RELATION BETWEEN THE CHANGE IN THE SURFACE POTENTIAL OF A SOLID IN VACUUM AND THE EFFECT OF ELASTIC DEFORMATION ON THE WORK FUNCTION

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A capacitor having a specific capacitance C and a potential difference φ is made up of smooth plates 1 and 2 having work functions φ_{01} and φ_{02} and held at a separation δ in vacuum. We denote by γ the tension along the working surface of plate 1, by ε and Ω the charge density on and the area of this surface, and by ϑ the relative change in Ω during elastic deformation of the plate $E = \varepsilon\Omega$. Then from $(\partial\gamma/\partial\varepsilon)_\vartheta = (\partial\varphi/\partial\vartheta)_E$, we find

$$\frac{\partial\gamma}{\partial\varepsilon} = \frac{\partial\varphi_{01}}{\partial\vartheta} - \varphi + \varphi_{01} - \varphi_{02} \tag{1}$$

The term $\varphi - \varphi_{01} + \varphi_{02} = \varepsilon / C$ is the contribution from the electric field between the plates. The physical properties of plate 1 are reflected in the term $\partial\varphi_{01}/\partial\vartheta$. This term drops out, and $\partial\gamma/\partial\varepsilon$ becomes a purely surface effect (the "estance" of a solid in vacuum [1]) if $\varepsilon = 0$, e.g., with $\varphi_{01} = \varphi_{02}$ and $\varphi = 0$. Near $\varepsilon = 0$ (if the effects of ε on C and $\partial\varphi_{01}/\partial\vartheta$ are slight), we find from Eq. (1)

$$\gamma(\varepsilon) - \gamma(0) = \frac{\partial\varphi_{01}}{\partial\vartheta}\varepsilon - \frac{1}{2C}\varepsilon^2. \tag{2}$$

With $\varepsilon = \Delta\varepsilon\cos\omega t$ (where ω is the frequency and t is the time), we have $\partial\varphi_{01}/\partial\vartheta = \Delta^1\gamma/\Delta\varepsilon$, where $\Delta^1\gamma$ is the amplitude of the first harmonic of γ, and the electrostatic forces (in particular, the voltage $\varepsilon^2/2C\delta$ between the plates) vary at a frequency 2ω. With $\varphi = 0$, their first harmonic is proportional to $\varphi_{01} - \varphi_{02}$. If plate 1 is rough, γ and ε in Eq. (1) refer to the median plane, and the term $\partial\varphi_{01}/\partial\vartheta$ must be multiplied by a coefficient ρ. For isotropic roughness we have $0 < \rho < 1$, because the charge concentrates at the surface protuberances, and the deformation of these protuberances reduces the effect of surface tension on the size of the plate as a whole.

LITERATURE CITED

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