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13. ABSTRACT (Maximum 200 words)

The AFOSR DURIP grant has helped us to setup a dual-chamber multi-technique (UPS and XPS) surface analysis system, purchased from Omicron Nano Technology. This is the most important equipment we have obtained in recent years. This instrument allows us to measure Ultra-violet Photoelectron Spectroscopy (UPS) and X-ray Photoelectron Spectroscopy (XPS), which are indeed the first such system at UCLA campus. The instrumentation was installed in May, 2004, and fully operational in July. Some important results have produced from this instrument even for its short operation time. These results are reports in the report in detail.

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Final Performance Report

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Integrated Instrumentation System for the Surface Characterization of Organic Electronic Materials and Devices

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This AFOSR DURIP grant has significantly helped UCLA in several aspects and projects. From the equipment point of view, this is the first complete system at UCLA, and the whole campus has already benefited from this instrument tremendously. (Please see the attached letters at the end of this report.) From the research point of view, several projects on organic electronic materials and devices, such as organic photovoltaic device, polymer light-emitting devices, and organic bistable devices etc. have already taken the advantage from this piece of instrument. The instrument was shipped to UCLA in early May, 2004, and was installed and tested in June. It became fully operational in July, after some debugging process.

1. System introduction

A dual-chamber multi-technique surface analysis system was purchased from Omicron NanoTechnology. This is the most important equipment we have obtained in recent past. This instrument allows us to measure Ultra-violet Photoelectron Spectroscopy (UPS) and X-ray Photoelectron Spectroscopy (XPS).

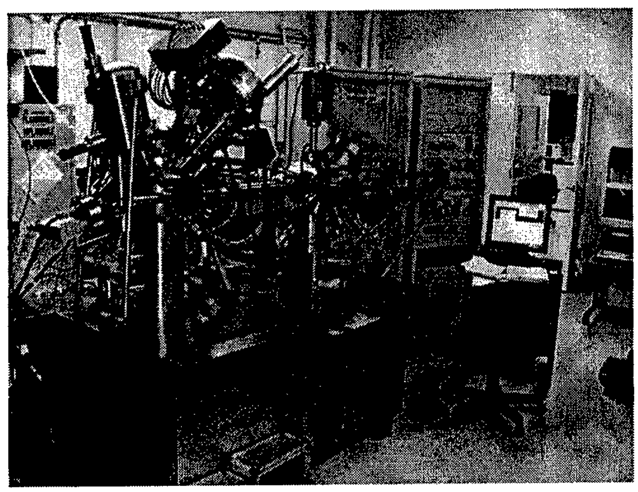

Fig. 1 Dual-chamber multi-technique surface analysis system.

The system has two ultra-high vacuum chambers and the vacuum in both the chambers can reach 1.0 x 10^{-11} mBar. Fig. 1 is the overall view of the system. The vacuum is achieved by two rotary pumps, two ion getter pumps and two titanium sublimation pumps.

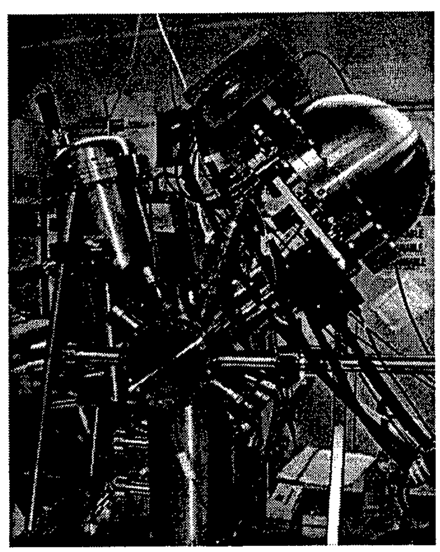

Fig. 2 Analysis chamber of the system

Analysis chamber (Fig. 2) is the main part of the system. It contains monochromatic X-ray source, high density UV source, and hemispherical electron spectrometer for XPS/UPS measurement. It also has a cold cathode sputter ion source to clean substrates or decrease the thickness of thin films. An electron beam source is also installed to neutralize the positive charge when the conductivity of the sample is insufficient to discharge the sample during the XPS/UPS measurement. The resolution of the XPS is 0.6eV and the maximum count rate is 228kcts/sec. The resolution for UPS is about 0.1eV and the maximum count rate is 7.7Mcts/sec. The position of sample holder on the manipulator in analysis chamber is controlled by four step motors that make it convenient for sample transfer and measurement.

For XPS/UPS measurement, it is important to have "in-situ" sample preparation capability to avoid unnecessary contamination. Our system is equipped with a sample preparation chamber to deposit metal and/or organic films in the same vacuum condition. Preparation chamber (Fig. 3) has two evaporation sources. One is thermally heated Knudsen-cell for organic material, and another one is electron-beam heated source for metal deposition.

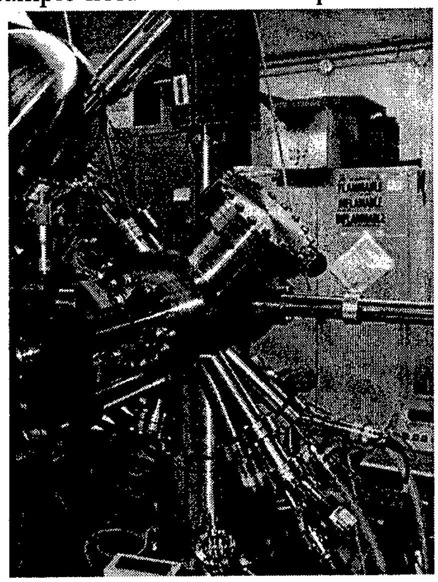

Fig. 3 Preparation chamber

The power supplies and controllers for all the electrical instrument, vacuum gauges, chiller for cooling the X-ray and UV source, controllers for pneumatic valves, etc., are installed in two electrical racks. (Fig. 4) The measurement of XPS/UPS is controlled by a PC with the special software (EIS) from Omicron.

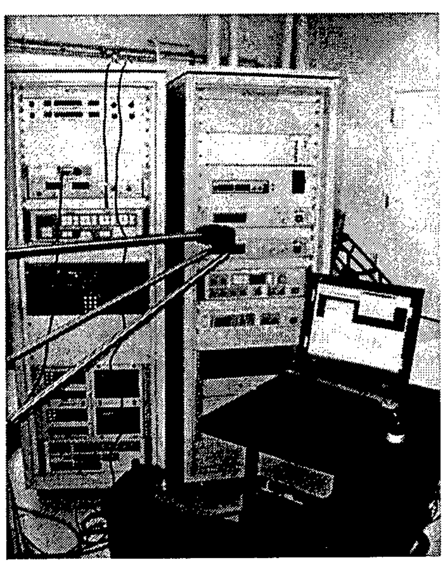

Fig. 4 Electrical racks and PC

2. Experiments results

In the process to train ourselves and familiarize with XPS/UPS, we invited Prof. Yongli Gao from Department of Physics & Astronomy at University of Rochester to our laboratory for one week. He is a world famous physicist on experimental surface physics, electronic interactions and morphology of interfaces and interface formation, transient behavior of charge transfer across interfaces, and interfaces in organic semiconductor devices. He has helped us to fine tune the system to its best performance.

We have already obtained some very important results, even though the system has been up and running only for a few months. Here are some examples:

(1) Identification of sp^2 and sp^3 identification (a joint work with Prof. Wudl)

Carbon of the sp^2-type (able to make one double bond with another atom) is responsible both for the high conductivity and smaller bandgap (black color) of graphite and for the way it is arranged in layers. This, in turn, accounts for the lubrication and other chemical and physical properties of graphite. Benzene is also sp^2-hybridized. We did some co-operation on this work with Prof. Fred Wudl at Chemistry & Biochemistry Department of UCLA. They synthesized some new material (HCCP15B) and we identified the carbon type of the material.
On the other hand, the sp^3 carbons (all single bonds) are what make diamond, an insulating, transparent, and very hard material. The last kind of carbon hybridization, sp (or "sp^1", one triple bond or two double bonds at the same atom), would make acetylene. From those preliminary experiments, it was known that the material is mostly composed of sp^2 carbon, which would explain, among other things, its dark color. In Fig. 5, XPS spectrum of c1s shows that the carbon in HCCP15B is more like the carbon in graphite rather than carbon in polyethylene. We know that the carbon in graphite and polyethylene is sp^2 and sp^3 style, respectively. This is the reason that HCCP15B shows good conductivity.

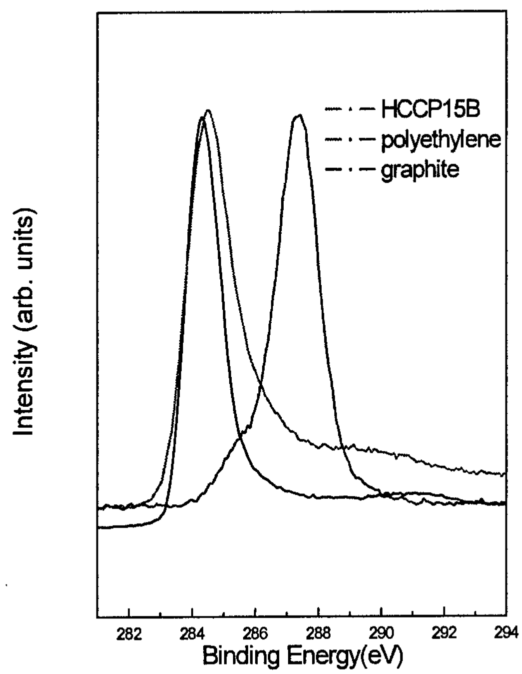

Fig. 5. C1s XPS spectrum of polyethylene, graphite and HCCP15B.

(2) Charge transfer in Au-nanoparticle

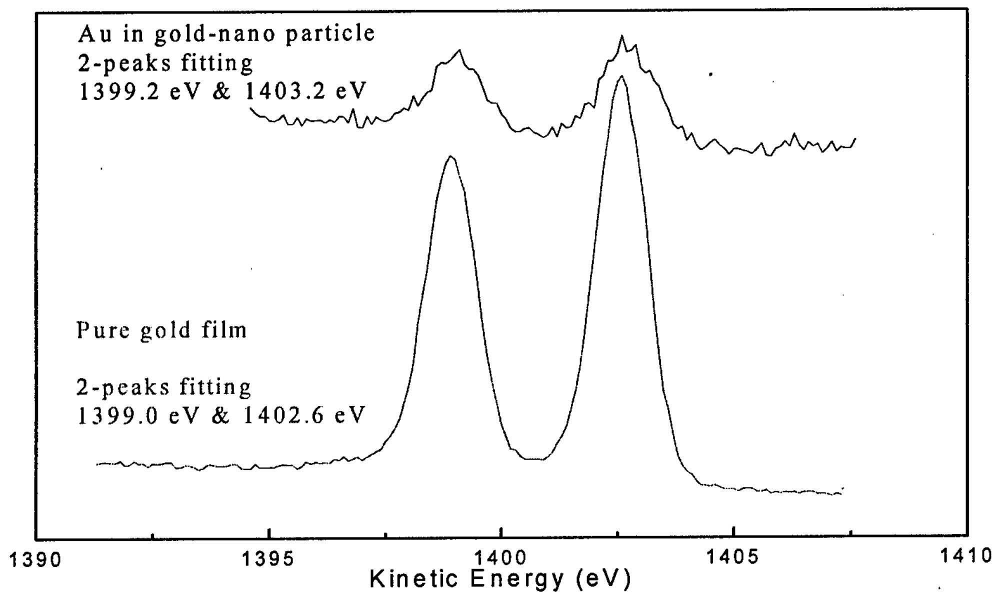

Fig. 6 XPS spectra of Au 4f in pure gold film and Au-nanoparticles

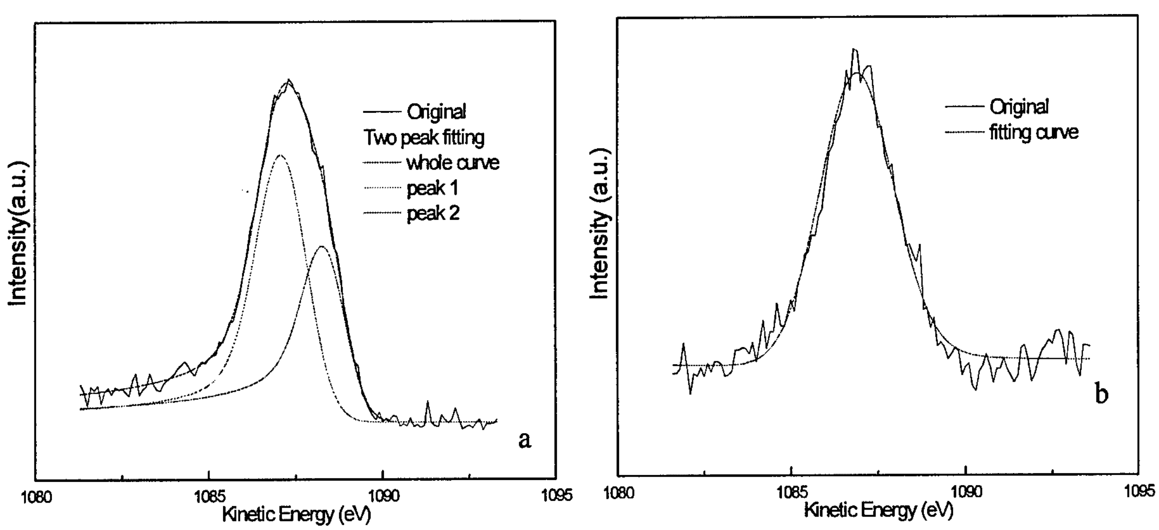

Fig. 7 XPS spectra of N1s in pure polyaniline (a) and composite of Au and polyaniline (b)

We also investigated the charge transfer between polyaniline and Au nano-particles. Fig. 6 is the results obtained from XPS/UPS system and we can see that the XPS Au 4f spectra are different in pure gold film and in Au-nanoparticles, which means Au in Au-nanoparticle has some charge transfer or chemical reaction with other elements. The Au 4f in Au-nanoparticle shifts by 0.2eV to high kinetic energy (low binding energy). Fig. 7 is the XPS N1s spectra of pure polyaniline and of the Au and polyaniline composite. The N 1s in polyaniline is a two-peak structure (there are two chemical states of Nitrogen in polyaniline), the position of the peaks are 1087.19eV and 1088.45eV, while the N 1s in Au-polyaniline composite cannot be decomposed to two peaks, the peak position is 1086.65eV. The N 1s shifts at least 0.5eV to low kinetic energy comparing with the Nitrogen in polyaniline. Au 4f and N 1s shift to opposite direction, so there is some charge transfer between gold and Nitrogen atoms, they form coordinate bond. These results can help us to understand the mechanism of our polymer system.

Summary:

This XPS/UPS system has help UCLA to enhance its research capability and training students. We look forward to productive results from this instrumentation. Several professors who was the initial results from this machine have provided their supporting letter at the end of this report.

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August 18, 2004

Dr. Charles Lee
AFOSR/NL
4015 Wilson Blvd, Room 713
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Dear Dr. Lee:

I am writing to thank the Air Force Office of Scientific Research for support of the photoelectron spectrometer recently assembled by Professor Yang Yang and his students. The OMICRON XPS/UPS system has already proven to be invaluable in helping solve some important scientific problems. My group is exploring high density, organic memory devices in collaboration with Prof. Yang and his students. We have developed a method for growing nanofibers of the conducting polymer polyaniline and decorating the fibers with gold nanoparticles of about 1 nm in diameter. Using this new material sandwiched between two electrodes, Professor Yang's group has demonstrated a remarkable non-volatile memory effect with a greater than 3 order of magnitude difference in conductivity between the on and off states. A critical question involves the mechanism of charge storage. Using the OMICRON XPS/UPS system has enabled us to discover that in the on state the gold nanoparticles have become negatively charged and the nitrogen on the polyaniline has become positively charged. This indicates that the mechanism involves charge tranfer and is helping us make rapid progress in this important area. Clearly the XPS/UPS in its early days is already playing an important role in advancing this field and we believe it will become even more important as we realize its full capabilities.

Sincerely,

Richard B. Kaner
Professor of Chemistry and
Professor of Materials Science & Engineering

RBK/klf

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August 17, 2004

Dr. Charles Lee
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Dear Dr. Lee,

I am writing to express my enthusiasm (and envy!) for Prof. Yang's OMICRON XPS/UPS system. Besides standard XPS features, his unit's sample preparation allow us to thermally evaporate organic molecules onto a biological substrate. I have great plans to utilize this system and look forward to working with Prof. Yang to develop the capabilities. Please call me if you require any more details or if you have any questions.

Sincerely,

Benjamin

Ben Wu, DDS, PhD
Vice Chair, Department of Bioengineering