TEMPERATURE DEPENDENCE OF SECONDARY PEAK OF ELECTROLUMINESCENCE OF ZnS—Cu

Karel Pátek
Institute of Physics, Czechoslovak Acad. Sci., Prague

The temperature and frequency dependences of the secondary peak of the brightness wave of electroluminescence were studied. The dependences found show a direct connection with the number and depth of the traps. The influence of a continuously increasing temperature on the secondary peak of electroluminescence of a sample, which has been irradiated beforehand, is found and a description given of a new method of determining trap depths and their number.

INTRODUCTION

If the electroluminescence of materials of the type of ZnS is excited by an alternating electric field, four peaks are usually found on the brightness wave of electroluminescence which are denoted primary and secondary and whose origin differs. While the primary peaks are produced by the direct action of the external electric field, the secondary peaks are explained by the action of polarization in the crystal. In both cases an important role is played by the traps in the crystal, the function of which, particularly in temperature and frequency dependence on the amplitude of the primary peak, was found to be decisive.

The temperature and frequency dependence of the secondary peaks was qualitatively studied by Haake [4], who also gave a survey of his own and earlier conceptions on the mechanism of formation of the secondary peak; according to him, the secondary maxima are caused by the recombination of the trapped electrons when freed by heat when polarization acts in the crystal. From the condition (explained in greater detail in part 4) that the electrons must be freed at a suitable moment of the voltage cycle, we arrive at the important conclusion that the shape of the secondary peak depends primarily on the parameter \( y = f \cdot \exp (E/kT) \), where \( f \) is the frequency of the electric field, \( E \) the trap depth during electroluminescence, \( k \) the Boltzmann constant, \( T \) the absolute temperature. Thus if for several frequencies we find the temperatures at which the secondary peak has the same appearance and plot the corresponding temperatures and frequencies in the graph of \( \log f \times 1/T \), we can determine the activation energy \( E \) from the slope of this graph. According to the measurements in Haake's paper this energy \( E \) is identical to the trap depth found from glow measurements.

The task of the present paper is to quantitatively study in greater detail the temperature and frequency dependences of the amplitude and phase of the secondary peak. In the second part we study the behaviour of secondary peaks for a continuously increasing temperature.
Temperature Dependence of Secondary Peak of Electroluminescence of ZnS-Cu

1. EXPERIMENTAL ARRANGEMENT

Measurement was carried out on powdered electroluminescent phosphors of different origin and having different characteristics so as to eliminate the influence of special conditions of preparation of any one phosphor. This was necessary due to the fact that the preparation of electroluminescent phosphors is still barely defined physically. Three samples were chosen as representatives of different groups and were investigated in particularly great detail: sample T, prepared in FIAN, Moscow, activated by $10^{-3}\text{Cu}$, annealed in $H_2S$ at $1200^\circ C$, sample V, prepared under similar conditions in the Research Institute of Vacuum Electronics, Prague, and sample $1064$, prepared by annealing to $850^\circ C$ in air, also activated by $10^{-3}\text{Cu}$, but also containing traces of iron, in the Institute of Physics, Czechoslovak Academy of Sciences.

As before [5], the samples of phosphor were arranged into layers 0.1 to 0.15 mm thick, containing around 30% (volume) ZnS in silicon-phthalate as a dielectric. The electric field exciting electroluminescence was obtained from a high voltage power amplifier ($U_a = 10\text{kV}$, frequency band up to 15 kHz) and applied to the sample located between two electrodes — a metallic electrode, thermally connected with the mass of a temperature chamber, permitting a change in temperature defined by the velocity from $-200^\circ C$ to $-100^\circ C$, and a transparent electrode, formed by a conducting cover of stannic oxide on glass (metallic conductivity, increasing with decrease in temperature).

The temperature chamber enabled the sample to be irradiated with ultraviolet light (discharge tube HBO 107 with metallic interference filter 364 m\(\mu\)) and contained a photomultiplier recording the electroluminescence brightness. A Křižik oscillograph was used for recording, having been adapted so as to have three channels (recording of voltage; electroluminescence; brightness and voltage zero level). The exciting voltage from 500 to 900 V was both sinusoidal or had the form of rectangular pulses of alternating polarity.

2. TEMPERATURE DEPENDENCE OF SECONDARY PEAK

The qualitative behaviour of the secondary peak during varying temperature and during excitation by a sinusoidal voltage has already been described [5] and our measurements confirm this dependence: at sufficiently high temperature the secondary peak is very small or cannot be ascertained, it appears at a lower temperature; with decreasing temperature the secondary peak gets further away from the preceding primary and approaches the following primary; at the same temperature but higher frequency the secondary peak is displaced towards the following primary (see Fig. 1). This dependence was used by Haake [4] to determine the trap depth: he determined the temperatures, when the secondary peak appears most isolated from the primary waves surrounding it, for several frequencies. The temperatures and frequencies thus coordinated gave a slope equal to $E/k$ in the graph of $\log f \times 1/T$.

Since the state “when the secondary peak appears most isolated” is too qualitative a condition, two conditions were used in this paper to define the temperature corresponding to a given frequency of the electric field: the con-