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THE INVESTIGATION OF FIELD IONIZATION PROCESS OF He GAS ABOVE THE SEPARATE SURFACE ATOMS OF TUNGSTEN EMITTERS

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Summary. Field ionisation current, generated above the single atom sites of (110) tungsten plane, in FIM working with low pressure He gas, as a function of field strength has been measured, by magnetic sectoral atom-probe FIM using. The field ionisation current from 6-14 Å size area, has been registered by channel plate detector, the field strength was calibrated on the base of best image conditions. The measurements has been done for metastable atoms sites on the steps of (110) plane, as well as for ledge atoms of top and next disks for [110] oriented emitter. The curves measured for metastable positioned atoms, displays a distinct maxima correspondence the BIP value, whereas the remaining curves showe a quite different character.

Introduction. The present paper is a short information about possiblities of investigations of par excellence local surface phenomena as field ionisation processes above the separate atoms sites by magnetic sectoral atom probe FIM using. This contribution should be a modest completion to the local surface phenomena investigations described by other authors [1,2,3].
Apparatus. The 60° magnetic sector atom probe FIN, built by authors and described previously [4,5] has been used to investigating of the field ionisation of the helium gas, above separate atom sites of (110) tungsten micromonocrystal plane. This apparatus has probe hole aperture angle amounts 16 mrad. At this angle of view the analysed surface area size is about 6 Å for the emitter radius 400 Å. Good vacuum conditions /partial pressure of gaseous contaminations not exceeding 5·10⁻¹⁰ hPa/ were obtained. The mass resolution ratio $\Delta M/M$ of the instrument was about 1/400, the detection system sensitivity was the order of 10⁻¹⁵ A. This system working with microchannel plate multiplier of the Philips G 640-50 type. The pressure of imaging gas during the experiment was $4 + 6.10^{-5}$ hPa. The ion image was observed by using the external image intensifier of the EMI 9912 type and registered by both photographic camera and video-tap recorder [6].

Experimental procedure and results. Field ionisation current, originated above the single atom metastable sites of the ledge of (110) plane [7], for the first and second net plane steps, as a function of applied field was measured. The measurements were made on the [110] oriented, well evaporated emitters with tip radii 360 Å, 470 Å and 870 Å, at the field range 3.5 to 5.5 V/Å and temperature 80 K. Comparatively the similar measurements were made for normal, ledge positioned atom sites on the first and second (110) plane net steps, as well as for adsorbate object /probably CO molecule/ situated similarly. The last measurements were made on the emitter with tip radius 420 Å. On the Fig.1 a, b, c, d the photographs all the investigated objects are presenting.

![Fig.1. The photographs of investigated object: a/ the metastable atom on the second net step of the 360 Å emitter; b/ adsorbate on the second step and the four normal positioned atoms on first and second step /R = 420 Å/; c/ metastable position, second step /R = 470 Å/; d/ metastable position, first step /R=870 Å/](image-url)
The results of the field ionisation current measurements above the all metastable sites and additionally for adsorbate shows Fig. 2. The field strength was estimated on the base of criterion, that the best image field amount to $4.4 \, \text{V/Å}$ [8]. On Fig. 3, the results of the same measurements for the normal ledge sites on the 1-st and 2-nd steps are presenting.

**Fig. 2.** The field ion current as a function of field strength for metastable atom sites for different tip radii

**Fig. 3.** The field ion current as a function of field for ledge atoms sites

**Discussion.** This experiment was carried out on the emitters with tip radii a few hundred Å, the greatest one was about 900 Å. For the angle aperture of probe hole system 16 mrad the limiting analysed areas are presenting on Fig. 4/the greatest area with diameter $\sim14$ Å/ and on the Fig. 5/the least one with diameter $\sim6$ Å/. It is well visible, that in the first case the analysed area covers more than twenty surface atoms, in the second, about four surface atoms and investigated one. In the both limiting causes the character of the measured curves /Fig. 2/ is the same, what prove that all measuring current was originated above metastable atom sites.

Figures 4 and 5 a,b suggest an observed metastable sites on the both emitters and two possible normal ledge sites. It is confirmed by author's observations, that only advanced position /left on the Fig. 5b/ is visible in the FIM working with pure He gas. It is worthy of being mentioned that according to author's evaluations, only one to about
25 and one to about 15 atoms sites are visible for the 900Å and 350 Å emitters respectively, for [110] direction vicinity.

The results of field ionisation current measurements, from so small areas, were described in physical literature very scanty. The photometrical measurements by Müller and all [9] were made for the greater region of (111) plane, Plummer and Rhodin [10] were measured the field ion current from steps of (100), (112) and (110) tungsten emitter planes, however without the BLV marked and evaluation of the investigating area. The most comparable results contains the paper of Chen and Seidman [11], but the measurements are presenting only to the BIV value, being in agreement with author's results.

Fig. 4. The metastable position on the 1-st step (011) plane on the emitter with tip radius 870 Å. The probe hole covers area about 14 Å diameter.

Fig. 5. a/ The metastable position on the surface of the second step, $R = 360 \AA$, analysed area has 6 Å diameter; b/ normal ledge positions of investigating atoms. Only left site is visible in experiment.
Authors are still incapable to interpret the obtained results, particularly the difference in the character of curves present on the Fig. 2 and Fig. 3. Although the possibility of existence of the indistinct maxima of field ionisation current, originating above bright spot of about 22 Å diameter, at electrical field 3 to 5 V/Å was predicted by van Eekelen with the aid of a simple gas dynamical calculation [12], the presenting results are rather different, especially in the case of the metastable atom sites. It is possible that observed effect is caused by external field interaction with the localized tungsten orbitals of d-type, especially with the one completely free and one partially occupied orbital from the metastable situated atom, which is interacting with three nearest neighbours only [13]. Although, distinguished properties of metastable positioned atoms to electrical field were found previously by Müller and Krishnaswamy [14] /they observed only one Jason's peak in the ion energy spectrum for ion originating above metastable atom sites/, the distribution of the local electrical field and symmetry of the interaction between external field and free orbitals is not clear yet.

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References


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