, the basic electronic processes taking place in a photoconductor are discussed. A brief review of available literature on the various photoinduced effects is also given.

Chapter II describes the design and fabrication of experimental set up employed in the present studies. It also outlines the preparation techniques of composite binder layers of ZnO, HgI_2 and CdS photoconducting pigments in polystyrene or in silicone resin binder. Details of the photoconductivity, photoelectret, thermally stimulated current, photodielectric effect and electrophotographic measurements are also included.

The study of the dependence of the dark and photocurrent on electric field, illumination, temperature and time is very effective in evaluating the photoconductor performance in opto-electronic devices. Chapter III deals with these aspects.

In Chapter IV, the charge carrier trapping is analysed using the photoelectret technique. The dependence of the dark depolarization current and photoelectret charge on voltage, time of polarization, temperature and intensity of illumination are given.

The thermally stimulated depolarization current analyses of the trapping and recombination kinetics in ZnO and HgI_2:CdS binder layers are presented in Chapter V. These studies have enabled the evaluation of the trap depth, capture cross section and attempt-to-escape frequency associated with prominent trapping centres.

Chapter VI contains a theory proposed for the photodielectric effect in real photoconductors, which takes into account the charge carrier trapping in addition to other parameters. The theoretical predictions are experimentally verified in the binder layers of ZnO and HgI_2.

In Chapter VII, a correlation between the photoconductivity, photoelectret and photodielectric processes has been established from the simultaneous analysis of their spectral, temperature and rise and decay characteristics.

Chapter VIII deals with the electrophotographic discharge studies on ZnO:HgI_2-silicone resin layers of various compositions which leads to the evaluation of the relative spectral sensitivity. Other electrophotographic parameters such as, acceptance potential and contrast potential, which enable the selection of photoconducting systems for the electrophotographic applications, are also discussed.

A brief summary of the results of the various studies on the electronic and dielectric processes in the inorganic photoconducting systems is presented in Chapter IX.

Part of the results presented in the thesis have also resulted in the following research publications:

1. Photoinduced A.C. impedance measurements in HgI_2 binder layers;
   Phys. Stat. Sol.(a), 33, K151 (1976).

2. A comparative study of photoconductivity, photoelectret and photodielectric results in HgI_2:CdS binder layers;
   Jap. J. Appl. Phys., 15, 803 (1976).

3. Investigations of the photoelectret and photodielectric effects in HgI_2:CdS system;
   presented in 146th meeting of the Electrochemical Society held in New York (December 1974).

4. Photodielectric effect in HgI_2:CdS system;
   Ind. J. Pure & Appl. Phys., 14, 826 (1976).

5. Study of polymer crosslinking by thermally stimulated current;
   Polymer, 17, 921 (1976).

6. Photodielectric effect in photoconductors;
   Phys. Stat. Sol.(a), 37, 491 (1976).

7. TSC studies in ZnO photoelectrets;
   communicated.

8. Determination of recombination and trapping kinetics in ZnO photoelectret
   communicated.

9. Non-isothermal relaxation in ZnO photoelectrets;
   Phys. Stat. Sol.(a), 38, K73 (1976).

10. Thermally stimulated current reversals in ZnO photoelectrets; Phys. Letts., 58A, 474 (1976).

11. Thermo-photoelectret effect in HgI_2 binder layers; communicated.

12. Non-isothermal decay in normal and photocrosslinked PVCn electrets; accepted for publication in J. Electrochem. Soc.

ABSTRACT

The charge carrier generation, trapping and recombination mechanisms in inorganic photoconducting binder layers have been studied by photoconductivity, photoelectret, thermally stimulated current (TSC), photodielectric effect (PDE) and electrophotographic techniques. The binder type photoconductors were prepared by dispersing ZnO, HgI_2, CdS, HgI_2:CdS and ZnO:HgI_2 pigments in 40% by weight of polystyrene or silicone resin.

The non-linear photocurrents in ZnO-polystyrene systems yielded a trap density of $\backsim 10^{13}$ cm^{-3} from space charge limited current (SCLC) analysis. The photoelectret and TSC studies also yielded a density of traps approximately 10^{13} cm^{-3}. The spectral maximum obtained from photoconductivity, photodielectric effect and electrophotographic studies occurs at $\simeq$ 400 nm in ZnO samples. In the case of HgI_2-polystyrene binder system, the spectral maximum occurs at approximately 660 nm in the PDE and electrophotographic studies. The spectral sensitivity of 50:50 ratio of ZnO:HgI_2-silicone resin layer has been found to be maximum among other compositions and is about four times greater than those in pure ZnO and HgI_2 binder layers.

The photoresponse time (τ_r) in ZnO-polystyrene sample obeys $\tau_r \propto I^{-0.8}$ relation, where I represents the intensity of illumination. The photocurrent is found to vary linearly with I, which suggests that monomolecular recombination predominates in ZnO sample. The thermally stimulated current (TSC) analysis also supports this view. The photocurrent, $i_{ph} \propto I^{0.7}$ dependence in HgI_2 and CdS samples call for an

exponential trap distribution and the TSC analysis shows bimolecular recombination in HgI_2:CdS binder system.

The PDE theory, which includes the effect of trapping, has been developed and verified in ZnO and HgI_2 samples. This also enables the estimation of trap-to free carrier-density ratio $\backsim 10^4$ in ZnO sample, from the PDE measurements. Using the above theory, Debye lengths of the order of 3×10^{-3}cm for HgI_2 sample and 1.35×10^{-3}cm for ZnO sample have been obtained.

The temperature dependence of the photoresponse time and the photoelectret charge, and TSC analysis give a trap depth approximately 0.4 eV in negative electrode illumination, and 1.17 eV in the positive electrode illumination for ZnO sample. The capture cross section $\backsim 10^{-22}cm^2$ and attempt-to-escape frequency $\backsim 10^4 sec^{-1}$ have also been found to be associated with trapping processes in ZnO samples.

The 50:50 ratio of ZnO and HgI_2 pigments in silicone resin have been found to be suitable for electrophotographic coatings and other large area opto-electronic devices.

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