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Author
Petermann, Gunter.

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Günter Petermann

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ABSTRACT

The influence of an electric field on the photoluminescence of pressed ZnO pellets was investigated. A quenching of the luminescence intensity was found. Suggestions are made to improve the original luminescence intensity and use this effect in practical applications.

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Günter Petermann*

Laboratory of Chemical Biodynamics, Lawrence Berkeley Laboratory,

University of California, Berkeley, California 94720

The quenching of photoluminescence by an electric field (Dechène effect) has been observed for several inorganic[1-4] and, to the author's knowledge, for one organic (poly-N-vinylcarbazole)[5] material. The inorganic compounds are usually Zn and Cd sulfides, and the investigations have been performed on single crystals as well as on polycrystalline thin layers. The effect is explained in terms of a decrease in the electron density due to the extraction of charge carriers from the illuminated surface by the field.[4]

The electric field induced changes of zinc oxide luminescence have been observed by Filinski and Skettrup,[6] who have used this effect to distinguish between various types of exciton complexes at low temperatures. Those investigations were confined to the luminescence in the narrow (360 to 380 nm) spectral range near the absorption edge of ZnO. In addition to this blue emission, zinc oxide possesses a broad green emission band; the relative intensity of both bands is strongly dependent on the doping and on the preparation of the material.[7] The quenching of the green luminescence by an electric field and its relationship to the photocurrent has been reported in crystals of ZnO.[8] Since the energy efficiency of the green luminescence in ZnO can be rather large (approximately 20%)[9] and the observed effect is very pronounced (a few volts were sufficient to yield extinction of the luminescence of these crystals), the development of practical applications such as display devices seems to be feasible.

Single crystals of ZnO are rather difficult to obtain,[10] but the technology for preparing large areas of ZnO seems to be well established (Electrofax paper).[11] Therefore it was of interest to compare the findings made on single crystals of ZnO to thin layers of polycrystalline material. The most obvious method would have been to use ZnO paper in the experiments, especially since its ZnO coating shows a slight green luminescence under ultraviolet illumination. However, it was not practical to use the Electrofax paper because of the necessity of making electric contacts, and a different arrangement was subsequently chosen for the preliminary investigations.

Zinc carbonate was calcined in air at 1000°C to obtain the green fluorescing ZnO.[12] This material was pressed into pellets and contacted with a wire on one side into which Indium had been diffused by heating to 600°C to obtain an ohmic contact. The pellets were then mounted as electrodes in an electrochemical cell, using a 1 M KCl solution as the second contact. The luminescence was excited with a Xenon la p (wavelengths range: 310 to 390 nm) and monitored with a photomultiplier while a positive voltage of 12 volts was switched on and off to the pellet. Further experimental details have been described in Ref. 13, where the same arrangement was used.

The result of this experiment is shown in Fig. 1. The application of the positive voltage leads to a reduction (less than 1%) of the green luminescence intensity of the ZnO pellet. The time response is approximately equivalent to the time response of the recorder; as yet, no attempts have been made to measure the real response time.

The voltage necessary to achieve an effect is much higher for the polycrystalline thin layers than it is for the single crystals of ZnO,[8,13] and the effect itself is rather small. Even the original luminescence of the pellets is much smaller, which is probably due to pressure quenching[14] as a result of the preparation method. The change in the luminescence intensity when the voltage is applied seems to be restricted; this is in contrast to the large reduction of the luminescence intensity of the single crystals. However, the experiments have shown that the effect also exists in thin layers of polycrystalline ZnO. Different preparation methods for the ZnO and the electrodes (e.g., reductive treatment after calcining which increases the luminescence intensity[11] and sintering of the ZnO powder onto a suitable base) might result in properties equivalent to those of the single crystals and lead to practical applications.

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*Present address: Inst. f. Physik. Chemie, Universitaet Duesseldorf, 4 Duesseldorf, Germany.

FIGURE CAPTION

Fig. 1. Influence of an electric field on the photoluminescence of ZnO pellets.

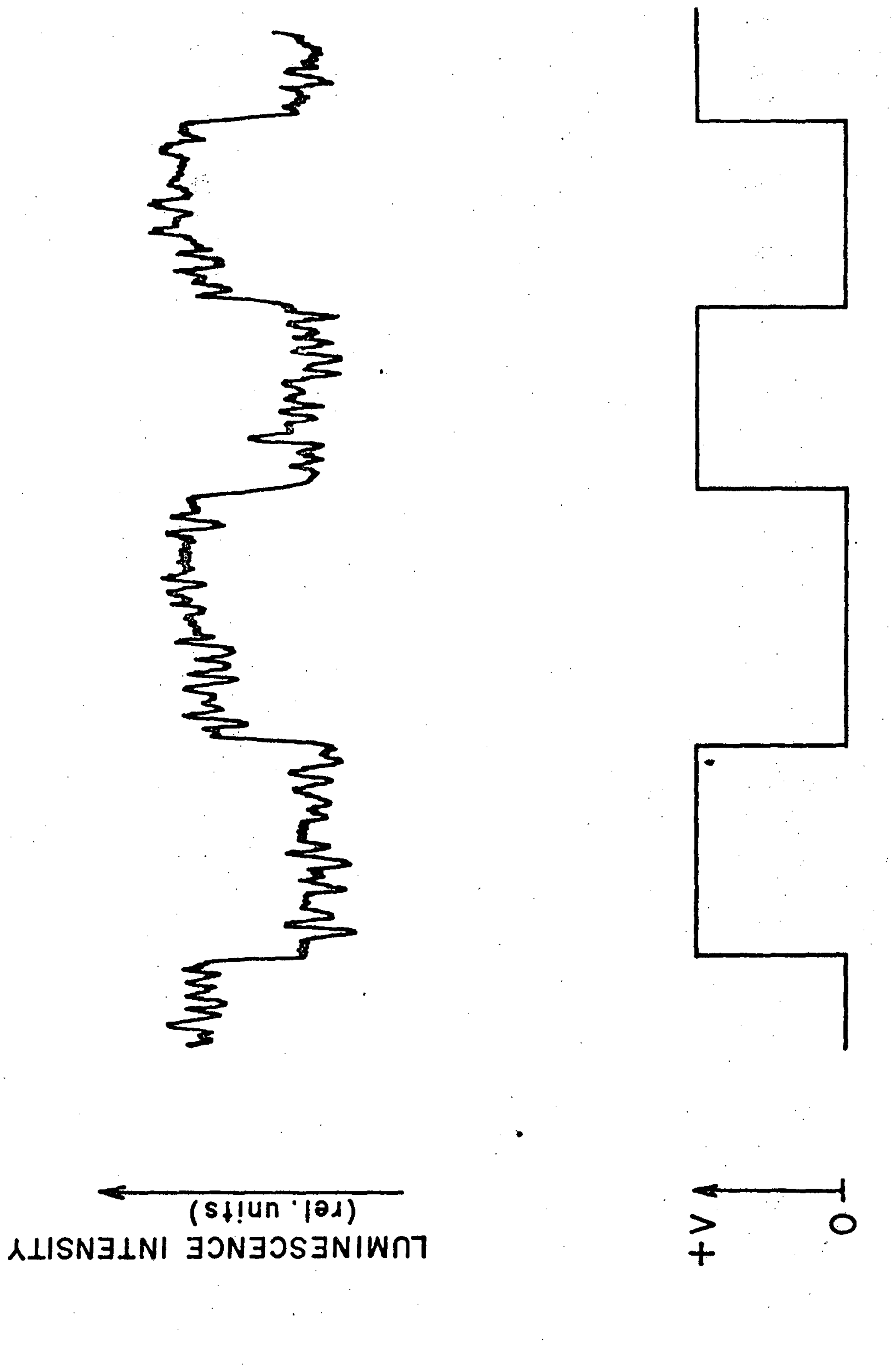

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Fig. 1