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CALCULATIONS OF SURFACE POTENTIAL ... E-PASSIVATED HIGH-RESISTIVITY

Berkeley, California

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June 22, 1964

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ABSTRACT

That the oxide-passivated surface of high resistivity silicon is characterized with a high density of donor states is taken into account in calculation of the surface potential.

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Since Kingston and Neustadter,[1] several authors[2] have carried out the numerical computation of the space-charge functions occurring in the description of the electrical behavior of the semiconductor surfaces. Most of these calculations, however, deal with comparatively low surface-charge density and conductivity. But the oxide-passivated surface of high-resistivity silicon is characterized by a high density of donor states giving the charge density of 10^{-8} coulombs/cm^2 or more. This corresponds to a high value of the surface potential compared with the bulk potential, and particularly so for the high-resistivity bulk. In calculating the space-charge functions we can therefore neglect the terms corresponding to the bulk potentials. Also because of the high density of donor states the contribution to the space charge from the holes can be neglected.

The charge density at a point corresponding to a potential ϕ (Fig. 1) in the space-charge region is therefore given by

$$\rho = - q\, n_i \exp(q\phi/kT) = - q\, n_i \exp(u)$$

where q is the electronic charge and n_i the carrier density in the intrinsic bulk semiconductor. Hence, if we solve Poisson's equation,

$$\frac{d^2\phi}{dx^2} = - \frac{4\pi\rho}{\epsilon} = \frac{4\pi}{\epsilon}\, q\, n_i \exp(u)$$

the surface charge density, Q_s is given by

$$Q_s = 2\, q\, n_i\, L_D \exp(u_s/2)\,,$$

and the surface excess is given by

$$\Delta N = 2 n_i\, L_D \exp(u_s/2),$$

where

$$L_D = (\epsilon kT/8\pi q^2 n_i)^{1/2}$$

is the Debye length and u_s the surface potential in units of kT. These equations are equivalent to putting $u_b = 0$ in Kingston and Neustadter's function

$$F(u_s, u_b) = \sqrt{2}\,[(u_b - u_s) \sinh u_b + \cosh u_s - \cosh u_b]^{1/2}\,.$$

Assuming $n_i = 1.5\times 10^{10}/\mathrm{cm}^3$ and $L_D = 2.4\times 10^{-3}$ cm (at 300°k), Q_s is calculated as a function of u_s in Fig. 2. For comparison a few of the functions $F(u_s, u_b)$ have also been shown in Fig. 2.

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FOOTENOTE AND REFERENCES

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† IAEA Fellow from Atomic Energy Establishment, Trombay, Bombay, India.

1. R. H. Kingston and S. Neustadter, J. Appl. Phys. 26, 718 (1955).
2. See, for a complete review of the literature, A. R. Plummer, *The Electrochemistry of Semiconductors*, Edited by P. J. Holmes (Academic Press, Inc., New York, 1962).

FIGURE LEGENDS

Fig. 1. Energy-level diagram for silicon—silicon dioxide system.

Fig. 2. Charge density as a function of surface potential. Curve (a) this work; (b) $F(u_{-7}, u_s)$, p-bulk, resistivity ≈ 1000 ohm-cm; (c) $F(u_7, u_s)$, n-bulk, resistivity ≈ 500 ohm-cm; (d) $F(u_6, u_s)$, n-bulk, resistivity ≈ 1000 ohm-cm.

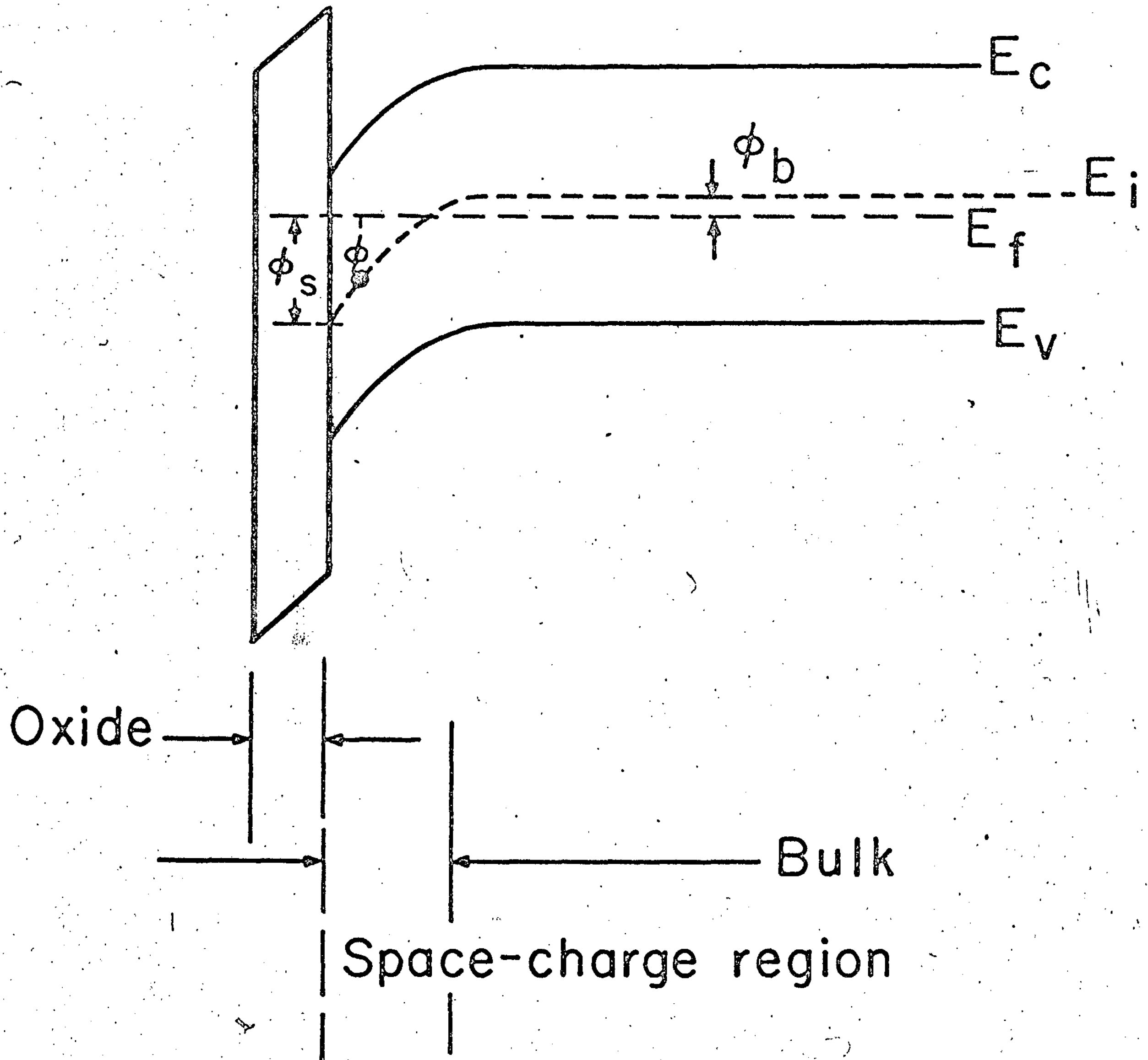

Fig. 1

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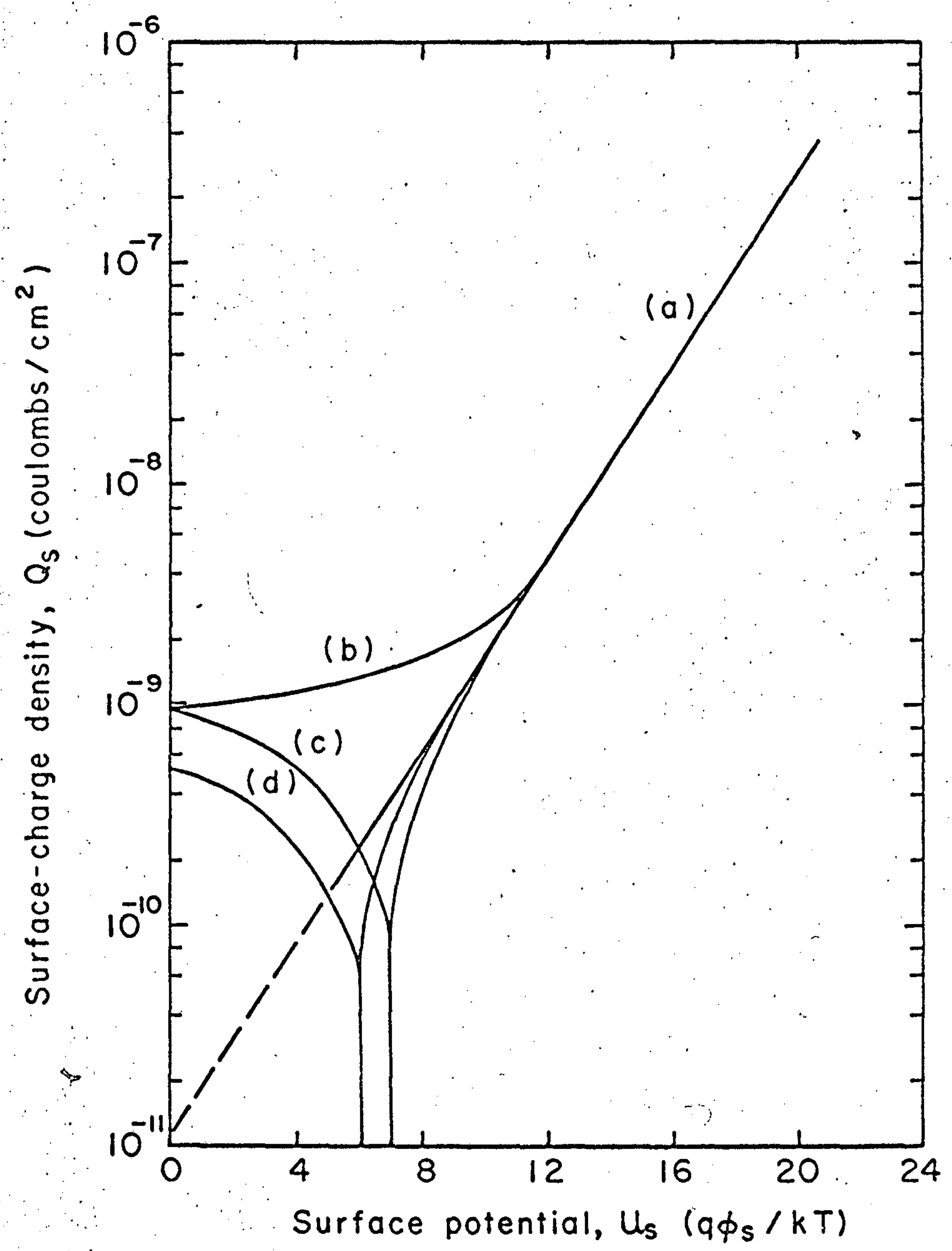

Fig. 2

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