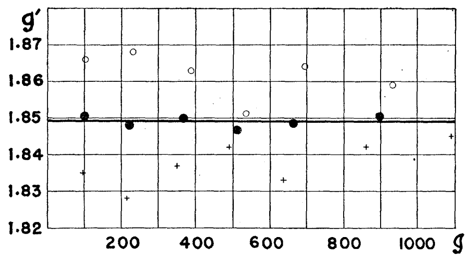

FIG. 1. Plot of g' *vs* intensity of magnetization for cobalt. Open circles are values obtained for General Motors rod. Crosses are values obtained for International Nickel Company rod. Solid circles obtained by averaging, for each value of the magnetizing current used, the g' and $\mathcal{J}$ values for the two rods.

cobalt specimen, the average value for g' is 1.862 ± 0.005. The magnetomechanical measurement of the gyromagnetic ratio of cobalt has always been more difficult than similar measurements for other metals. However, the precision of this work is such that the 1.4% difference between the g' values for these two rods cannot be accounted for on the basis of accidental error.

It will be noted by referring to reference 2 that each of these rods had impurity contents of over 1%. It is considered probable that difference in this impurity content is the cause of the 1.4% difference in the g' values. If this is correct, g' values for slightly impure samples of cobalt could be considerably different from the true value for the pure metal. In this case the true g' value for cobalt could only be obtained with samples of a much higher degree of purity than those used in these experiments.

CONCLUSIONS

The results of this series of experiments on cobalt show that the gyromagnetic ratio of this metal is independent of the intensity of magnetization, within the range of intensity values used. The results also indicate that the true value of g' for cobalt could only be found by using specimens of high purity. It is hoped that in the future opportunity may present itself to investigate further the effect of small amounts of impurity on the gyromagnetic ratio of this metal.

The author wishes to thank the management of the General Motors Research Staff for having had the opportunity of making the series of measurements on gyromagnetic ratios which have been reported in this and in other recent papers.

PHYSICAL REVIEW VOLUME 104, NUMBER 6 DECEMBER 15, 1956

High-Frequency-Induced Electroluminescence in ZnS

G. G. HARMAN AND R. L. RAYBOLD
Electron Tube Laboratory, National Bureau of Standards, Washington, D. C.
(Received August 29, 1956)

A brief presentation of data is given for electroluminescent measurements made on several ZnS crystals over a frequency range of 1 cps to 370 Mc/sec. Electroluminescent relaxation becomes apparent in the order of 10^5-10^6 cps. A simple exponential equation, $I=A(V-V_0)^B$, was found to fit the time-average electroluminescent intensity *vs* voltage over four decades of intensity.

ELECTROLUMINESCENCE in ZnS has been measured with excitation frequencies ranging from 1.0 cps to 370 Mc/sec. Thin, flat, conductive crystals, about 2 mm on a side, were used. The experimental apparatus is described elsewhere.[1] Measurements of the voltage threshold of time-average light output as a function of frequency are shown in Fig. 1. It should be pointed out that threshold data are a reciprocal function of the usual frequency-dependent data obtained at constant voltage. The former may be regarded as more fundamental for wide frequency excitation, since high excitation, particularly at high frequencies, produces considerable heating. This in turn may produce inconsistent or misleading results.[2,3] At no time during the threshold measurements did the temperature rise exceed 2°C above the constant ambient, as measured by a thermocouple attached to the crystal body. The data for single crystals are approximated by a series of straight lines on log-log paper. This method of presentation, however, was not used since it resulted in confusion due to vertical compression. At very low frequencies the single-crystal curves approach the dc threshold values and there is some correlation between the low-intensity luminescent decay time and low-frequency flattening of the curves. This decay time was not significantly different following dc or high-frequency excitation. It is apparent that electroluminescent relaxation processes become significant at about 10^5-10^6 cps.

In addition, the time-average light output *vs* voltage has been measured at dc and at high frequencies over a

[1] G. G. Harman (to be published).
[2] G. F. Alfrey and J. B. Taylor, Brit. J. Appl. Phys., Suppl. No. 4, S44 (1955).
[3] C. H. Haake, Phys. Rev. **101**, 490 (1955).

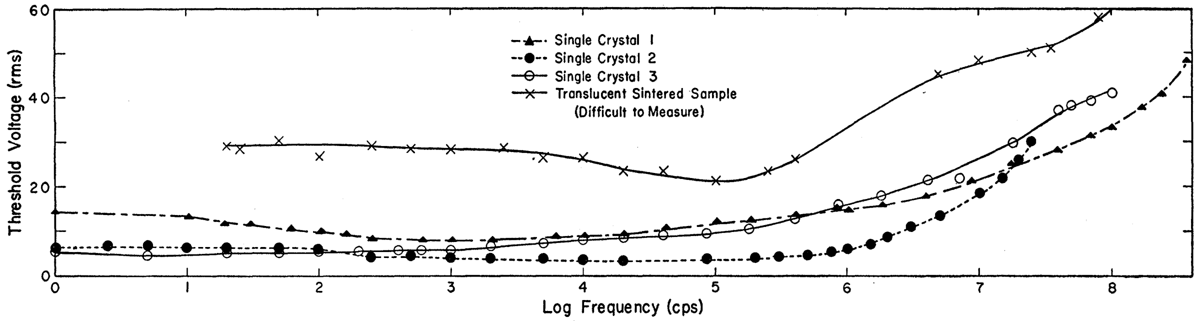

FIG. 1. Voltage necessary to produce threshold electroluminescence (V_0) *vs* logarithm of frequency for four ZnS samples.

range of four decades of light intensity (Fig. 2). The various experimental curves fit the simple equation

$$I = A(V - V_0)^B, \quad (1)$$

where I is photomultiplier current, A is a constant for a given curve and is dependent on the frequency, V is the applied voltage and V_0 is the voltage necessary to produce the threshold of luminescence. The exponent, B, for various crystals at different frequencies ranged from 2.5 to 3.7, with the lower figure being associated with dc and low frequencies. Often a slight downward adjustment of the measured V_0 is necessary to improve the curve fit. This is readily explained by the fact that the photomultiplier is not sensitive enough to measure the true threshold. The adjustment seldom exceeds 15% of the measured threshold values. The data fit the equation to within the over-all accuracy of measurement, which is about 7%. It is interesting that this relationship is the same as was found for $BaTiO_3$, $SrTiO_3$, TiO_2,[4] and more recently for $KNbO_3$. Light emission and other characteristics of these materials will be reported in detail at a later date.

Previous tests on $BaTiO_3$ and SiC (unpublished) have indicated that it is possible to bias the crystals to the threshold of luminescence with dc or rf and then to produce relatively large values of luminescence by superposing a very small voltage of widely separated frequency. Three out of four single-crystal ZnS samples required that each different frequency reach its own independent threshold before any change in luminescent intensity was noted. However, at considerably higher than threshold intensities, there was some superlinear interaction. The fourth single-crystal ZnS sample showed some interaction around the threshold but this was far less than observed in the other types of crystals.

In the future it is planned to study more samples at high frequencies to determine the effects of various activators and of superposed absorption edge irradiation. The measurements may be extended into the microwave region.

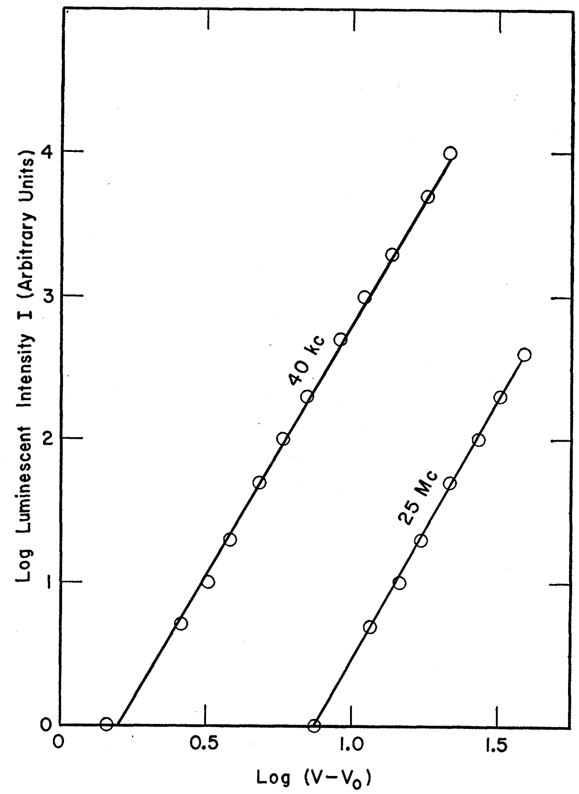

FIG. 2. Time-average electroluminescent intensity (I) *vs* voltage above the threshold ($V - V_0$) for one ZnS single crystal measured at two frequencies.

ACKNOWLEDGMENTS

The authors wish to thank Dr. Frank Matossi and Dr. Sol Nudelman for many valuable discussions and suggestions. The crystals were kindly supplied by Dr. A. Kremheller of Sylvania Laboratories.

[4] G. G. Harman, Bull. Am. Phys. Soc. Ser. II, 1, 112 (1956).