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CROSS-CORRELATION OF THE FIELD EMISSION FLICKER NOISE FROM COADSORPTION LAYERS W(110)K-Ni

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Abstract - The cross-correlation (CC) of the field emission flicker noise from two probed edge regions of the covered W(110) plane was determined for a constant potassium dose coadsorbed with various nickel doses. The CC coefficient and the noise power were strongly reduced at medium nickel coverages. The cross-correlation and the noise power are discussed in relation to the work function changes of the W(110)Ni system.

I - INTRODUCTION

In 1982 Ogbrowski and Kleint initiated cross-correlation (CC) investigations of field emission flicker noise (FEFN) by the determination of the correlation of the adsorbate induced field emission current fluctuations from two probe holes /1/.

The correlation is described by the cross-correlation function (CCF) which combines two field emission current fluctuations in the following way:

\[ R_{xy}(\tau) = \lim_{T \to \infty} \frac{1}{T} \int_0^T i_x(t) i_y(t+\tau) \, dt, \]  

(1)

where \( i_x(t), i_y(t) \) are two field emission current records detected from two small areas, \( \tau \) denotes the time delay for one of the records, and \( T \) is time duration.

The CCF related to the noise power is called the normalized CCF:

\[ \varphi(\tau) = R_{xy}(\tau) \sqrt{\frac{i_x^2(t) i_y^2(t)}{t}}, \]  

(2)

In the first CC measurements which concerned the noise of potassium submonolayers on the W(110) plane a profound coverage and temperature dependence of the CC coefficient \( \varphi(\tau=0) \) was obtained /1/. The subsequent CC investigations of potassium submonolayers and of potassium-nickel coadsorption layers across the W(112) plane provided many interesting results on the dependence of the CCFs on temperature.
and the potassium and nickel coverage /2-4/. The mechanism of the cross-correlation is not well known. For the range of small potassium coverages the surface diffusion model was proposed and for medium coverages - a soliton or domain propagation mechanism was suggested /3,5,6/. To verify or postulate a reasonable CC mechanism more experimental results concerning this problem are needed. In this paper some results of the influence of preadsorbed nickel atoms on the CC across the W(110) plane of potassium submonolayers are presented.

II - EXPERIMENTAL

The CC measurements were carried out using a sealed-off glass FE tube supplied with nickel and potassium sources. The experimental arrangement and electronics were similar to the one previously used /2-4/. The vacuum was about \(3 \times 10^{-10}\) Torr \((4 \times 10^{-8}\) Pa) during the experiment. The lowest temperature of the emitter could be achieved by cooling the emitter loop with a dry ice-alcohol mixture.

The currents of two small probed areas were selected from the total emission by two probe-holes in the screen of the tube. The currents were detected by two Faraday collectors. After amplification the a.c. components of the collector currents were correlated by a stochastic analyzer* to determine the CC.

In this work the probe holes were set at the (110) plane of the field emission image by means of the external magnetic deflection. The probe areas were localized at the edges of the (110) plane with a diameter of about 300 Å symmetrically to its center. The distance between the areas with diameters of \(\sim 100\) Å was about 300 Å. The direction between the probe regions was almost parallel to the [112] direction (fig. 1a).

The experiments were performed in the two following ways. (1). The nickel dose (given in minutes) was deposited on the thermally cleaned emitter at room temperature. Then a constant dose of potassium corresponding to the average coverage \(8 = 0.6\) was deposited on the nickel layer and the CC was measured at room temperature. This procedure was repeated with different nickel doses. (2). The CC measurements were also carried out at dry-ice temperature after the deposition of successive nickel doses on the emitter with a \(8 = 0.6\) potassium submonolayer kept at dry-ice temperature. (The average coverage \(8 = 0.6\) corresponds to coverage \(8_{110} \approx 0.6\) on the (110) plane /7/.

III - RESULTS

In general the cross-correlation monotonically decreased with the increase of delay time \(\tau\) both at room temperature and dry-ice temperature for a potassium coverage of \(8 = 0.6\). In fig. 1b two records of profound and weak CCFs are presented. (The CCFs strongly depended on the positions of the probe-holes relative to the (110) plane center.)

Fig. 2 shows the following dependences on the deposition time \(t_{Ni}\) of nickel onto the W(110) plane with the emitter held at room temperature:

* Two correlators were used, D ISA Elektronik (Denmark) Type 55A06 and NSA-1000 (KFKI and EMG, Hungary).
Fig. 1(a) - Field emission pattern of the tungsten emitter - two white circles on the (110) plane approximately correspond to the position of the probe-holes; (b) - examples of the CCF records.

(1) of the high voltage $U$ at a constant collector current $I_c = 3$ nA measured at the center of the W(110) plane for the emitter without potassium; (2) of the CC coefficient $\rho(o)$ across the W(110) plane with the ($\Theta = 0.6$) potassium submonolayer; (3) of the noise power $(\delta \xi)^2$ at the edge of the W(110) plane measured during determination of the CC; (4) of the noise power $(\delta \xi)^2$ measured at the center of the W(110) plane with the potassium submonolayer $\Theta = 0.6$.

It is seen from fig. 2 that $\rho(o)$ reaches zero at the interval of deposition time $3 \text{ min} < t_{Ni} < 7 \text{ min}$. Minimum of the $U$ vs $t$ curve appears at $t_{Ni} = 5 \text{ min}$. The $\rho(o)$ drop is accompanied by the noise power $(\delta \xi)^2$ decrease. At the time range $t_{Ni} < 7 \text{ min}$ $\rho(o)$ and $(\delta \xi)^2$ first increase and then $\rho(o)$ continues the increase with a decrease of $(\delta \xi)^2$.

Similar relations between $\rho(o)$, $(\delta \xi)^2$ and $U$ were observed at dry-ice temperature, when nickel was successively deposited on the emitter with a preadsorbed potassium submonolayer of $\Theta = 0.6$ (fig. 3). In this case the nickel source operated approximately two times as efficient as in the experiment of fig. 2 making that $U$ in fig. 2 and fig. 3 saturates almost at the same nickel density.

IV - SHORT DISCUSSION

Adsorption of nickel on the large W(110) plane causes at first a drop of the work function $\psi_{110}$ and then its rise. In the range of decreasing $\psi_{110}$ nickel is adsorbed as islands of pseudomorphic structure /8/. The minimum of $\psi_{110}$ occurs at the completion of a loosely packed pseudomorphic layer. The rapid increase of $\psi_{110}$ beyond the minimum is accompanied by the formation of the coincident densely packed layer /8/. The adsorption of nickel on the W(110) plane of the field emitter is also connected with the appearance of a minimum in the $\psi_{110}$ ($\Theta_{Ni}$) dependence /9/, [Błaszczyszyn, R., to be published (B)]. As it was found the depen-
Fig. 2 - The figure shows different dependences on the nickel deposition time $t_{\text{Ni}}$ for the W(110) plane at room temperature: (1) the high voltage $U$ at a constant collector current $I_c$ measured at the center of the W(110) plane without potassium; (2) the CC coefficient $g(\gamma=0)$ across the W(110) plane with a $(\theta=0.6)$ potassium submonolayer; (3) the noise power $(\delta I)^2$ at the edge of the W(110) plane measured during determination of the cross-correlation, $I_c=3\ \text{nA}$; (4) the noise power $(\delta I)^2$ at the center of the W(110) plane with a potassium submonolayer $(\theta=0.6)$, $I_c=3\ \text{nA}$.
To obtain correct $(\delta I)^2$ values the constant $C=6 \times 10^5\ \text{A}^2$ should be taken.

Fig. 3 - Nickel coverage dependences at dry-ice temperature: (1) of the high voltage $U$ at constant collector current $I_c=6\ \text{nA}$ at the center of the W(110) plane without potassium; (2) of the CC coefficient $g(\theta)$ across the W(110) plane; (3) of the noise power $(\delta I)^2$ at the edge of the W(110) plane measured simultaneously with the CC determination, $I_c=6\ \text{nA}$; (4) of the noise power $(\delta I)^2$ at the center of the W(110) plane, $I_c=6\ \text{nA}$; Nickel was deposited on the emitter with $\theta=0.6$ potassium submonolayer at dry-ice temperature. To obtain correct $(\delta I)^2$ values the constant $C=6 \times 10^5\ \text{A}^2$ should be taken.
dence of the high voltage $U$ on the nickel coverage at a constant collector current $I_c$ reflects the $\theta_{110}$ change. At room temperature nickel does not escape from the (110) plane of the tungsten emitter to its surroundings /B/. Although the cross-correlation was measured of the coadsorption nickel-potassium layer and a certain mobility of single nickel adatoms on the W(110) plane at room temperature should take place /10/, we think that the FE noise and CC effects at higher nickel coverages are created mainly in the potassium adlayer adsorbed on top of the nickel layer. This supposition is based on the fact that lowering the emitter temperature from room temperature to dry-ice temperature (at which the mobility of nickel adatoms can be neglected) reduced essentially $(\delta t)^2$ and $\gamma(t)$ but gave a similar relationship between the $(\delta t)^2$ and $\gamma(t)$ dependences to the one at room temperature.

An essential change of the way of deposition of the coadsorption layer (namely deposition of nickel on the emitter with the $\theta = 0.6$ potassium layer at dry-ice temperature) led also to similar $\gamma(t)$ and $(\delta t)^2$ results (fig. 3). The sequence of deposition of potassium and nickel did not essentially affect the $\gamma(t)$ and $(\delta t)^2$ results. Therefore we think that FEFN and CC effects were generated in the potassium submonolayer adsorbed on top of the nickel-tungsten layer. This coadsorption picture would also result from the much higher nickel-substrate bonding than the potassium-substrate one /11,12/.

The decrease of $\gamma(t)$ together with the decrease of $U(\theta_{110})$ is connected with the drop of FEFN represented by $(\delta t)^2$. This relationship can be understood as follows: the $(\delta t)^2$ drop is a result of the reduction of the adparticle (potassium) mobility. Adsorption of nickel in the form of islands at this nickel coverage should be responsible for this due to the roughing effect /8/. The increase of $\gamma(t)$ and $(\delta t)^2$ at the coverage range of the $U(\theta_{110})$ rise can be a result of the smoothing effect when the densely packed nickel layer is formed. The CC of K submonolayers on the smooth W(110) plane is characterized by very high values of $\rho(t)$ /1/. In this paper the highest $\rho(t)$ value occurs at the nickel density which, according to ref /8/, corresponds to almost the atomic density of the Ni(111) plane (figs. 2 and 3). The interpretation of high CC of the K submonolayer on the smooth substrates is an open problem. From fig. 2 and 3 is seen that in the higher nickel coverage range the increase of $\gamma(t)$ is accompanied by the decrease of $(\delta t)^2$. This can indicate that the mechanism of the correlation should not be considered in terms of the diffusion model /3,6/ but rather in terms of another one (soliton model) /3,5/.

The deposition of nickel on the W(110) plane at dry-ice temperature led also to a relatively high CC from which one can conclude the formation of the densely packed nickel layer at this temperature. This is also in a good agreement with the FE results /B/ which provided similar $\theta_{110}(O_{Ni})$ values for the high nickel coverages obtained by the deposition of nickel at 78 K (without spreading), 300 K and 375 K.

A more extensive discussion of the presented $\rho(t)$ and $(\delta t)^2$ results in terms of the CC's soliton model /3,5/ and Gomer's FEFN theory /13/ could not be done without taking into account additional autocorrelation and $\theta_{110}$ measurements for the coadsorption K-Ni system.

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