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A NEWLY DEVELOPED FEM-FIM-IAP SYSTEM(1)

W. LIU and D.M. REN*

Department of Physics, Huazhong Normal University, Wuhan, Hubei, People's Republic of China

*Center of Fundamental Physics, University of Science and Technology of China, Hefei, Anhui, People's Republic of China

ABSTRACT- A new version of the FEM-FIM-IAP combination system is being built in the Institute of Quantum Optics and Field Emission at the Huazhong Normal University. With a specially designed convertible chevron channel plate assembly, kinds of power supplies and a pulsed laser, the system can work not only as the conventional FEM, FIM or IAP but also in somewhat new modes. Using it we can get comparable data from the same sample in different ways. It has wide applications. In particular, it provides us a means to approach the effects of the applied field and laser pulse on the results obtained with the field emission technique.

1-INTRODUCTION

In 1967 the great pioneer of this area, E.W. Muller, described his genius creation of the atom probe field-ion microscope (AP FIM) (1) by combining the FIM with a time-of-flight mass spectrometer. This made possible the chemical identification of different species observed in the field-ion microscope. Since then the power of the FIM has been markedly increased and several variants of the design of the atom probe have been developed and reviewed(2). Specially the following improvements made it one of the most powerful instruments available for the study of surface science and material science. They are the adopting of the energy compensating section to improve the mass resolution(3), introducing the imaging atom probe (IAP) to get the elemental maps of the specimen surface(4), using the laser pulse in place of the conventional high voltage pulse (HVP) to remove the particles from the specimen to bring in significant advantages(5), and the improvements in the area of data acquisition and analysis(6).

As in many other areas, the unique potential of the field emission technique has been demonstrated in surface chemistry. For example, with the FEM it has been shown that the hydrogen and oxygen reaction on Rh surface proceeds by a Langmuir-Hinshelwood mechanism at the boundary between islands of immobile O atoms and mobile H atoms(7). With the IAP and the AP FIM, the synthesis of

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ammonia on transition metals(8) and methanation on Rh surface(9) are directly revealed to take place by dissociative mechanism under experimental condition. To make a combined system of both will enhance such power. On the other hand, we directly detected the dissociation of CO on Rh stepped surface with the AP FIM(10), but Gorodestkii et al reported that they could not find any trace of the dissociation of CO on Rh surface with the FEM even up to 1000°k(11). In order to resolve the paradox, one of the things we can do is to repeat the experiments in both ways but on the same sample. Such consideration stimulated us to build a combined system as the present one. In addition, as we know that during the chemisorption process the particles in the solid surface are likely to relocate and experience charge density redistribution as the surface bond forms. This chemical bond involves sharing (covalent bond) or transfer (ionic bond) of electrons between the adsorbates and the substrate. When we study the chemisorption by the FEM and the IAP, the opposite external fields would be expected to affect the chemisorption differently. So the comparable results provided by the new system may not only solve some particular problems but may also give us the information to understand the effects of the applied fields.

2-INSTRUMENTATION

Basically the new system is a combination of the IAP and the FEM. The main components and the structural features are shown in figure 1 and figure 2. Since the IAP and the FEM have been introduced in more detail elsewhere(4, 12), we only summarize our model below.

The vacuum system of the FEM-FIM-IAP consists of dual UHV stainless steel chambers to allow pretreatment and rapid change of the specimens. The pump system is a mixture of "oil" and "none oil" ones to achieve high efficiency and to lower the cost. The main pump is an ion pump. It maintains the UHV of the main
chamber to the $10^{-8}$ Pa range without the contamination of the regurgitation from the "oil" pump. There is a diffusion pump as boost pump. It only operates at need, for example, during the change of the specimens or after exposing the main chamber to atmosphere. The volume of the main chamber is rather small; the vacuum of it can achieve the range of $10^{-6}$ Pa within a few hours after the exposure of it to atmosphere.

When we study a sample in different modes, to the same sample, the field strength established by the applied voltage in the FEM mode is usually only a few tenth of that in the FIM mode. In order to get good field-ion image, the samples should be sharp enough. Therefore, in the FEM operation, the voltages applied to the samples are mostly too low to make the channel plate detector to work in the level part of its characteristic plot. In other words, the gain of such detector varies with the energy of the emitted electrons. To ensure the accuracy of the measurement of the emitted current, we designed and assembled a convertible detector with home-made channel plate. When the channel plate with its frame is rotated onto the screen by an airproof rotation axis and is fixed by clamps, the detector works as a conventional image intensifier, signal detector and gated image viewer. When it is turned away and grounded, the screen collects the impinging charges directly.

As pointed out(4), we have to make a compromise between the mass resolution and the visible angle of the sample surface. We are more interested in the microstructure and the local properties where the field emission technique has its unique power. We chose longer flight path, 17 cm, to limit the intrinsic error to 2 percent with a 70 mm diameter flat detector. But the image half an-
The temperature of the sample is controlled by a cold finger and a closed-cycle helium-gas cryogenerator. The specimen can also be heated to high temperature by electric current when the applied high voltage is turned off.

The sample is mounted on a goniometer which permits the sample to be rotated by 30° about two orthogonal axes with the apex of the needle at the center of the rotation. With it we can identify the orientation of the sample and examine its topograph without difficulty.

The system can be considered as a HVP/PL IAP system extended to have the FEM function, it has the basic features of the both. In view of the performance features, we would like to make few more comments on the reason for combining the IAP and the FEM.

We prefer the IAP because it can collect data either from the whole visible portion of the specimen or only from a small region with a probe hole. It can map the origin of certain detected particles. If there is a trace of surface reaction, we should be able to detect it and locate it. Comparing with the AP FIM, we need much less time to collect data with the IAP and the data is more statistically reliable. The shortcoming of it is its limited mass resolution.

In relation to the FEM, besides its own applications, it can also perform many important functions in the combined system. For example, with it we can check the cleanliness of the specimen that often gives rise to the confusion in the interpretation of the results. We can measure the coverage of the adsorbates by the FEM but not by the IAP. In certain case, we may use the FEM as an alternate method to identify the adsorbate, etc.

In return, analyzing the composition of the "first layer" with the IAP, we can prove the origin of the change in work function of the specimen.

Obviously, the most important feature of the new system is the ability to provide the comparable information about the same sample. Besides the comparison of the results obtained by the FEM mode, the FIM mode and the IAP mode, it can also provide some information which we can not get from the conventional FEM, FIM or IAP.

For example, when the system works in the FEM mode, we can impose the HVP or LP to the negative bias voltage. That is, the system operates in a dynamic mode. Comparing the result with that got by the conventional HVP/PL IAP mode, we should get new information on the effects of the applied field or the laser pulse.
As another example, we can study the effects of the external field in the following way: one applies a positive HVP in place of the dc voltage onto the sample to establish the ionization field and uses the synchronized laser pulse to remove the particles from the specimen when the system operates in the IAP mode. Changing the amplitude, the frequency or the width of the HVP, we will get the information on the external field. Comparing the result with that of the conventional PL IAP and that of the corresponding FEM mode, we should get further information about the applied field effects.

From the discussion above, it is obvious that the newly developed system greatly expands the power of any one of its components but costs much less than their sum. So the efficiency and the economy are also among the features of the new system.

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REFERENCES

(2) For example; M.K. Miller, Int. Mat. Rev., 32 (1987) 221 and references there.
(6) For example;