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LETTER TO THE EDITOR

Field emission studies of the lanthanum hexaboride/tungsten system

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Abstract. Tungsten deposited with lanthanum hexaboride (LaB_6) is of interest, as LaB_6 is characterized by the properties of an excellent electron emitter. This note reports a field emission study of the LaB_6/tungsten system prepared by depositing LaB_6 *in situ* on to a tungsten tip. The observed maximum decrease in the average work-function was from 4·52 eV (clean tungsten) to 1·75 eV (LaB_6 deposited on tungsten). The field emission pattern of tungsten deposited with LaB_6 shows preferential adsorption around the {111} and {100} planes.

Lanthanum hexaboride (LaB_6) possesses excellent electron emitter properties such as a low work-function, a high melting point and resistance to ion bombardment (Lafferty 1951). It has therefore been very important in the development of cathodes, especially for producing high-brightness electron probes (Ahmed and Broers 1972, Ahmed and Nixon 1973, Verhoeven and Gibson 1976). Field emission from a single crystal of LaB_6 has also been attempted by many workers (Elinson and Kundintseva 1962, Windsor 1969, Shimizu *et al* 1975). We therefore thought it would be interesting to evaporate LaB_6 on to a tungsten field emitter and study the change in work-function caused thereby. The purpose of this letter is to report these observations.

Sealed-off field emission tubes, with tungsten emitters with a four-probe arrangement for measuring the temperature at the tip, were used in this investigation. The tubes were constructed and vacuum processed in accordance with the method described by Gomer (1961). Each tube had a titanium getter in a side bulb and also contained a tungsten filament cataphoretically coated with LaB_6, as a source of adsorbate.

Initially, a good vacuum of the order of 10^{-10} Torr was obtained; this was confirmed by the clean pattern of tungsten as shown in figure 1 (plate). The source was then heated to evaporate the material on to the tip. The material deposited on one side of the tip is shown in figure 2 (plate). It was 'well spread' on the tip because of surface migration when the tip was heated to about 1300 °C for 30 s. This was judged from the pattern shown in figure 3(*a*, plate). At this stage, a comparison of the slopes of the Fowler–Nordheim plots for clean tungsten and the composite surface at room temperature shows the lowering of the workfunction to a certain extent. It was found that any further heating at 1300 °C did not appreciably change either the pattern or the work-function. Further heating above 1300 °C caused evaporation of the adsorbate and a gradual increase in the work-function as measured at room temperature, tending towards the value for clean tungsten. A series of patterns at different stages during thermal desorption of adsorbate from the tip are shown in figure 3(*a*–*d*).

A number of such cycles were repeated. The magnitudes of the work-function obtained for the 'well spread' adsorbate on the tip for these cycles were found to be 3·95, 3·44, 2·96 and 1·75 eV; that of clean tungsten was taken to be 4·52 eV. The decrease in the magnitude of the work-function can be attributed to the increased amount of the adsorbate tending to form a unit coverage for which the work-function would be a minimum (Good and Muller 1956). At this stage we are unable to specify the adsorbed species, but these are likely to be LaB_6 as inferred by Oshima *et al* (1974).

The significant points arising from this work are stated below.

(i) In each cycle of operation, the adsorbate spreads uniformly over the tip when it is heated to about 1300 °C for 30 s.
(ii) Further heating at 1300 °C does not cause an appreciable change either in work-function or in the appearance of the pattern shown in figure 3(*a*).
(iii) Figure 3(*a*) shows preferential adsorption of the adsorbate around the {111} and {100} planes.
(iv) In each case adsorption of LaB_6 causes a significant decrease in the work-function with an observed maximum reduction in the value of 2·77 eV.

Further work on the adsorption of LaB_6 on tungsten and on other refractory metals is in progress and will be published soon.

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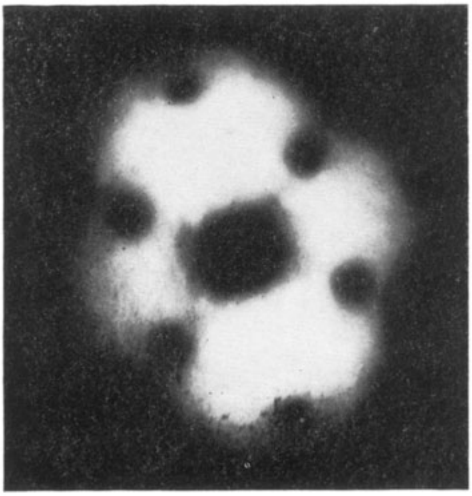

Figure 1. Field emission pattern of clean tungsten (5 kV).

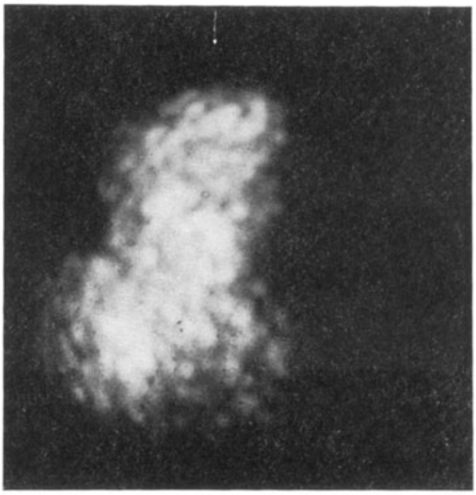

Figure 2. Field emission pattern of tungsten after LaB_6 had been evaporated on to it (4 kV).

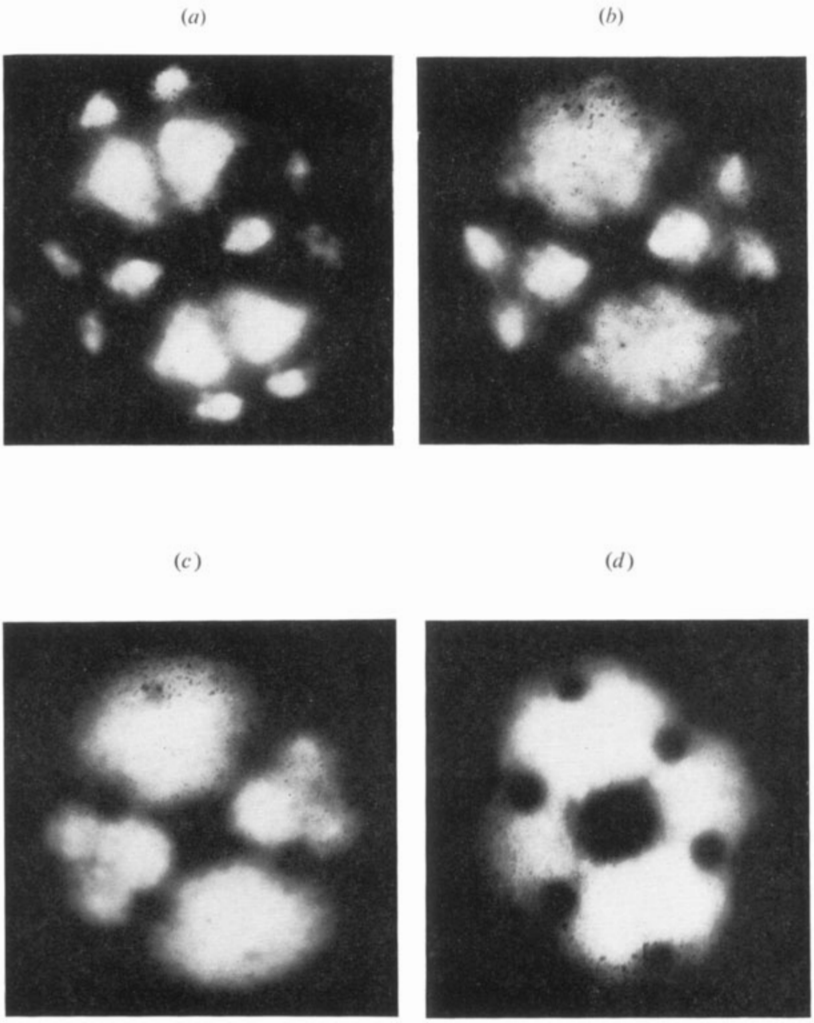

Figure 3. Field emission patterns of the same tip at room temperature after it was heated to (*a*) 1300 °C for 30 s (4 kV); (*b*) 1900 °C for 20 s (4·2 kV); (*c*) 1900 °C for 2 min (4·6 kV); (*d*) after flashing at 2200 °C (5 kV).