X. SEMICONDUCTOR NOISE

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A. 1/f NOISE IN GERMANIUM

An account of a theory of the mechanism and physical origin of 1/f noise in germanium filaments, and its extensions to explain a portion of the excess noise in p-n junctions, appears in the joint Research Laboratory of Electronics Technical Report 295 (Lincoln Laboratory Technical Report 80) by A. L. McWhorter.

The theory attributes the noise to the fluctuating occupancy of slow-acting states (traps) in or on the surface oxide layer. The existence of these traps, and the distribution of their time constants, is supported independently by experimental results and theoretical conclusions from collateral studies of the "field effect" in germanium. Estimates of the energy and density of the traps are consistent with the present knowledge of the behavior of the Fermi level at the surface, drawn from independent investigations of "channel effect" in germanium. The theory accounts for the required $1/f^n$ noise power spectrum over the observed 7-8 decades of frequency, with $n \approx 1$. It also yields noise magnitudes which are in agreement with the general level observed in good single-crystal filaments.

By postulating a carrier tunneling process between the surface traps and the germanium, a more detailed picture of the noise phenomenon is developed. While this refinement is not essential to the noise magnitude or spectrum calculations, it is completely consistent with them, as well as with reported independent determinations of the oxide-layer thickness and potential barrier at the surface. The tunneling hypothesis is especially attractive, however, in view of the relatively weak temperature dependence usually found for the excess noise down to very low temperatures.

The noise correlation phenomena which have been observed in the past on germanium filaments are predicted by theory when it is applied to the nonequilbrium case in which current is flowing in the sample. The important conclusion of the present theory is that the extent to which correlation is observed over a minority-carrier life path depends greatly upon the detailed condition of the sample and its surface inversion layer. Basically the theory leads to a fluctuation of majority-carrier concentration but, depending upon the detailed conditions, this fluctuation may be modified to either a comparatively large or a comparatively small extent by the ordered flow of minority carriers under conditions of nonequilibrium.

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