

FIG. 1. Thermoluminescence curve of potassium iodide starting from liquid oxygen temperature, after excitation by cathode-rays at 10 kv for five minutes. The temperature record No. I corresponds to the thermoluminescence curve. The dotted part of temperature record No. II gives the temperature range at which coloration disappears on heating from 91°K after bombardment.

bluish green in color, presumably as a result of strong *F*-center absorption in the red region. It has been found that if the sample after bombardment is heated from liquid oxygen temperature, the coloration suddenly disappears at about 235°K, which is also the maximum glow temperature of the last luminescent trap. The present case is similar to that observed by Pringsheim<sup>1</sup> in the case of LiF, at -135°C, where an absorption band at 3200Å disappears with strong emission in the blue region. Further, it has been seen here that the most favorable temperature for the bluish green coloration of potassium iodide is about 200°K, and this is also the temperature at which bombardment and subsequent thermoluminescence gives large amount of stored energy from the trap released at 235°K. If the heating is begun from 200°K after bleaching the coloration with visible light, the output of the peak decreases. On the other hand, if irradiation with visible light is done at liquid oxygen temperature, then the shallow traps are reduced in relative intensity while the trap with maximum glow at 235°K is enhanced (see Fig. 2). This suggests the destruction of shallow traps while the one at 235°K increases in population.

In accordance with the observation of Pringsheim,<sup>2</sup> it has been found that the weak coloration produced at room temperature is more stable than that produced at liquid oxygen temperature. When colored by bombardment at room temperature, it dis-

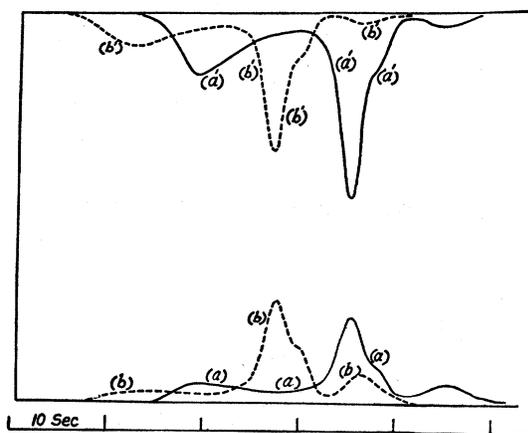


FIG. 2. The lower curves give the thermoluminescence records in which the sample (KI) after bombardment was irradiated with (a) total light and (b) red light from an Fe-arc. Obviously it shows quenching of shallow traps and enhancement of the last 235°K trap. The upper curves are simultaneous records for comparison from the portion of the sample which was protected from the arc light.

appears at about 160°C, and here too it is associated with a faint luminescence.

Similar phenomena have been observed in potassium chloride. On bombardment at liquid oxygen temperature it gets colored pink.<sup>3</sup> On heating, the color disappears in two stages, at about 200°K and 520°K. At first the pink color disappears, leaving a magenta coloration which dies out at the higher temperature. Both colors are destroyed with strong luminescence peaks. When cathode-ray bombardment is done at about room temperature, only the latter coloration is produced.

In sodium chloride considerable bombardment at liquid oxygen temperature produced a greenish yellow color. On heating, at about 165°K it became dark brown and this color disappeared at about 500°K. Both the colors give strong emissions when they are thermally destroyed. The emission in NaCl in the latter case is so strong that even in a normally illuminated room its blue light could be easily seen. In another experiment, the sample was bombarded at room temperature and left for eighteen hours. On heating the color again disappeared, with strong emission in the blue region.

Since *F*-centers are most easily and copiously produced, it appears that their destruction is intimately connected with a high temperature strong emission peak.

The author is thankful to Professor S. N. Bose, Khaira Professor of Physics, University College of Science, Calcutta, for his guidance and helpful interest in the work.

<sup>1</sup> P. Pringsheim and P. Yuster, *Phys. Rev.* **77**, 90 (1950).

<sup>2</sup> Delbecq, Pringsheim, and Yuster, *J. Chem. Phys.* **19**, 574 (1951).

<sup>3</sup> H. N. Bose, *Proc. Phys. Soc. (London)* (to be published).

### Temperature Dependence of the Line Half-Width of Ferromagnetic Resonance in Single Crystals of Zinc-Manganese Ferrite

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(Received October 29, 1951)

SINGLE crystals of nickel ferrite<sup>1</sup> and zinc manganese ferrite<sup>2</sup> were prepared by Galt, Yager, and others, and the *g*-factor, line half-width, anisotropy constant, and other physical properties were determined precisely at room temperature. According to their experimental results on the width of the resonance line at the

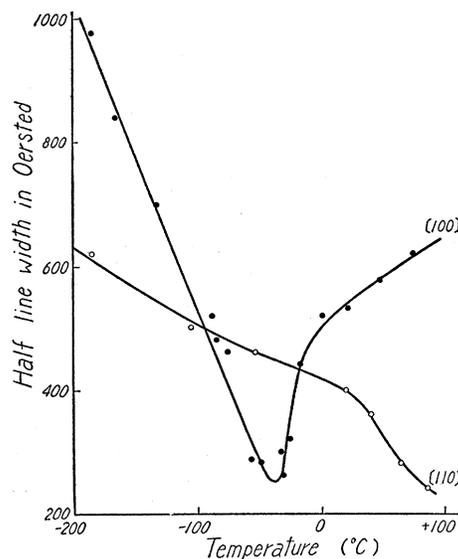


FIG. 1. Temperature dependence of the line half-width for a single crystal of  $\text{MnOZnO}_2\text{Fe}_2\text{O}_8$ .

frequency of 24,160 Mc, the variations in  $\Delta H$  with crystallographic direction were not large enough to be significant.<sup>2</sup> Recently, we have also succeeded in preparing by almost the same method<sup>1,2</sup> single crystals whose composition is approximately  $\text{ZnOMnO}_2\text{Fe}_2\text{O}_3$ . The resulting crystals formed regular octahedra, whose size was 0.6~0.8 mm on the edge. A cone was cut out whose base plane is (100) and ferromagnetic resonance measurements were made at a wavelength of 3.22 cm, with the [110] and [100] directions respectively parallel to the static field. From the experimental data, the line half-widths with crystallographic direction were determined at various temperatures, and considerable difference was found between the [100] and [110] directions.

The experimental procedure and method were given in previous papers.<sup>3,4</sup>

The half-widths were observed from liquid nitrogen temperature to the Curie point *ca* 110°C. All the measurements were made while warming the crystal from the temperature of liquid nitrogen at the rate of 0.5° per minute. The results obtained are shown graphically in Fig. 1; the ordinate gives the half-width in oersteds, and the abscissa gives the temperature in degrees centigrade; open circles denote the [110] direction, and solid circles the [100] direction. For the [100] direction,  $\Delta H$  decreases rapidly with rising temperature from -185°C up to *ca* -40°C; then it increases abruptly and afterwards increases slowly. On the other hand, in the case of the [110] direction,  $\Delta H$  always decreases continuously with rising temperature and finally vanishes near the Curie point.

The experiment was repeated on the other single crystal having the same composition, and the same tendency was always observed in the same temperature range.

Thus, it was confirmed that the value of  $\Delta H$  depends considerably on crystallographic direction and the variation of  $\Delta H$  with temperature is quite different for different crystallographic directions. At room temperature, the value of  $\Delta H$  is large compared to the result of Galt and his co-workers;<sup>2</sup> the reason for this seems to depend on the crystalline imperfection and the form of the specimen.

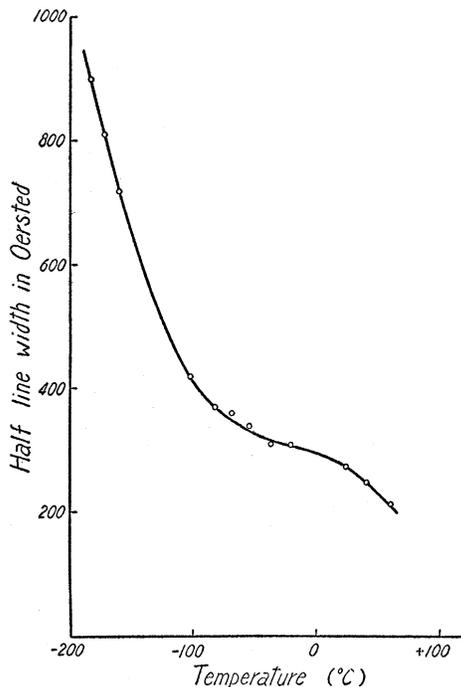


FIG. 2. Temperature dependence of the line half-width for a polycrystalline specimen of  $\text{MnOZnO}_2\text{Fe}_2\text{O}_3$ .

Next, we performed also a resonance experiment on a disk-formed polycrystalline specimen of  $\text{ZnOMnOFe}_2\text{O}_3$ , 4.5 mm in diameter and 0.22 mm in thickness, at low temperature and at the same wavelength. The temperature variation of the line half-width is shown in Fig. 2; in the range -95°C to -115°C in which the half-width begins to increase rapidly, double peaks were observed in the resonance curves, which are similar to those found recently by the authors in  $\text{MnOFe}_2\text{O}_3$ <sup>5</sup> and  $\text{NiOFe}_2\text{O}_3$ <sup>6</sup> at low temperature.

Therefore, the occurrence of double peaks seems to be intimately connected with the change of crystalline anisotropy of the sample at low temperature, as expected.

Experiments on a thin-disk-formed and a sphere-formed specimen of the single crystal are being planned.

Details of this work will be published in the Science Reports of the Research Institute of Tohoku University.

<sup>1</sup> Galt, Mathias, and Remeika, *Phys. Rev.* **79**, 391 (1950).

<sup>2</sup> Galt, Yager, Remeika, and Merritt, *Phys. Rev.* **81**, 470 (1951); Yager, Merritt, and Guillard, *Phys. Rev.* **81**, 477 (1951).

<sup>3</sup> Okamura, Torizuka, and Kojima, *Sci. Repts. Research Inst. Tohoku University* **2**, 663 (1950).

<sup>4</sup> Okamura, Torizuka, and Kojima, *Sci. Repts. Research Inst. Tohoku University* **3**, 209 (1951).

<sup>5</sup> T. Okamura and Y. Torizuka, *Phys. Rev.* **83**, 847 (1951).

<sup>6</sup> T. Okamura, *Nature* **168**, 162 (1951); T. Okamura and Y. Torizuka, *Sci. Repts. Research Inst. Tohoku University* **3**, 219 (1951).

## A Steady State Transient Technique in Nuclear Resonance

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(Received December 26, 1951)

THIS title heads two recent Letters to the Editor of this Review.<sup>1</sup> The authors do not seem to have noticed that some previous articles have already described the same effect and given its full theory.<sup>2,3</sup> We wish to draw attention to the fact that this phenomenon was discovered by the late Dr. Gooden.<sup>4</sup> We do not intend to review our previous theory, but will only give its new development concerning the measurement of  $T_2$  in liquids in the presence of field inhomogeneities larger than the mean value of the intramolecular field.

When  $T_2$  is larger than about  $10^{-3}$  sec a well-known transient phenomenon is observed.<sup>2,3</sup> The decay of the oscillations (Fig. 1) is determined by phase shifts produced by both the molecular field  $h$  and the inhomogeneities  $\delta = H_z - H_0$  of the magnetic field.

After resonance, the molecular field produces a phase shift  $\varphi(t) = \int_0^t \gamma h(t) dt$ , and we have to integrate over all the values of  $\varphi$ . These values are distributed according to a Gaussian probability function. The fact that the decay is described by the function  $\exp(-t/T_2)$  and not by  $\exp(-t^2/T_2)$  as it seems at first, is produced by the fact that  $\langle \varphi^2 \rangle_{AV}$  is related to  $\langle h^2 \rangle_{AV}$  not by  $\langle \varphi \rangle_{AV}$

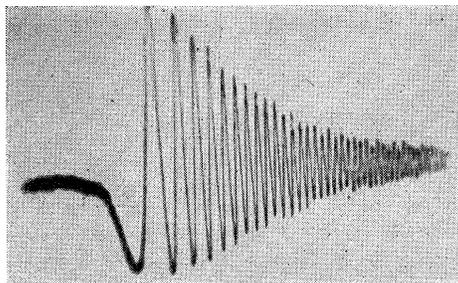


FIG. 1. Decay of oscillations for a Gaussian distribution of field inhomogeneities.