MONTE-CARLO SIMULATION OF HOT CARRIER NOISE

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1. Introduction

The semiconductor $A^{III}B^{V}$ compounds have been increasingly used for various semiconductor equipment in the last years, particularly in the microwave field.

The main noise at lower fields results from the random fluctuations of carrier velocity, caused by the thermal motion the so called Johnson's noise. However, the time fluctuations between two sollisions are also reflected on the fluctuations in carrier drift and are manifested as current noise (1,2). At lower fields, the current noise may be neglected related to the Johnson's, since the drift velocity is far smaller than the thermal one. At higher fields the current noise must be taken into account as the drift velocity becomes comparable with that of the thermal. Now the problem will be analyzed "microscopically", in the way that the electron drift will be computer-aided simulated by Monte-Carlo method. As a matter of fact, the goal is to discover the participation of some noise components (thermal and current noise) in the total noise, in terms of the spplirf field rate at a temperature of 77 K in an intrinsic semiconductor InP.

2. Theoretical model and Monte-Carlo noise simulation

We used a considerably simple model to; calculate the relations of spectral densities in current noise owing to the fluctuations of initial current carrier velocities and the time fluctuations of drifting. An electron moving at speed v in a semiconductor of unit length will cause a current ev in an outer circuit. This current will last as long as the time between two collisions. The current pulses obtained by electrons during their motion between two successive collisions are not in correlation with the previous and the following pulses.

If the immediate electron relocity after the collision is v_i in the direction of a field K, then the current obtained by the moving electrons in the time t after the collision is given by

$$v(t) = v_i + \left(\frac{eK}{m^*}\right)t_i \qquad (1)$$

where m^* is the effective mass of electrons and t_i the time between two collisions. The total spectral density of the noise current per unit frequency range of all electrons is

$$\bar{i}_u^2 \simeq 2e^2\left|\frac{\Sigma v_i^2 t_i^2}{\Sigma t_i} + \left(\frac{eK}{2m^*}\right)^2 \frac{\Sigma t_i^4}{\Sigma t_i}\right| \qquad (2)$$

The first element of the above term is a noise component which dominates at lower fields and corresponds to the diffusion component of the noise current, $\bar{i}_D^2$ and may be transformed into the Johnson's noise. The second element of the same term is the consequence of unequal motion duration between two successive collisions, $\bar{i}_S^2$. For the case of high fields both elements are important and their participation can be calculated only by direct comparison what has been done here.

The whole calculation has been performed for a model of quazifree electron with a spherical equienergetic surface. There has been taken only the scattering on the polar optical phonons.

The procedure for the noise calculation by means of Monte-Carlo method uses the technique given in (3) where two series of random numbers are generated, one for finding the time between two collisions and the other for finding velocity components immediately after the collision.

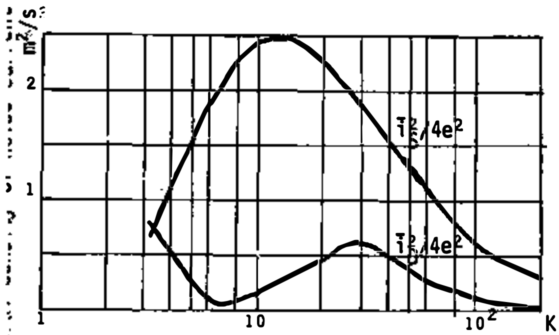

Fig.1 Dependency of spectral density of noise current on the electric field rate

Fig.1 gives the results of the calculations for the spectral density of noise current $\bar{i}_D^2/4e^2$ and $\bar{i}_S^2/4e^2$.

At the beginning the diffusion element is predominant since the fluctuations in initial velocities are also predominant. As the field increases the fluctuations of the drifting time (see equ.2) begin to increase since the drifting element is proportional to Σt^4. With the increased emission there increases the probability of scattering, and consequently, with the increased field the fluctuations in drifting time decrease (the number of fictive collisions decreases). So, the emission decreases the time between collisions t_i, and thus $\bar{i}_S^2/4e^2$, because the directing of electron motion increases.

3. Conclusion

The calculation has been done at temperature of 77 K and so only the scattering on the polar optical phonons has been observed. The scattering, on the acoustical phonons has been neglected since the value of the deformation potential constant is 9,2 eV. Neglecting this kind of scattering only the small error appears, but the calculation is considerably simplified.

This model can be applied to other materials where the polar optical scattering dominates. However, the calculation can be also done for the nonpolar semiconductors taking into account the scattering mechanisms dominating in them.

References

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