YU ISSN 0015—3206
FZKAAA 15 (3) 247 (1983)

A STUDY ON ELECTRON INJECTION IN KBr SINGLE CRYSTAL

AJOY K. MAITI, KUSHALENDU GOSWAMI and ANJAN K. LAHIRI

Department of Physics, Jadavpur University, Calcutta — 700 032, India

Received 22 February 1983

UDC 538.93

Original scientific paper

A crystal of KBr is coloured by means of electron injection under elevated temperatures and applied voltages. The growth of space charge limited (*SCL*) current and colouration have been studied and the efficiency of *F* centre formation in *SCL* region was found to be anomalous near 748 K. The roles of temperature and the injection voltage for the production of trapping centers have been discussed.

1. Introduction

Space charge is thought of as the space filled with a net positive or negative charge, and such conditions are found in semi-conducting and insulating solids. If a cathode emits more electrons than the space can hold, the remaining electrons will form a negative space charge which will produce a field in order to reduce the rate of electron emanation from the cathode. Hence the current is controlled not by the injecting cathode, but by the bulk of the semiconductor or the insulator. The solid contains traps of various distribution and the electrons emitted by the cathode within the space charge are sometimes localized in the traps. It is known that a metal with a sufficiently sharp pointed tip in contact with a solid may produce an intense electric field near the contact to reduce the blocking barrier width thus enhancing electron tunnelling[1] at relatively small applied voltages. Once the carrier injecting contact can provide a reservoir of carriers, the behaviour of the injected carriers and hence the current is controlled by the properties of the solid in which the carriers are flowing. Although the electron injection contact is not perfect because of the presence of the intrinsic resistance of the solids which is generally quite large, yet the space charge limited (*SCL*) current is always observed. Mott and Gurney[2] have initiated the analysis of *SCL* current injection into an insulator on the assumption that traps are absent. Later Lampert et al.[3] used *SCL* current method to determine the energy and kinetic parameters of carrier traps. There has been a continually growing interest in the properties of current into insulating solids which yielded valuable information about the deffect states in the forbidden gap and also about the transport coefficient in these materials. It is known[4,5] that the growth of current during electrolytic colouration exhibits four distinct zones. According to Paramo et al.[6] during initial stage electrolysis in the bulk of the crystal occurs by the influence of the electric field, as a result of which both alkali metal and halide ions are produced. In some previous publications[7,8] it has been found that the space charge plays a dominant role in the formation of colour centre during its growth in the second zone in potassium halide crystals. In the present paper the injection experiment has been carried out in KBr crystal and the role of temperature and the applied voltage during injection within the *SCL* region is discussed.

2. *Experimental*

Single crystal of pure KBr was grown by Kyropoulos method in our laboratory. High purity material in the form of powder was taken in a quartz tube and before melting heat treated at about 500 C in order to remove water vapour and other occluded absorbed gases or volatile compounds. The crystal was cleaved from the single crystal blocks. The injection procedure was conducted under constant temperature and voltage. The detailed experimental procedure for production and measurement of defect centers was described elsewhere.[8] The injection process was restricted within the second zone where current was found to be nearly steady. The colouration so produced in the crystal due to electron injection had been allowed to beach under constant temperature by with-drawing the electric field applied within the specimen. The rate of fall of colouration was recorded by the pen recorder.

Injection current and optical density are plotted against time under various temperatures and voltages, as shown in Fig. 1 and Fig. 2. The graph for rate of bleaching of colour centers as a function of temperature is plotted for KBr crystal as shown in Fig. 3. The plots of injection current against time are found to be almost linear in the second zone (*SCL* current). The optical density curves against time are either linear or are found to fit in an equation of the type $y = a\, t^b + c$, where, y, t are the optical density and time, respectively, a, b and c are suitable parameters.

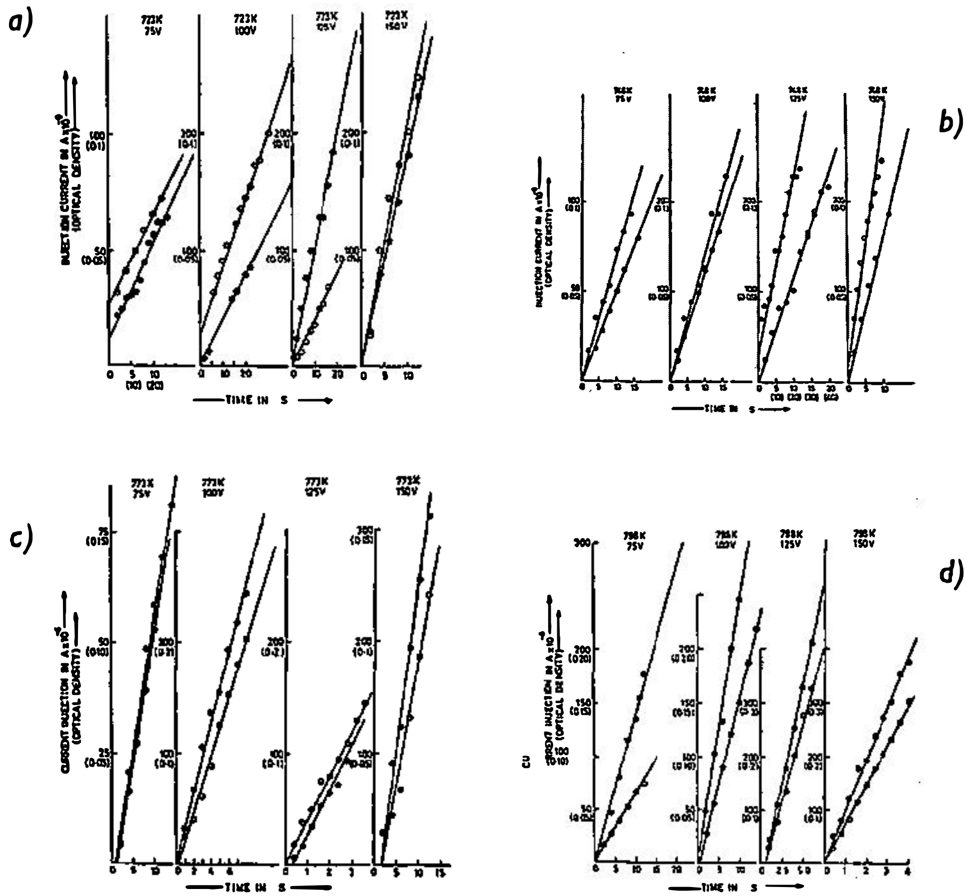

Fig. 1. Current injection and optical density against time for various injection temperatures (a) 723 K, (b) 748 K, (c) 773 K, (d) 798 K under applied voltages at 75 V, 100 V, 125 V and 150 V. Open circle indicates current value and filled circle indicates optical density value.

3. *Discussion*

From the plots of injection current against time, it is evident that the second zone current generally increases with the increase of applied voltage at a constant temperature. In order to have a relative comparison of various cases of injection, the slopes of *SCL* current for different injection voltages are evaluated and are shown in Table 1.

The slope of *SCL* current against time curve at 773 K under 150 V is $2 \times \times 10^{-5}$ As^{-1}, which seems to be an anomalous data if one closely observes the trend of the result. But from Table 1, it may be seen that the slope of colouration at 773 K under 150 V is also reduced appreciably in comparison with other slope values. This apparent anomaly in the slope values may be explained in the folowing

Table 1.

Temp. in K	Slope values of current (in A $s^{-1} \times 10^{-6}$) and colouration (in $cm^{-2} s^{-1} \times 10^{-2}$) for applied injection voltage. Voltage in V: 75	100	125	150	250
673	—	—	—	—	90
	—	—	—	—	0.55
723	3.8	3.0	2.0	10	175
	0.40	0.20	0.257	0.40	3.80
748	5.0	12.3	11.5	29	—
	0.675	0.70	0.50	0.775	—
773	6.0	26	4.0	23	230
	1.17	3.04	4.375	1.625	6.16
798	6.4	16	58	85	—
	1.40	2.42	3.25	1.90	—
823	—	—	—	—	500
	—	—	—	—	14.40

Table-1. Slope of injection current and colouration with respect to time for various temperatures under different injection voltages. For each temperature, first row indicates the slope values of current and the other row indicates the slope values of colouration.

way. The injection current and the colouration are not at all independent. The traps within the solid at the injecting temperature will decide the conducting power of the carrier electron. If we further evaluate the ratio of the slopes of *SCL* current and colouration, the ratio for 773 K at 150 V indicates that there is no anomaly in the results, as the ratio of the slopes is an increasing function of voltage for a constant injecting temperature of the crystal. It implies that the condition of the ohmic contact within the crystal is not severely disturbed to cause anomalous trapping distribution within the crystal. In our earlier publication[7] it has been observed that the efficiency of *F* centre formation (η), which is defined the energy necessary to create *F* centre is an increasing function of the injection temperature. But no compensation for *F* colour bleaching was considered in those cases. In the present case the data were accumulated for a regular interval of voltages for each of the temperature records during growth of colouration. The rate of fall of colouration at a particular fixed temperature is compensated by the rate of growth of colouration and then the η values are calculated.

Comparing the thermal bleaching of *F* centers in case of KBr, KCl and KI (data for KCl and KI are not shown) under electron injection, it has been observed that thermal bleaching of *F* centre for KBr is extremely high. It suggests us to believe that the *F* centre trap in KBr are rather shallow in nature. It is known that the alkali-halide crystals contain both the shallow and deep lying traps. However, only the shallow traps are held responsible for creating *F* colour centers. In the present case, energy necessary to create *F* centre i. e., efficiency (η) value at 748 under 100 V, 125 V and 150 V are extremely large when compared with η values for other temperatures (Fig. 4). This difference in the η values around the temperature of 748 K may be thought of as due to the lower distribution of the shallow traps. Injection under 250 V is found to be quite reasonable, since most of the electrons go to the conduction band without trapping, thus the temperature and the injection voltage play some definite roles in the formation of colour centers within the space charge limited region for pure KBr crystal.

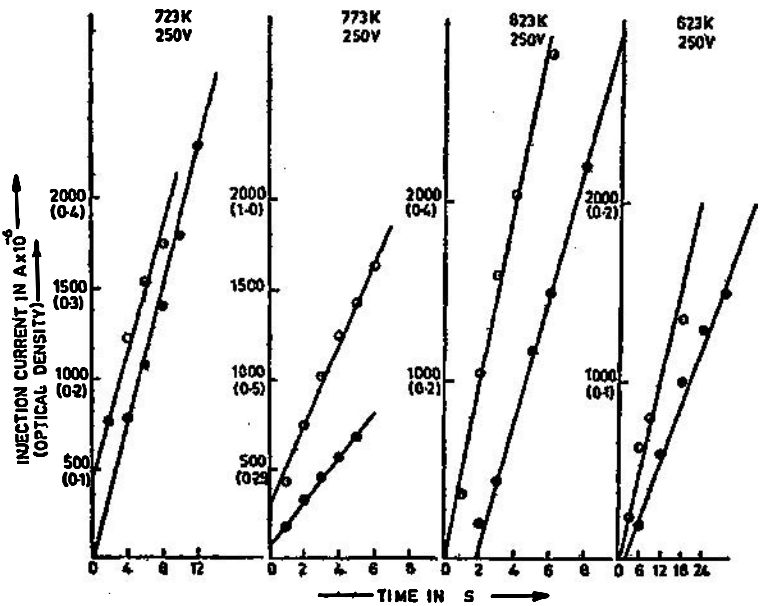

Fig. 2. Current injection and optical density against time for various injection temperatures 723 K, 773 K, 823 K and 623 K under an applied voltage of 250 V. Open circle indicates current value and filled circle indicates optical density value.

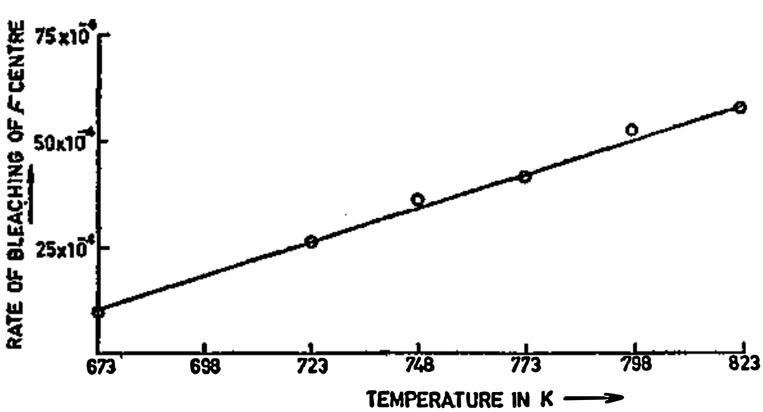

Fig. 3. Rate of bleaching of F centre against various injection temperatures.

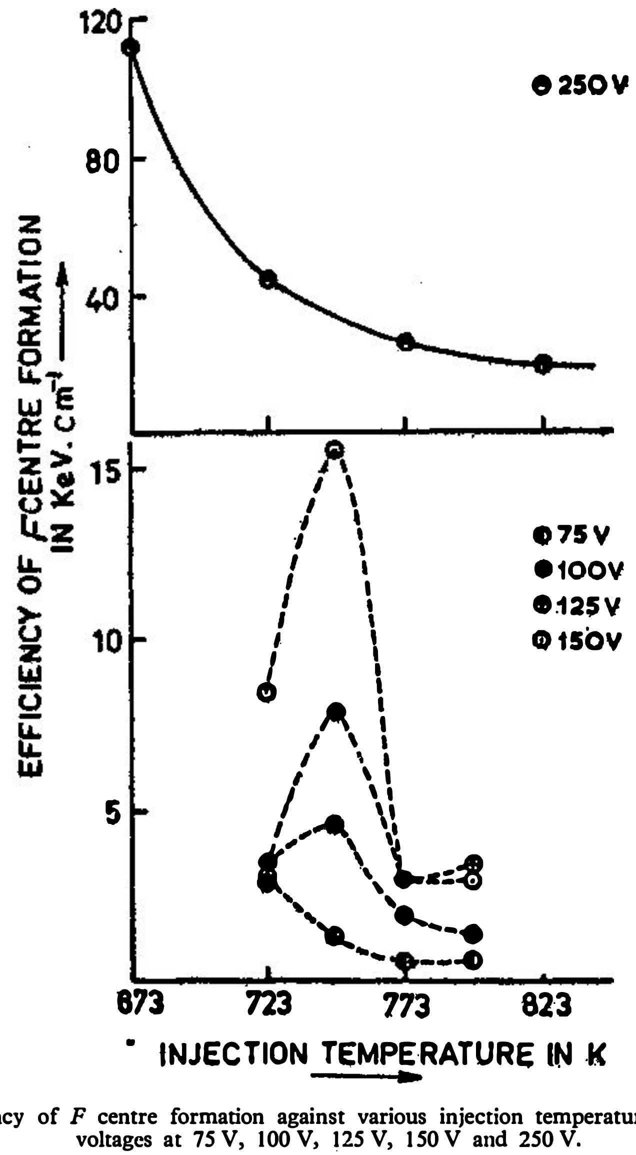

Fig. 4. Efficiency of *F* centre formation against various injection temperature under applied voltages at 75 V, 100 V, 125 V, 150 V and 250 V.

Acknowledgments

The authours are grateful to R. Pyne and A. K. Dey for extending their help during the preparation of the crystal.

References

1) K. C. Kao and W. Hwang, *Electrical Transport in Solids*, Ist. Ed., Pergamon Press (1981);
2) N. F. Mott and R. H. Gurney, *Electronic Process in Ionic Crystals*, Ist. Ed; Oxford University Press, New York (1940);
3) M. A. Lampert and P. Mark, *Current Injection in Solids*, Academic Press Inc., New York (1970);
4) G. A. Andreev, G. B. Semushkin and A. N. Tsikin, Soviet Physics Solid State **9** (1968) 2564;
5) M. T. Montojo and C. Sanchez, J. Phys. Chem. Solids **35** (1974) 1437;
6) N. Paramo and C. Sanchez, J. Phys. Soc. Japan **30** (1971) 1106;
7) A. K. Maiti, K. Goswami, S. Choudhuri and A. Choudhury, J. Electro-chem. Soc. **128** (1981) 1995;
8) A. K. Maiti, K. Goswami, A. Manna, S. Choudhuri and A. Choudhury, Fizika **14** (1982) 7.

ISTRAŽIVANJE UPUCAVANJA ELEKTRONA U KBr MONOKRISTALE

AJOY K. MAITI, KUSHALENDU GOSWAMI i ANJAN K. LAHIRI

Department of Physics, Jadavpur University, Calcutta -700032, India

UDK 538.93

Originalni znanstveni rad

Kristal KBr obojen je pomoću upucavanja elektrona kod različitih temperatura i napona. Proučavani su rast struje ograničene prostornim nabojem (*SCL*), i obojenost. Nađeno je da je efikasnost stvaranja *F* centara u području *SCL* anomalna blizu 748 K. Diskutirana je uloga temperature i napona u stvaranju centara boje.