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LOW FREQUENCY NOISE IN LOW MOBILITY INSULATORS

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Analytical expression for the spectral intensity of low frequency noise voltage has been evaluated for the trap-free insulted diode operating under low and high injection levels of currents. It is shown that the low frequency noise is suppressed greatly due to the presence of the space charge in the low mobility insulator.

KEYWORDS : Low frequency noise, Insulator, Spectral intensity, Space Charge, Current injection.

INTRODUCTION

The study of low frequency noise is made by open circuiting the output. It is caused by carrier density voltage fluctuations which are caused by a fluctuations in the carrier density.

In low mobility insulators, the carrier mobility in directly proportional to the carrier density [1-3, 6]. Therefore, the carrier mobility fluctuations are well connected with carrier density fluctuations. Thus, the carrier mobility and carrier density fluctuations both contribute to total low frequency noise across the low mobility insulator [1-7].

Let us consider lour mobility insulator without thermal free carriers and trapping states but characterized by a finite conductivity. In order to evaluate voltage fluctuations, the single injection current flow in low mobility insulators is considered at low and high injection levels of currents. The insulator operates under ohmic conduction at low injection levels and it has pure space-charge-limited (SCL) single injection current flow regime at high injection level [1-3, 6, 7]

The general equations for current flow, Poisson's law and carrier mobility in a perfect trap free low mobility insulator as [1-3, 6]

$$J = e\mu n(x)\, E(x) \qquad \dots (1)$$

$$\frac{\varepsilon}{e} \cdot \frac{dE}{dx} = n(x) \qquad \dots (2)$$

$$\mu = hn(x) \qquad \dots (3)$$

where h is proportionality constant and all current is carried by electrons.

Low frequency noise caused by carrier density fluctuations

The equations (1) - (3) are used to study the low frequency noise. The small singal a.c. equation are given by

$$E = E_0 + \Delta E, \quad J = J_0 + \Delta J, \qquad n = n_1 + \Delta n$$

$$\mu = \mu_0 + \Delta\mu_0, \qquad \text{and} \qquad \Delta\mu = h\Delta n \qquad ...(4)$$

where higher order terms are neglected. The linearization of eqn. (1) gives.

$$\Delta J = eh[2E(x)\ n(x)\ \Delta n(x) + n^2(x)\ \Delta E(x)] \qquad ...(5)$$

The main assumption to calculate to the low frequency noise is that the injected electrode is relatively a small barrier and the anode is a blocking contact with relatively a large barrier [2]. Thus, the carrier density at the anode is considered to be practically zero at all times, so that $\Delta J = 0$

By putting $\Delta J = 0$ in eqn (5) give

$$2E(x)\Delta n(x) + n(x)\ \Delta E(x) = 0 \qquad ...(6)$$

Complete low frequency noise characteristic

The complete low frequency noise characteristic of single injection current flow in low mobility insulator is divided into two low frequency noise regimes well separated by the critical point as described below:

3.1 Spectral intensity calculations at low injection level

The complete low frequency noise characteristic is started from low injection level when the injected space charge is negligibly small n(x) = n_0 and uniformly distributed throughout the insulator. The fluctuations in the electric field strength in the insulator are obtained from the eqn. (5) with $\Delta J = 0$ $\Delta J = \delta n_1$ and $n_1 \cong n_0$ as

$$\Delta E = -\frac{2E_0}{n_0}\delta n_0 = -\frac{2J}{hn_0^3}\delta n_0 \qquad ...(7)$$

where the field strength at low injection level is derived from eqns. (1) and (2). The integration of eqn. (7) between the limits 0 to L give the voltage fluctuations across the insulator at low injection level as

$$\Delta V = -\frac{2JL\delta n_0}{ehn_0^3} \qquad ...(8)$$

Performing a Fourier analysis of (7), the spectral intensity of voltage fluctuations of single injection current flow in insulator at low injection level is obtained as [2]

$$S_{v_e}(f) = 4kTR_l = \frac{4J^2L^2}{e^2h^2n_0^6}S_{n_0}(f) = \frac{8SJ^3L^2}{e^3h^2n_0^6} \qquad \ldots (9)$$

where k is boltzmann's constant, R_l is the noise resistance of the sampel. T is the lattice temperature, S is the area of cross-section and $S_{n_0}(f) = \frac{2SJ}{e}$ ref [2]. The eqn. (9) shows that the low frequency noise is constant depending strongly on the concentration of free carriers and the injection level of current.

3.2 spectral intensity calculations at high injection level:

Adopting the procedure of section 3.1, the eqn. (6) gives the voltage fluctuations across the insulator at high injection level as

$$\Delta V(x) = -\frac{6}{5} \cdot \frac{eL^2}{\varepsilon} \delta n_1 \qquad ...(10)$$

Performing a Fourier analysis of eqn. (10), the spectral intensity of voltage fluctuations of single injection current flow in insulator at high injection level as [2]

$$S_{V_h}(f) = 4kTR_h = \frac{9}{25} \cdot \frac{e^2 L^4}{\varepsilon^2} Sn_1(f) = \frac{18}{25} \cdot \frac{eSJL^4}{\varepsilon^2} \qquad \ldots (11)$$

where $\quad S_{n_1}(f) = \frac{2SJ}{e}$

The eqn. (11) shows clearly that the low frequncy noise is very much dependent on device length and the injected space charge highly suppressed the noise due to linear variation of noise with the current density.

3.3 Low frequency noise at cross-over voltage V_{er}

The transition of low injection level to high injection level occurs at a critical point (J_{cr}, V_{er}) in the complete low frequency noise characteristic insulator. Following the procedures of previous sections, the eqn. (6) provides the low frequency noise of insulator at cross-over voltage as

$$S_{V_{er}}(f) = 4kTR_{cr} = 0.52 \frac{e^3 n_0^3 SHL^5}{\varepsilon^3} \qquad ...(12)$$

which is a constant quantity depending greatly on device length. Discussion and Conclusions

The complete low frequency noise characteristic of single injection current flow in low mobility insulator is divided into two low frequency noise regimes with the help of critical voltage. The low frequency noise source at low injection level is obtained by the fluctuations in the carrier density and carrier mobility of the free current carriers operating under thermal-equilibrium conditons. At high injection level of current, the low frequency noise is highly suppressed by eh space charge above the cross- over voltage.

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