TRIBOTHERMOLUMINESCENCE

By R. E. Nyswander and Byron E. Cohn
Department of Physics, University of Denver

(Received August 22, 1930)

Abstract

Glass, certain crystals and frits are rendered thermoluminescent by the process of grinding, emitting light of very low intensity. The phenomenon is observed not only in samples of low purity but also in compounds prepared from chemically pure grade materials. Quantitative measurements of light intensity were made by means of a polarization photometer. The particles tested were graded in size by means of a set of screens ranging from 20 to 200 mesh. The results show that the quantity of emitted light depends upon the nature of the substance and the size of the particles, and diminishes slowly with the time after grinding. Common glass tubing crushed to various grain sizes emitted the maximum amount of light when the linear dimensions of the average mesh size fell between 0.015 cm and 0.025 cm respectively.

CERTAIN substances, when powdered, store up energy which is released by heat in the form of light of very low intensity. As in other types of thermoluminescence, the temperature of emission is below that of incandescence. Wiedemann[1] applied the term triboluminescence to the light given off when certain materials are rubbed or scratched and Levison[2] designated as tribophosphorescence the luminescence of more prolonged duration excited by rubbing. The term tribothermoluminescence has been given to the phenomenon under consideration which involves the process of grinding followed by the application of heat.

Tribothermoluminescence has been observed in crystals, glasses and frits. In all cases the material tested was first heated in an electric furnace to destroy any trace of thermoluminescence which might have been present, and then ground in a mortar and screened to the desired size. Tribothermoluminescence was observed in clear, colorless crystalline fluorite, and also in lithium borate which forms a white vitreous opaque mass (frit) when fused, as well as all samples of clear colorless glass tested with the exception of a specimen of chemically pure boric anhydride.

The energy of triboluminescence has been discussed by Imhof,[3] Trautz[4] and Schmidt.[5] One of these suggested explanations involves the recombination of electrons displaced by the process of rubbing, in the other the energy is the result of small electric sparks induced by differences of potential, the electrical doublet theory. In the case of tribothermoluminescence the latter

[1] E. Wiedemann, Wied. Ann. **34,** 446 (1888); Nature **27,** 181 (1889).
[2] W. Levison, Science **19,** 826 (1904).
[3] A. Imhof, Phys. Zeits. **18,** 78 (1917) and **20,** 131 (1919).
[4] M. Trautz, Ion **2,** 77.
[5] H. Schmidt, Phys. Zeits. **19,** 399 (1918).

theory does not seem directly applicable after the following test. The particles immediately after grinding were immersed in an electrolyte of dilute nitric acid which would allow the recombination of all electric charges which might result from the process of grinding. The glass was then washed with distilled water filtered and dried in the dark. After this treatment to remove all electric charges, the glass showed the usual thermoluminescence.

Ultraviolet light is very active in exciting the energy of the thermoluminescence in glass.[6] If ultraviolet light is emitted in the process of grinding, this might be the source of energy of the thermoluminescence of the glass particles. Accordingly, three similar samples of glass were tested in the following manner. The first was ground in a mortar in the usual way, i.e. in the presence of air. The second sample was ground under water then washed in distilled water and dried. The third sample was ground in a dark solution washed and dried as before. The presence of the water and the opaque solution would re-

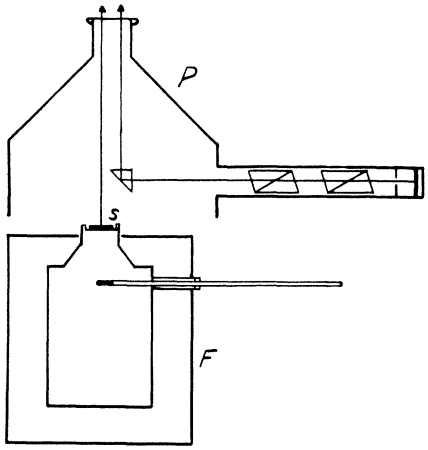

Fig. 1. Diagram of apparatus showing arrangement of polarization photometer and furnace.

duce through absorption the light radiated to the adjacent particles by the process of grinding. When these samples were tested for thermoluminescence the first emitted a much larger quantity of light than the second, and the second emitted more than the third, which gave out scarcely more than the threshold value.

All light measurements were made by means of a polarization photometer.[7] The usual form was modified to allow a larger angular contrast background, as shown in Fig. 1, in which *P* is the photometer, F the furnace and S the substance to be tested. The samples were heated in small brass cups with cavities 0.8 cm diameter and 0.4 cm deep, which were placed on top of the large brass post of the electric furnace. By means of a thermometer in the furnace it was possible to hold the temperature of the sample constant for any period. Light measurements were made at time intervals from the

[6] Nyswander and Cohn, J.O.S.A. **20,** 131 (1930).

[7] Nyswander and Lind, J.O.S.A., and R.S.I. **13,** 651 (1926).

beginning to the end of the period of luminescence. These light intensities were plotted as ordinates with the corresponding time intervals measured from the beginning of luminescence as abscissas. The total quantity of light emitted by the sample is proportional to the area under the curve. These areas were measured by means of a planimeter. All light measurements are expressed in terms of relative values.

The quantity of light emitted by the material was found to be dependent upon (1) the nature of the substance, (2) the size of the particles, (3) the time elapsed after the process of grinding. The effect of the nature of the material is brought out by the following measurements of the light given out by fused sodium borate glass as compared with zinc borate glass (45.5 percent zinc

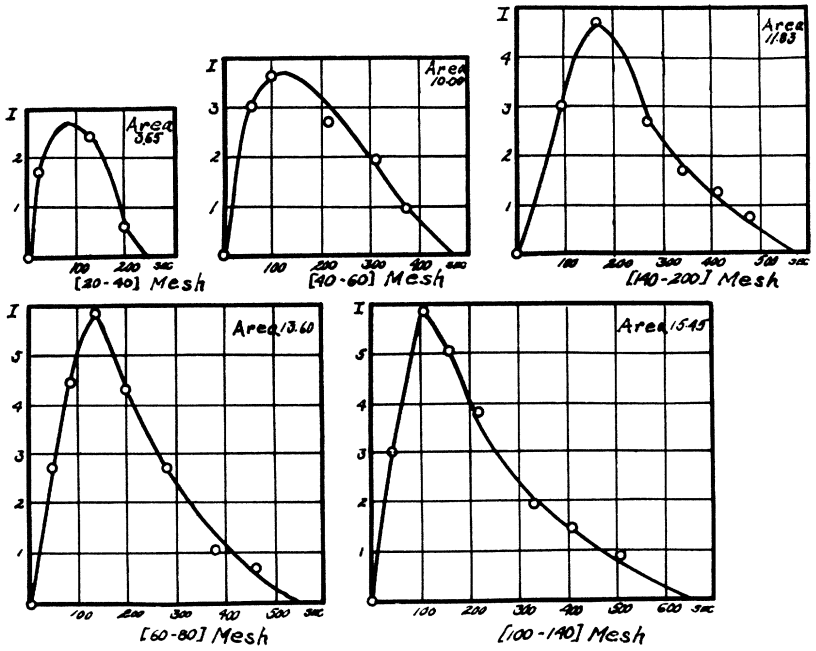

Fig. 2. Total quantities of light emitted by glass for various screen sizes.

oxide to 54.5 percent boric acid). The total quantities of emitted light in the two cases are 16.5 and 1.72 respectively. The two sets of measurements were made under similar conditions. The particles were sieved between 180 and 200 mesh screens, and the temperature of the furnace was 330°C. The results also show that chemically pure grade materials sometimes exhibit tribothermoluminescence.

To detemine the effect of grain size on the quantity of light emitted, the particles were separated into groups by means of a series of screens. To obtain the size of the screen openings, eight measurements were made on different parts of each screen by use of a comparator, and the mean value used. Ordinary soft glass tubing was heated to remove all traces of luminescence

and then ground in a porcelain mortar and sieved. The graded sizes were heated in the furnace held at 360°C and a series of intensity-time curves obtained and plotted as shown in Fig. 2. The areas of these curves were then used as ordinates with the mean of the two corresponding mesh openings as abscissas and plotted as shown in Fig. 3. Curve *A* represents the total light energy for the graded sizes two days after powdering, while *B* was determined 24 days after grinding. The difference between these two curves clearly

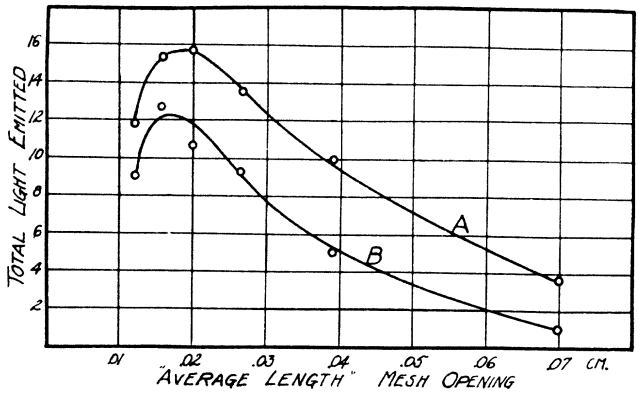

Fig. 3. Variation of emitted light as dependent upon grain size.

shows the decay of luminescence with time. The smaller the size of the particles the greater the amount of energy stored, however, the smaller the size of the particles the less the quantity of light which reaches the surface through a given thickness of the powdered material. These two factors would seem to determine the position of maximum light emission of the curves *A* and *B*. Tribothermoluminescence has been observed in glass of sizes less than 100 mesh one year after it had been powdered.