THE RADIOThERMOLUMINESCENCE
OF (ZnS : CdS : Ag : Ni : Co) PHOSPHORS
IRRADIATED WITH BETA-RAYS

M. S. ELMANHARAWY
Physics Unit, The Cancer Institute, Cairo University, Cairo, Egypt

Z. E. A. MOSTAFA
Electron Microscopy Unit, National Research Centre, Cairo, Egypt

The radiothermoluminescence characteristics have been studied for a number of (ZnS : CdS : Ag : Ni : Co) phosphors, with various cobalt impurity contents, after exposure to $^{90}$Sr beta-rays at room temperature. Thermoluminescent spectra show a peak wavelength of 7000 Å, which remains unchanged with increase in cobalt concentration. Thermoluminescence curves exhibit a single well-defined peak appearing at temperatures far above room temperature. This peak shifts to lower temperatures with increasing cobalt content. The relation between thermoluminescence response and dose is linear over the dose range of 1 to 500 rads. Thermoluminescence measurements made after storing the irradiated phosphor for 48 hours in dark have revealed an information loss of 4% over this storage period. The radiothermoluminescence characteristics, storage capacity and storage stability of these sulphide phosphors compete reasonably with those of lithium fluoride over the dose range of 1 rad to 500 rads.

INTRODUCTION

When impurity-activated zinc sulphide type phosphors are exposed to ionizing radiation, electrons are ejected from both the valence band and the activator centres into the conduction band. Vacancies, crystal imperfections and other impurity centres, if present, can act as trapping states for the freed electrons. Such traps are usually situated, according to their energy depths, beneath the conduction band. If the traps are sufficiently deep, they are generally capable of storing the electrons very efficiently. A heat treatment can liberate the trapped electrons, if sufficient thermal energy is provided to surmount the potential barrier of the trapping state. The freed electrons can then recombine with empty activator centres, via the conduction band. The emitted light, measured as a function of temperature, gives peaks at temperatures corresponding to the energy depths of the traps in the irradiated phosphor.

Phosphors of the zinc sulphide class are used for dosimetry purposes, but their application has been limited to dose rate measurements using their photoconduction characteristics [1]. Few attempts have been made, so far, to investigate their radiothermoluminescence characteristics. This is because their thermoluminescence curves exhibit several peaks which are not usually well separated and appear at temperatures far below room temperature.

The radiothermoluminescence of \((\text{ZnS : CdS : Ag : Ni : Co})\) phosphors...

However, in a recent study [2], experiments led to the preparation of some phosphors belonging to this class which showed thermoluminescence peaks at temperatures far above that of the laboratory. The doping of \((\text{ZnS : CdS : Ag})\) phosphor with nickel impurity gave rise to deep trapping states with an energy depth of 0.78 eV. The resulting thermal glow peak appeared at temperatures much higher than room temperature. When a number of such phosphors with various host matrix lattice compositions and nickel impurity concentrations were exposed to \(^{60}\text{Co}\) gamma-rays at room temperature, a single thermoluminescence peak was found [3]. This peak shifted gradually to lower temperatures when either the cadmium sulphide content of the matrix lattice or the nickel impurity concentration was increased. The thermoluminescence response — expressed as the area under the glow curve — was a reasonably linear function of dose over the exposure range of 1 R up to at least 200 R, though at higher exposure levels of \(10^3\) R and above saturation of the traps occurred and the relation was no longer linear. However, reproducibility, storage stability and storage capacity of the phosphors were satisfactory.

Further doping of \((\text{ZnS : CdS : Ag : Ni})\) phosphors with cobalt impurity resulted in new phosphors with much deeper trapping states (energy depth of 1.09 eV) than those produced by nickel doping alone. In addition, the original thermal glow peak (0.78 eV) found for \((\text{ZnS : CdS : Ag : Ni})\) phosphors was observed to shift to below room temperature on doping with cobalt. The formation of the very deep trapping states in \((\text{ZnS : CdS : Ag : Ni : Co})\) phosphors has been attributed to an association phenomenon between the various impurity centres present [4].

The present paper reports attempts made to study the radiothermoluminescence characteristics of these new phosphors. Irradiation was performed with beta-rays from a Strontium-90 source having a surface dose rate of 16 rad/min. In such case, the phosphor is exposed to both the 0.54 MeV beta-rays as well as the 2.27 MeV betas from Yttrium-90 which is in equilibrium with \(^{90}\text{Sr}\). A commercial LiF powder was also irradiated in the same way; the merits of LiF for routine dosimetric work have been pointed out by several authors [5]. It seemed interesting to compare the results obtained for the sulphide phosphors with this well-known and successful thermoluminescent system.

**MATERIALS AND EXPERIMENTAL METHODS**

Studies were made on a series of \((\text{ZnS : CdS : Ag : Ni : Co})\) powder phosphors, in which the concentration of cobalt dopant varied from 0.00013% to 0.013%. All phosphors had a host matrix ZnS : CdS ratio of 41% : 59%. The choice of this ratio was based on results of previous investigations, where the ratio of 41% ZnS : 59% CdS was found to be the threshold value for bringing the thermoluminescence peak due to deep trapping states to temperatures low enough to make its detection by direct thermoluminescence measurements feasible [2]. In all phosphors, both the