NEW PHENOMENA OF a.e. ELECTROLUMINESCENT LINES IN ZnS:Cu SINGLE CRYSTAL

Zuo-Chen YANG

Changchun Institute of Physics, Chinese Academy of Sciences, Changchun, Jilin, China

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Observations under high magnification show that electroluminescent lines in ZnS:Cu single crystal may be in the form of intermittent arrays of tiny bright spots or segments instead of continuous luminescent lines. Three types of internal structures of segmented electroluminescent lines – linear segment type, bamboo joint type, and pearl string type – were recognized.

1. Introduction

Among the luminescent regions within ZnS:Cu single crystals induced by a.e. excitation, most are in the form of lines and some in the form of spots or bands. The color of the light emitted by luminescent bands is usually blue.
Both green and blue luminescent lines have been observed and can coexist in one crystal. An interesting fact is that some of the linear luminescent regions may emit blue light at one part and green light at another. As shown in fig. 1, the form of the luminescent linear regions is variable. Some look like double comets, whereas some are simply straight lines.

Existing literature shows that a great deal of investigations have been done on the irradiation features as well as electrical properties of a.c. electroluminescent phenomena [1–10]. It has been assumed that the luminescent lines form a kind of evenly luminescent, continuous linear pattern. However, our work on the a.c. luminescence of ZnS:Cu single crystals showed that this assumption is not always true and we did find discontinuity within electroluminescent lines.

2. Experimental

The ZnS:Cu single crystals used in our experiments were grown by using the HCl gas transportation method. Temperatures of the constant temperature region and the crystallization region are 1150°C and 1050°C, respectively. Growth time is 8 h. Cu dopant was controlled at $1 \times 10^{-3}$ g/g. The single crystals obtained exhibit frequently a well-developed hexagonal (0001) face typical of crystals belonging to the hexagonal crystallographic system. A single crystal with cross section measuring about $3 \times 4$ mm$^2$ was mounted with the (0001) face up in a small plastic ring with epoxy resin and then carefully polished.

A pair of copper electrodes was fixed at the opposite edges of the polished surface of the sample. The distance between the electrodes is 3–4 mm. A stabilized a.c. current of 350 V and 3 kHz was applied to the sample for excitation. Observations were conducted under an NU-2 optical microscope with high power oil-immersion objective.

3. Results and discussions

Our observations showed that the electroluminescent lines in ZnS:Cu single crystals are not evenly and continuously linear patterns as generally described but are intermittent arrays of tiny bright spots or segments arranged in different patterns. In other words, there exist non-luminescent regions within a.c. electroluminescent lines.

Three types of internal structures of luminescent lines were revealed in our experiments:

(i) Linear segment type. The luminescent lines are composed of short linear segments in series connection. Varying in length, the linear segments may form
and can coexist with nonluminescent regions as shown in fig. 1. These systems look like double lines have been done with a.c. electro-luminescent lines. However, our experiments showed that this behavior within electro-luminescent structures can be observed in ZnS:Cu single crystals grown by using an indirect temperature gradient method. The single crystal was mounted with the (0001) face parallel to the sample holder and then carefully polished. The thickness of the polished crystal is 3–4 mm. A typical microscope image of the sample is shown in fig. 2.

![Image of luminescent lines](image)

**Fig. 2.** Internal structures of segmented luminescent lines. ×1408. 1. Linear segment type; 2. Bamboo joint type; 3, 4. Pearl string type.

(iii) Straight-line segments. These segments may form straight, curved, or zigzagged patterns (fig. 2–1, right).

(ii) Bamboo joint type. This type of electro-luminescent line is composed of segments with one end thick and round and the other thin and pointed. The round end of a segment is followed by the pointed end of the another segment. The whole pattern looks like bamboo or a series of comet lines arranged along a straight line (fig. 2–2, left).
(iii) Pearl string type. In this type of luminescent line, tiny nonluminescent round dots rimmed by thin luminescent arc lines are distributed alternately with short straight linear segments. The arc-shaped lines sometimes may link with the adjacent linear segment. The whole luminescent line looks like a string of pearls (fig. 2-3, 4).

We call the luminescent phenomena illustrated by the above structures the “segmented luminescence”.

In order to test the stability of the segmented luminescence, we made repeated observations as a function of the depth in the sample by removing a layer of material from the sample surface by further polishing and at raised excitation voltage, e.g. 750 V and 20 kHz. The segmented luminescence described above could still be observed. This may be considered as a clear indication of the stability of these phenomena, which cannot be attributed to the degradation of luminescent materials during the course of excitation by Fischer [11].

The segmented luminescence is most frequently observed within green luminescent lines. In some cases, however, only by very careful observations can they be discerned under the optical microscope. The extant gaps or dots are so small sometimes that they can hardly be recorded in microphotographs. It seems that those continuous electroluminescent lines in which no extinction phenomenon is observed may probably have extintive dots and gaps smaller than the magnitude of the resolving power of the optical microscopes.

We believe that further studies on the origin and implications of the segmented luminescent phenomena will reveal more interesting facts and deepen our understanding of a.c. electroluminescence.

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References

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