Excitation Processes and the Theory of the Arc Discharge

No satisfactory theory exists to account for the current transfer at the cathode of an arc the cathode material of which has a low boiling point, such as mercury or copper. Whereas thermionic emission can account for the mechanism of arcs with cathodes of high boiling point, such as carbon and tungsten, this seems highly improbable for substances which boil far below their emitting temperature. Field emission of electrons[1], current transfer by positive ions only[2], and other suggestions[3] have been made; but they cannot account for both the observed high current densities[4] of order 10^6A./cm.^{2} and the low cathode fall, which can be smaller than the ionization potential of the cathode material[5].

A new theory is proposed in which electrons are released from the cathode by excited atoms the potential energy of which exceeds the work function. The intensely luminous 'cathode spot' suggests that, immediately above the current-carrying area of the cathode, there is a region of excited metal vapour the density of which is many orders of magnitude greater than elsewhere in the arc. There is a net flow of neutral atoms through this region which can be regarded as the difference between the gross cathode evaporation and the return of atoms to the cathode by back-scattering. Most of the returning atoms will be excited, but because of the short distance they have to travel they will reach the cathode surface before they have time to radiate. Consequently they will behave like metastable atoms, which are known to cause emission of electrons with a very high yield[6]. The emitted electrons gain energy in the cathode fall, which is so small that they can only produce excitation of the vapour and then carry the arc current into the adjoining positive column. Ionization in the vapour will occur by collisions between excited atoms. The positive ion current to the cathode need only be sufficient to provide the space charge for the cathode fall and supply energy for evaporation. The presence of a foreign gas should not affect appreciably this cathode mechanism.

Known measurements[7] on a mercury arc give a rate of evaporation of 3×10^{-4} gm./coulomb; for a current density of 10^6 amp./cm.^{2}, this is equivalent to 10^{24} atoms/cm.^{2} and sec. The gross evaporation and hence back-scattering may be at least an order of magnitude greater, namely, 10^{25} atoms/cm.^{2} and sec. If most of the latter are excited, such a flow should be ample to release 10^6 amp./cm.^{2} of electrons from the cathode.

The cathode fall can be estimated from a balance of the rates of production and loss of excited states in the cathode spot. The losses include radiation, ionization, diffusion towards the positive column and, most of all, back-diffusion to the cathode. If the latter accounts for at least half the total loss, then the cathode fall would be less than twice the principal excitation potential of the cathode vapour. For mercury this excitation potential is 4·9 V., and thus the cathode fall should be rather less than 10 V., as observed.

The proposed model is in accord with a previous theory of the retrograde motion of cathode spots in transverse magnetic fields[8]. In addition, it is proposed that the high current density in arc spots is due to the self-magnetic field operating in the ionized vapour. A detailed treatment of the contraction and the emission processes will appear in the near future.

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Optical Aspherizing by Vacuum Evaporation

J. Strong and E. Gaviola[1] described the preparation of optical aspherics by vacuum evaporation. They used layers of aluminium to parabolize mirrors, but found that with thickness greater than 5λ the coating began to show a bloom and scatter light. Apparatus for the production of refracting elements by this method was described by L. G. Schulz[2]; Schulz used lithium fluoride and was able to produce aspheric films giving a retardation $[(n-1)t]$ of up to 2·5λ. At that thickness the films began to peel off. The retardation could be doubled by covering the lithium fluoride film with a layer of collodion and evaporating on to this another layer of lithium fluoride.

We have now prepared zinc sulphide films giving retardations up to 30–40λ mercury green light, the upper limit of thickness not having yet been reached. The films did not show any signs of weathering or instability over periods of one to two months. Longer-term experiments are in progress. There was also no change in optical thickness.

Using ordinary quality zinc sulphide containing appreciable impurities (including more than 1 per cent silicon), the films are yellowish when viewed by transmission; but a layer giving about 30λ retardation would transmit about 85 per cent of the light in the 5000–7000 A. region incident upon it, allowing for surface reflexion losses. Films made from a much purer sample of zinc sulphide are less coloured. This material is being investigated further.

The reflexion losses at the zinc sulphide – air and zinc sulphide – glass interfaces are considerable, but they can be reduced by using anti-reflexion coatings. Two-layer coatings for each interface were computed using zinc sulphide and magnesium fluoride, and were found to work well in practice.

The present apparatus is similar in principle to that of Schulz. The distance between the boat and the plate or lens on to which the film is evaporated is about 11 in. Glass plates of diameters up to 4 in. can be accommodated at present. The boat can be recharged several times, so that a film of retardation up to 10λ can be deposited without breaking the vacuum.

The films produced show very good revolution symmetry. In a typical case, at a point of 25λ retardation which lay on a circle of diameter 8 cm., the eccentricity was 0·05λ retardation. The direc-