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Surface Gas Eruption and Van der Waals Cohesion on Tungsten

In some experiments on the detection of single atoms and molecules reported earlier[1], it was noticed that, in the early stages of the conditioning of the point, there were occasions when, on increasing the field by some 20 per cent, an abrupt instability in the field current occurred; this invariably produced excessively large currents. The field emission pattern of the emitting facets of the point, previous to this, was, of course, badly blurred, with no definition comparable with that from clean points, but it was possible to discern 'out of focus' non-emitting areas on the fluorescent anode; as soon as the instability arose, there was complete loss of resolution, and the pattern showed a uniform streaming as if a sheet of gas was moving across the point. When the point had been fully 'conditioned', it required a much higher field to produce the effect. If, however, the whole vacuum system was let down to air at atmospheric pressure and soon after pumped out, it was possible to obtain repeated gas eruption and current instability without further increase of field.

We have in this simple observation a method of determining the Van der Waals cohesion of the topmost atoms in a multilayer gas film on tungsten. The effect of the field, E, is to polarize the adsorbed gas layer and put a strain on the film; the force on a single atom $\alpha E \mathrm{d}E/\mathrm{d}z$ where α is its polarizability works out at $\sim 1/10^{12}$ newtons. This tensile force acts in the presence of a random positive ion bombardment of the point by molecular and atomic ions of oxygen, nitrogen, carbon monoxide and carbon at a rate of about 500/sec; the recovery time of the surface may have values up to and beyond 1 msec.

The random nature of the bombardment is shown in Fig. 1(*a*), where it is seen that the interval between successive ion impacts may lie within the recovery time of the surface; when this happens, the surface gas is violently disturbed, the field current rises abruptly, and it may take several msec for the surface to come to a stable equilibrium. This behaviour is consistently repeatable on letting the system down to air and re-pumping; it must result in the stripping off of the topmost loosely held gas layer (or layers). An excellent example of the fluctuating currents caused by three impacts within the recovery time of the surface is shown in Fig. 1(*b*).

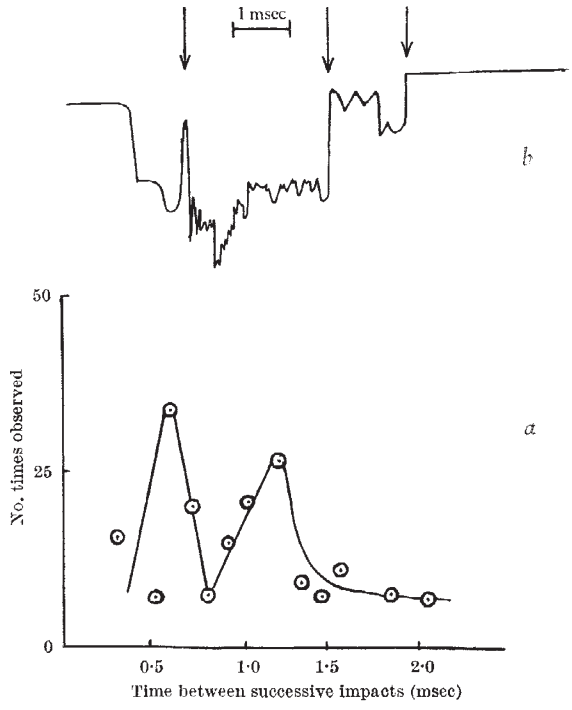

Fig. 1

A value for the cohesive energy of the gas can be derived by considering the momentum of the impacting particle to be shared between the gas and the tungsten/oxide substrate, according to their binding energies B_g and 10 eV, respectively. At 2 kV the incoming momentum is proportional to $1{\cdot}6 \times 10^7$, so that $1{\cdot}6 \times 10^7\, B_g/10 \times 10^7$ represents the velocity taken up by the gas, as a unit, since there are approximately 10^7 atoms on the sensitive surface of the point. An average recovery time of 1 msec corresponds to gas moving over the linear dimensions of the point, 10^{-5} cm, with a velocity of $1/10^2$ cm/sec, hence $B_g \sim 1/16$ eV per atom. This value is in reasonable agreement with that calculated by London for the Van der Waals energy for molecular crystals of oxygen as given in Seitz—1·69 kcal/mole.

It is interesting to note that an oxygen ion at a distance of 10 Å from the tip would have a field of 10^9 V/M associated with it and would act on a single surface atom with a force of the same order as that of the external field. The ensuing field emission and neutralization of the ion by an electron from the conduction band of the semiconducting tungsten/oxide contact should result in an Auger transition involving the emission of a secondary electron into the gas.

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