On the Field Emission from Ni, Gd, and EuS Evaporated on to Tungsten

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Tungsten tips coated with Ni, Gd and EuS are studied in a field electron microscope. Reproducible patterns are observed. The Gd-patterns show epitaxy with the W-substrate. With tempered tips the work functions are:
Ni 5.1 ± 0.3 eV, Gd 3.2 ± 0.3 eV and EuS 3.1 ± 0.3 eV.

For the production of polarized electrons by field emission from materials with spin polarized bandstructure [1–4] the field emission from Gd, Ni and EuS is of interest.

1. Experiment

Investigations with a field electron microscope (FEM) showed that it is probably impossible to obtain clean tips from Gd wire (supplied by Koch Light, England) in the usual way by etching. With Gd all known methods of cleaning the tips in situ failed, and even an ion bombardment in a gas discharge proved unsuccessful. The method used was that of [5].

An arrangement was therefore set up (Fig. 1) to coat pure tungsten tips in UHV with the substance in question and observe them in the FEM. Gd was evaporated from a tantalum furnace, Ni from a MgO furnace heated by electron bombardment. Tantalum is the material with the greatest resistance to Gd [6]. EuS was evaporated by direct electron bombardment. From a position above the furnace the emision tip can be shifted to the FEM by means of magnets. The pressure measured during the investigations was mostly a few 10^{-10} Torr.

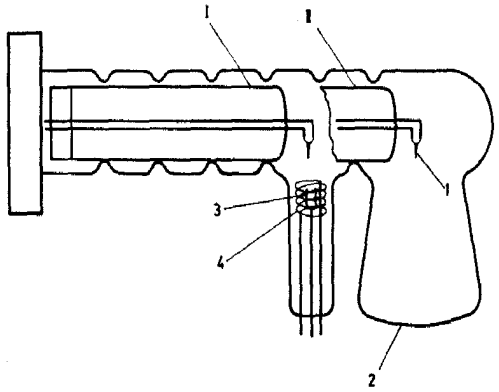

Fig. 1. Scheme of the experimental set-up. I Tip-position for evaporation. II Tip-position for FEM. 1 — Tip; 2 — screen; 3 — oven, 4 — cathode for electron bombardment.

2. Results

Figures 2 *, 3 and 4 show the clean W tip prior to coating, after coating with Gd, and after tempering of the coated tip respectively. Symmetric FEM pictures as in Fig. 4 are observed when the coated tips are heated to about 800 °C. The temperature can readily be reproduced by means of the heating current for the tip loop (Fig. 1). The temperature is micropyrometrically determined to within ±50 °C. If the Gd-coated tips are heated to over 1100 °C, the symmetry of the FEM picture gradually deteriorates. Tempering of the tips at somewhat different temperatures reproduces the patterns observed by other authors [7] for Y and Gd.

Our experience with EuS was similar in principle. Fig. 5 shows a W tip prior to coating with EuS, Fig. 6 after, and Fig. 7 the FEM picture of the same tip after annealing to about 1200 °C.

3. Work Function Measurements

The work functions have been evaluated via the Fowler-Nordheim (FN) plots of the clean tungsten and the covered tips. From the slope of the FN-plots we calculated the work functions relative to the work function of W, assuming that the tip-geometry is not altered. By averaging over the results from different tips the influence of a change of the tip-radius is eliminated, but, of course, the influence of the surface geometry is still seen in the results of freshly evaporated tips. The results for Ni, Gd and EuS are shown in Table 1.

Work function (eV)	Ni	Gd	EuS
Freshly evaporated	3,4	2,4	1,8
Tempered	5,1	2,7 [a]; 3,2 [b]	3,1

Table 1.

The experimental error of the absolute values is ±0.3 eV. "Freshly evaporated" is characterized by FEM patterns as shown in Figs. 3 and 6. Similar patterns are obtained from Ni. The "tempered" values correspond to Figs. 4 and 7 for Gd [b] and EuS respectively. The Gd [a]-structure has been published earlier [7]. For Ni we observed two different patterns, which may be due to a (111)-orientation or a (100)-orientation. The slight difference of the work function of the patterns is within the experimental error.

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* Figs. 2—8 see pp. 1980 a and b.

4. Discussion

Highly reproducible FEM pictures of Gd and EuS were obtained by evaporation and tempering in UHV. The Gd pictures (Fig. 4) are correlated to the hexagonal structure of this material and via epitaxy to the W structure (Fig. 2). Fig. 7 shows the main symmetric elements of Figs. 2 and 4. The epitaxy is obvious. The Gd grows with its (0001) plane on the (011) plane of the W. But as the angle between the (112) planes of the W is about 67° the Gd with its 60° angle between the (0112) planes has to find an arrangement (Fig. 8).

The work functions of the tempered tips are in good agreement with the result of FEM [8] and photoemission [12] measurements for Ni, of photoemission [9, 12], FEM [5] and contact potential measurements [10] for Gd and contact potential measurements for EuS [11].

In point of view of the measurement of spin-polarization of either field-emitted or photoemitted electrons from the studied materials the great changes of work function and emission paterns due to annealing conditions are of interest, as it may be expected that the degree of polarization may be altered as well.

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Strahlungsdefekte in organischen Einkristallen*

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Herrn Prof. Dr. W. HANLE zum 70. Geburtstag gewidmet

Hochenergetische γ-Strahlen können in organischen Einkristallen orientierte Radikale erzeugen. Vor kurzem erschienen einige Arbeiten über EPR-Messungen solcher Radikale in bestrahlten Anthracen-Einkristallen [1–5]. HARRAH und HUGHES [2] und INOU [3] ordneten das beobachtete Vierlinien-Spektrum dem Dibenzocyclohexadienyl-Radikal zu, das durch Anlagerung eines H-Atoms an Stellung 9 oder 10 entsteht. Das komplementäre Radikal, mit einem dissoziierten H-Atom, wurde nicht gefunden.

An dieser Stelle wird über Strahlungsdefekte an reinen Einkristallen von Anthracen, Fluoren und Carbazol berichtet.

Als intensive Strahlungsquelle diente die von 45 MeV-Elektronen in einem Wolframtarget erzeugte Bremsstrahlung. EPR-Spektren wurden mit einem X-Band-Spektrometer der Firma AEG aufgenommen. Um Sättigungsverbreiterungen der EPR-Linien zu vermeiden, wurde die Mikrowellenleistung auf 10 μW abgeschwächt.

Unter diesen Bedingungen wurde in Anthracen bei einigen Kristallorientierungen eine bisher in der Literatur nicht angegebene Triplett-Hyperfeinstruktur gefunden mit einer Kopplungskonstanten $a_{\mathrm{II}} = 4 \pm 0{,}5$ Gauss (Abb. 1). Sie läßt sich durch Wechselwirkung des freien Elektrons mit den Protonen der äußeren Benzolringe erklären. Wegen der geringen Auflösung konnte nicht entschieden werden, ob es sich um eine Wechselwirkung mit zwei oder vier äquivalenten Protonen handelt mit entsprechenden Linienintensitäten von 1 : 2 : 1 oder 1 : 4 : 6 : 4 : 1.

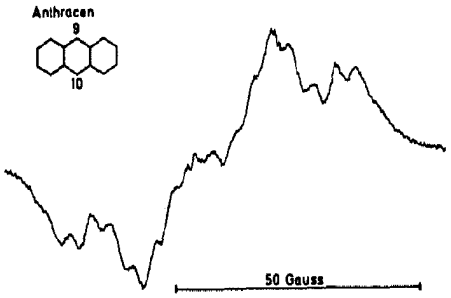

Abb. 1. EPR-Spektrum von einem bestrahlten Anthracen-Einkristall.

In den heterozyklischen Systemen Fluoren und Carbazol wurden im Gegensatz zum Anthracen je zwei verschiedene Radikale gefunden. Fluoren besitzt orthorhombische Kristallsymmetrie [6] mit der Raumgruppe P_{nam} und vier Molekülen in der Einheitszelle. Aus Symmetriegründen erwartet man, daß in der *ac*- und in der *bc*-Ebene die EPR-Spektren aller verschieden orientierten Radikale zusammenfallen.

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