

Pre-breakdown electron production in a spark gap is related to the time-lag of sparking, and considerable information on electron production can be obtained from analysis of time-lag data; under certain conditions, the inverse of the statistical lag is a measure of the rate of electron emission from the cathode under the given gap conditions. In this way, the rates of electron emission from cold nickel and tungsten electrodes, in short parallel-plate gaps in the atmosphere, under the influence of spark over-voltages up to 200 per cent, have been investigated in this laboratory, using a technique which permitted the effect of a single initial electron to be recorded. The spark current was suitably limited so that effects such as electrode erosion were negligible. The investigation showed that the surface condition and previous treatment of the cathode exerted great influence on the rate of pre-breakdown electron emission. A most significant result was that enhanced cold emission occurred when the average electric field F ($= V/d$) in the gap was of the order of 10^6 volts/cm., and it is not easy to see how electron emission of the magnitudes observed could be field emission from a metal, as it is well known that such emission requires fields of 10^7 volts/cm. or more.

In order to investigate this problem, the rate of electron emission i from the cathode was measured for various values of gap voltage V , and a relationship between i and V was found. For a cathode of nickel, oxidized by previous sparking in air, considerable electron emission of the order of 10^4 electrons per second was found for values of the macroscopic electric field in the gap of the order of 10^5 volts/cm. The relationship between i and V experimentally established was:

$$\ln(r) = -A/V + B, \quad (1)$$

where $r = id^2/V^2$.

The following interpretation of this equation indicates that the mechanism of emission of these initiatory electrons was a field process.

The Fowler-Nordheim³ field emission equation can be written:

$$\ln(i/F^2) = -(6.8 \times 10^7 \varphi^{3/2})/F + \ln(CS),$$

where S is the area of the emitting surface, and $C = 38.8 \times 10^{12} (\mu)^{1/2}/(\mu + \varphi) \varphi^{1/2}$, in which φ is the work function of the surface, and μ is the parameter of metallic electron distribution in the Fermi-Dirac statistics.

This equation can be written:

$$\ln(r) = -(6.8 \times 10^7 \varphi^{3/2} d)/V + \ln(CS). \quad (2)$$

Thus, equations (1) and (2) are the same when $A = 6.8 \times 10^7 \varphi^{3/2} d$, giving the same slope in the $\ln(r)$, $1/V$ curves; and $B = \ln(CS)$, giving the same intercept on the $\ln(r)$ axis.

Thus, the experimental equation (1) leads to estimates of φ , the work function of the source from which the electrons were extracted, and also of S the area of the emitting surface. Values thus obtained are $\varphi = 0.1$ volt, and $S \sim 10^{-14}$ cm.².

If the value of $\varphi \sim 4.5$ volts for common metals is used in equation (1), then to obtain the measured emission of 10^4 electrons per second, F must be of the order of 10^7 volts/cm.

In this work, F , given by V/d , is of the order of 10^5 volts/cm. Consequently, we have alternative conclusions to draw; either F in these experiments at the surface of the electrodes is some hundreds of times greater than the macroscopic applied field, and the electrons are released from the pure metal, or φ ,

the effective work function of the surface layer, is much less than 4.5 volts, and the electrons are released from that surface.

Schottky⁴ has estimated a maximum value of about 10 for the intensification of the local field at microscopic points on the electrode surface, and substitution of this value in equation (1) gives $\varphi = 0.48$ volt.

On this view, then, the electrons could not have come from a pure metal, still less from a metal with an electronegative monomolecular oxide surface film with a still higher effective work function. The most reasonable suggestion is that the electrons come from the surface oxide layer itself, and these estimated values of φ and of the emitting area of approximately molecular cross-section suggest oxygen ions as the source. These results, therefore, support the view that the cathode oxide layer, always present on electrode surfaces in air, is the source of electrons, extracted by field emission, which can initiate impulse sparks.

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¹ Llewellyn Jones, *Proc. Phys. Soc.*, **62** B, 366 (1949).

² Cobine and Easton, *J. App. Phys.*, **14**, 321 (1943).

³ Stern, Gossling and Fowler, *Proc. Roy. Soc.*, A, **124**, 699 (1929).

⁴ Schottky, *Z. Phys.*, **14**, 63 (1929).

Ultra-Violet Absorption Spectra of Gallium and Indium Monofluorides

RECENT work on equilibria involving aluminium monohalides¹ suggested that gaseous gallium and indium monofluorides might be formed by reaction of the metals with aluminium trifluoride. This has proved to be so, and we have been able to photograph the absorption spectrum of gallium fluoride at about 1,000° C., and that of indium fluoride at about 1,400° C.

Vibrational analyses of the three band systems for each molecule expected by analogy with the other halides² have been completed. The constants derived are given in the accompanying table.

State	ν_e	ω_e	$x_e \omega_e$	$y_e \omega_e$
GaF	C ¹ I ₁	47364 ⁶	541 ⁹	8 ⁹
	B ³ I ₁	33427 ⁷	666 ⁴	4 ⁸
	A ³ I ₀	33098	659 ⁴	4 ⁰
	X ¹ Σ ⁺	0	623 ²	3 ⁴
InF	C ¹ I ₁	42808 ³	463 ⁸	7 ⁴
	B ³ I ₁	31257 ⁷	572 ⁶	3 ⁴
	A ³ I ₀	30442	571 ⁶	3 ⁴
	X ¹ Σ ⁺	0	534 ⁷	2 ⁵

The assignment of states A and B as ³I₀ and ³I₁ respectively is supported by the fact that the bands of the systems $A-X$ are single-headed, whereas those in $B-X$ possess two heads. The ¹I₁ states converge rapidly to give dissociation limits at about 6.3 eV. for gallium fluoride and 5.7 eV. for indium fluoride. A more detailed account of these systems will be published later.

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² Miescher and Wehrli, *Helv. Phys. Acta*, **1**, 331 (1934).