# CARRIER NUMBER FLUCTUATION AND MOBILITY INHIGH FIELD INSULATING MATERIALS WITH SHALLOW TRAPS AT LOW FREQUENCY

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**Abstract-** The analytical expressions for the low frequency noise resistance have been evaluated for the single injection current flow in insulator operating in high field regime in the complete range of current-voltage characteristic. It is shown that the complete noise characteristic is started from the carrier density fluctuations in ohmic regime at low injection level of current which is dominated by the space charge at high injection level above a critical point.

**Keywords –** Noise resistance, single injection, current-voltage.

## I. INTRODUCTION

The studies on the electrical conduction and noise behaviour for single injection current flow in insulator at high field have open the promising directions to develop the important devices by the workers (1-7). The noise source at low frequency in injection devices at high field is obtained from the fluctuations in carrier density and mobility described by Sharma (1974). It is observed by the workers of the field "that the mobility is dependent on the electric field strength above a critical field described by Nicolet,Bilger and Zijlstra (1) and Lampert and Mark (5)« The current flow is dominated by the space charge in single injection devices to give nonlinear effects on current-voltage and noise characteristics.

## II. GENERAL EQUATIONS

Let us consider a single injection current flow in perfect trap free insulator at high field. The general equations for the current flow and the Poisson's law for the problem are given by (3-7)

$$J = e\mu_0 \left(E_c\right)^{1/2} n\left(x\right)\left[E\left(x\right)\right]^{1/2} \tag{1}$$

$$\frac{\in}{e}\frac{dE}{dx} = n \tag{2}$$

where $J$ is the current density,$e$ the magnitude of electronic charge, $\mu_0$ the low electric field mobility, $E_c$ the critical electric field defined elsewhere (7), $n(x)$ the concentration of free carriers in insulator at distance $x$, $E(x)$ the electric field strength at position $x$, and $\in$ the permittivity of the insulator. The above equations are subjected to the boundary condition for ohmic contact as

$$E(0) = 0 \tag{3}$$

The applied voltage across the insulator is given by

$$V = \int_{-}^{L} E(x)\, dx \tag{4}$$

where $L$ is the device length.

The current carriers are considered to be electrons for the simplification. The theory is also applicable to the hole injection current flow in insulator at high field with slight change in terminology. The carriers are injected at cathode and collected at anode. The electric field strength applied across the insulator is sufficiently large to provide the high field regime described by Nicolet (1) and Gisolf (7). The great advantage of the study of single injection space-charge-limited current flow at high field is that the carrier distribution may be maintained in stationary state in insulator without exceeding the power limitations. The new informations are obtained on the behaviour of electrons at high field strength from noise studies in single injection mode. The detailed theory of single injection current flow in insulator at high field follows from elsewhere ($3_5$ 6, 7)•

## NOISE CHARACTERISTIC

The low frequency noise characteristic of single injection current flow in insulator at high field is started from the pure ohm's law regime which merges into spacecharge regime at a critical current and critical voltage. Adopting the previous procedures described by Sharma (3.), Lampert and Mark (5) and Gisolf (7)The general equations are used to derive the noise resistances at three injection levels of current in the complete range of noise characteristics as described below in order.

The injection level is very low in the starting of noise characteristic. It is the pure ohm's regime of current-voltage characteristic of insulator at high field and the current is carried by the carriers which are present in the insulator before current injection. The low frequency noise resistance of single injection current flow in insulator at high field and low injection level of current is obtained from the general equations as (3, 7).

$$R_\ell \frac{2e\,\mu_0^2 E_c S V^2}{L\,k\,T\,J} \quad (5)$$

where $S$ is the area of cross-section of the diode, $k$ Boltzmann's constant and $T$ the lattice temperature. It is evident from equation (5) that the effect of injection level of current is small on the noise resistance and the cube power law dependence of the noise resistance on the applied voltage appears at low injection.

The noise characteristic changes its farm at the critical current $J_0$ because the injection level issufficiently large so that the space charge may dominate on the current flow. The critical low frequency noise resistance is obtained from the general equations (1)-(5) as

$$R_0 = \frac{2e\,\mu_0^2 E_c S V^2}{L\,k\,T\,J_0} = \frac{0.82\,e^{5/2}\mu_0 n_0^{5/2} S E_c^{1/2} L^{9/2}}{\in^{5/2}\,kT} \quad (6)$$

which is a constant quantity and there is a large change in noise resistance with slight change in device length.

At high injection level of current, the low frequency noise is dominated by the presence of space charge in the insulator. The noise resistance in this regime is derived as described by Sharma (3)

$$R_h = \frac{9\,e\,S\,J\,L^4}{50\in^2\,kT} \quad (7)$$

which is dependent on the injection level of current.

## III. DISCUSSION AND CONCLUSION

The complete low frequency noise characteristic of single injection current flow at high field is divided into two noise regimes. The characteristic is started from low injection level of current at which the noise resistance is obtained by the ohmic contributions. The concentration of injected current carriers is negligibly small, therefore the contribution of noise sources due to space charge is very small.

This noise regime is terminated at the critical noise resistance above which the concentration of injected current carriers is dominated over the current carriers present before the current injection. The noise characteristic above critical noise resistance is obtained by the space charge contributions and the ohmic contribution is small at high injection level of current. The effect of mobility fluctuations is large at high injection level of current because the high field mobility decreases with the increase of applied field described by Gisolf (7).

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