Charges and vacuum flashover

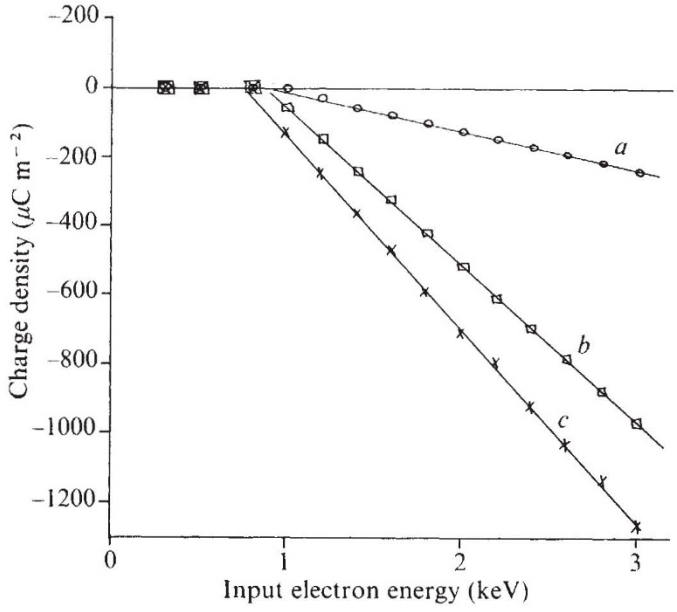
THE increasing importance of vacuum insulation in technology[1] and the recognition of the disruptive effects of surface discharges on satellites in space[2] both impart fresh impetus to the understanding of the flashover effect. Solid insulators are certainly a source of gas *in vacuo*, particularly under bombardment, and can also cause local enhancement of electric stress through the acquisition of surface charges.

de Tourreil and Srivastava[3], among others, have measured positive charges on insulators at stresses well below those necessary for flashover. They proposed a charging process based on secondary electron emission following bombardment of the dielectric by electrons initially field-emitted from the cathode. A secondary emission coefficient, δ, greater than unity (more out than in) obtains for most dielectrics[4] but strictly between well defined limits of input electron energies, that is, $\sim$ 1 eV $< E <$ a few k eV, for instance. Outside these limits the insulator would charge negatively. Moreover, the emission energy of the secondary electrons is quite small, $\sim$ few eV (ref. 5), and so very little positive charge on the insulator would preclude further emission. These effects are clearly illustrated by the simple experiment, shown schematically in Fig. 1 of ref. 6, in which electrons, with energies of up to 3 keV, are directed through a counter electrode on to insulator specimens, and the charges produced measured.

Specimens of fused silica (300 μm thick) and of two polymers—polycarbonate (55 μm) and polyimide (50 μm)—have been investigated. Figure 1 presents the measured charge densities for zero extracting field plotted as a function of the input beam energy. The upper secondary emission threshold energy (E_2) of the primary electrons is clearly displayed. For higher input energies, the insulator charges negatively, thereby slowing incoming electrons which thus arrive at the surface with precisely the threshold energy, so that equilibrium is attained ($\delta = 1$). The full lines agree with the calculated geometric capacitance of the specimens to within 5%.

The occurrence of this dynamic process, rather than of complete repulsion of a high energy, primary beam (the other stable condition) is important since it indicates continued interaction even in the highly charged equilibrium state. Local discharges would probably dissipate larger areas of charge, for example, because of the increased surface conductivity.

Fig. 1 Charge densities measured on SiO_2 (*a*), polycarbonate, (*b*), and polyimide (*c*), specimens, plotted against input electron energy.



For input energies below the threshold (E_2) very little (virtually random) charge is detected on the dielectrics. If an extracting field is generated, however, by applying positive potentials to the counter electrode, positive charge densities are observed, these being independent of the primary beam energy but linearly dependent on the extracting potential. Above the threshold the extracting potential has no effect.

These observations suggest that the straightforward secondary emission theory of insulator charging, leading subsequently to breakdown, may be inadequate. The electric stress at flashover is usually greater than around 5 MV m^{-1}, so the maximum free path for primary electrons in this field, if they are to collide with the insulator surface with energy less than the upper threshold energy, $\sim$ 1 keV, is less than 0.2 mm. Thus, for insulators of greater length, such primary electrons must originate from adjacent sites on the dielectric surface itself. That may be possible; but what happens to the electrons with greater than the threshold energy, that is, those originating further than 0.2 mm from the point of collision? They would charge the insulator negatively, irrespective of any apparent extracting field, except, perhaps, in three possible conditions:

- At low (near grazing) angles of incidence the considerably reduced normal depth of penetration of the primary beam may result in the emission of secondaries, even at high primary beam energies, that is, the secondary threshold energy may be greatly increased.
- The enhanced conductivity of the irradiated surface layers of the insulator may have an important role in establishing local potential gradients.
- The collision of particles originating from both the electrode and the dielectric surfaces may have an important independent role in charging the insulator surface.

To my knowledge these aspects have not been investigated.

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Aspartic acid racemisation in dentine as a measure of ageing

THE L-amino acids initially present in bone protein undergo slow racemisation over geological time at a rate which is proportional to temperature[1,2]. We have shown[3] that at the human body temperature of $\sim$37 °C aspartyl residues in tooth enamel protein also undergo racemisation at a rate which corresponds to an enrichment in the D-aspartic acid content of $\sim$0.1% per year. No D-aspartic acid increase was detected in haemoglobin, a protein with a more rapid turnover. We concluded that D-aspartyl residues accumulate in the metabolically stable protein in tooth enamel during the human lifetime as a result of *in situ* racemisation. We proposed that the irreversible first-order rate equation calculated from the enamel results could be used to deduce the age of any stable