Bohr model with an effective mass $m^*=0.34m$ derived from the mean curvature of the "heavy" hole band. This gives an ionization energy of 0.018 ev.

Calculations of the acceptor levels in silicon are in progress.

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Generation of $1/f$ Noise by Levels in a Linear or Planar Array

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TRAPPING levels in a linear or planar array (at edge dislocations or the surface), or agglomerates of levels, will possess the following important property. A trapped charge will cause a potential barrier to further trapping of like charges, and a fluctuation in the trapped charge will produce a proportional fluctuation in the barrier height (although the energy of ionization from the levels will be constant). We will show that trapping with this simple barrier property may lead to $1/f$ noise.

This barrier property has been associated with the Elovich equation[1–3] which describes in numerous cases the rate of irreversible adsorption. Thus, the application of the model to the many apparently disconnected cases of $1/f$ noise is possible.

Denoting by N the trapped charge in excess of equilibrium, we obtain from an analysis of the model:

$$dN/dt=B(e^{\beta N}-1), \quad (1)$$

where β is related to the "capacitance" between the levels and the bulk material, B represents the equilibrium rate at which charge crosses the barrier, and is very sensitive to temperature. The first term is thus the trapping rate, the second the ionization rate.

From Eq. (1),

$$N=-\beta^{-1}\ln(1-Ae^{-\gamma t}), \quad (2)$$

with A the constant of integration, $\gamma=-\beta B$.

If one assumes that the distribution $g(N)$ of N over the levels is Gaussian, with mean $\bar{N}$ and standard deviation ξ, the autocorrelation function can be calculated. The use of this distribution function is not critical to the theory. Then the spectral distribution of noise becomes:

$$G(\omega)=-4\int_{N=-\infty}^{\infty}\int_{\tau=0}^{\infty}N\beta^{-1}\ln\{1-Ae^{-\gamma\tau}\}\times g(N)\cos\omega\tau d\tau dN, \quad (3)$$

where $A=1-e^{-\beta N}$.

For large barriers, γ can be very low. For example, surface traps on germanium, as detected by field effect measurements,[4,5] have decay times about a minute at 20°C, yielding $\gamma=10^{-2}$ sec^{-1}.

If one assumes $\omega\gg\gamma$ as a lower limit, the contribution to $G(\omega)$ from the negative values of N turns out to be small, as the decay rate is slow.

For positive N, when the decay is fast, the logarithmic term in (3) can be expanded and the integration over t performed. Replacing the resulting summation by an integration, thus neglecting terms in γ/ω^2, and using the rough approximation that $\mathrm{Ci}(x)\sin x-\mathrm{Si}(x)\cos x+\frac{1}{2}\pi\cos x$ is a step function, zero for $x>1$ and $\pi/2$ for $x<1$, we obtain

$$G(\omega)=\tfrac{1}{2}\pi(\beta\omega)^{-1}\left\{\int_0^{\infty}Ng(N)dN-\int_0^{\beta^{-1}\ln(\omega/\gamma)}N(2\pi\xi^2)^{-\frac{1}{2}}\times\exp[-(N-\bar{N})^2/2\xi^2]dN\right\}; \quad (4)$$

and if $N-\bar{N}\ll\sqrt{2}\xi$ the second integral is a slowly varying function of ω and the $1/\omega$ distribution of noise is obtained. The requirement sets an upper limit on the $1/\omega$ spectrum, namely $\ln(\omega/\gamma)<\beta(\sqrt{2}\xi+\bar{N})$. It is interesting that the temperature-sensitive quantity γ does not appear in the expression for $G(\omega)$, except in the insensitive logarithmic form.

We have here developed the frequency spectrum of the trapped charge. Noise will appear in bulk conductivity measurements since charge trapped represents a decrease in current carriers. In contact or rectifier studies, the noise may arise from fluctuations in the barrier height; for small fluctuations the barrier height is proportional to the trapped charge. Thus the concepts presented may be extended to carbon contact devices and metal films, as well as semiconducting devices.

A more detailed discussion of the model and the experimental results on the field effect which led to this analysis will be published later.

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