PHOTOELECTRON SPECTROSCOPY

Gas Detection for Life **Model AC-3**

Features

- Atmospheric pressure operation (unique in the world)
- Estimate work function, ionization potential, density of states (DOS)
- Measure thickness of thin films on the material surface (less than 20 nano-meters)
- Measure the sample of powder and liquid
- Low photo - excitation energy (5.0 - 6.20eV)
- Measurement for just 5 minutes
- Easy sample introduction and removal
- Full computer control

Riken Keiki developed simple photoelectron spectrophotometer in atmospheric pressure conditions by applying the open counter as an electron detector. Invented by Rikagaku Institute (Physical and Chemical Research Institute, Japan), it has been marketed mainly to study organo-electronic materials for organic EL and photocopying.

Now, we have developed a special optical system able to irradiate the above 6.2eV far ultraviolet rays to the sample, although it is said that it is impossible to perform in air.

Features:

- Easy to measure the Density of States (DOS) around the highest occupied orbital, work function and ionization potential.
- Information for tiny surface on nanometer order and tiny thin film thickness (0-20nm) can be measured
- Powder and liquid samples which are unable to bring into the vacuum also can be measured
- Measurement taken in just 5 minutes (when measured in 5.0 - 7.0eV energy search range with step 0.1eV)

Applications:

- Measurement of ionization potential on organic materials used in solar cell, fuel cell organic EL and organic TFT
- Measurement of ionization potential on photocatalyst
- Evaluation of MgO film quality on plasma display panel (PDP)
- Measurement of electronic states for carbon nanotube and fullerene
- Measurement of electronic states on carbon thin film and diamond thin film
- Measurement of electronic states for cosmetics, medicine and chemicals
- Measurement of ionization potential on sensitive materials
- Measurement of contamination and oxidized film thickness for electrode, lead frame, contacts, steel plate, silicon wafer and compound semiconductor wafer
- Measurement of work function on metallic materials for various electrodes

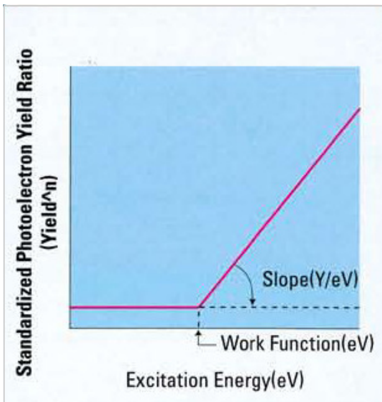
RIKEN KEIKI

Basic Features:

When a surface is bombarded with a slowly increasing amount of ultraviolet energy, photoelectrons start to emit at a certain energy level. This energy level is called the "Photoelectron Work Function" or "Work Function".

When the photoelectron output is plotted on an X/Y axis, with horizontal axis as the UV energy applied, and the vertical axis as the standardized photoelectron yield ration (YieldÛn, or Y), the result is a line with a specific slope of degree (Y/eV).

* 1 standardised photoelectron yield ration (YieldÛn) is the ratio of photoelectron yield achieved per unit of UV energy (light) applied to the sample surface, where "n" represents the strength of the UV evergy applied. The "n" value is reported as 0.5 for metal and as 0.3 to 1 for semiconductor surfaces, based on the ability of the surfaces to emit electrons.



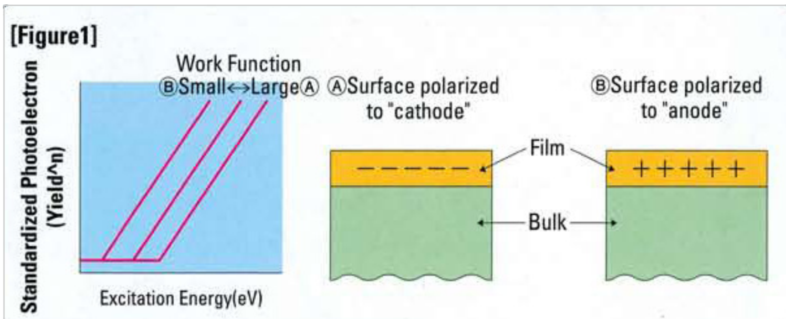
Basic Analysis Method:

1. The Work Function is a particular value for each substance or material, and represents the valence belt maximum of each substance and ionization potential.

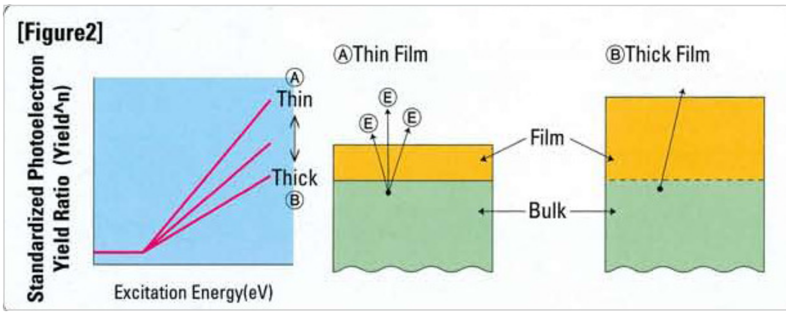
2. The Work Function changes depending on the surface condition of the material. If there is a thin film, contamination or absorption on the surface of the substance, the Work Function changes, depending on the polarization condition (Figure 1).

3. The slope is related to the quantum efficiency of the photoelectron emitting substance and the thickness of any film on the substance surface (within several hundreds of A).

4. Slope changes depending on the film thickness on the bulk surface. As a film gets thicker, it is more difficult for the photoelectrons to escape through the film, so they are not emitted to be counted. The slope (quantity) of the emitted electrons becomes less (Figure 2).



[Figure1]



[Figure2]

5. The Work Function changes depending on the crystal direction of the substance surface.

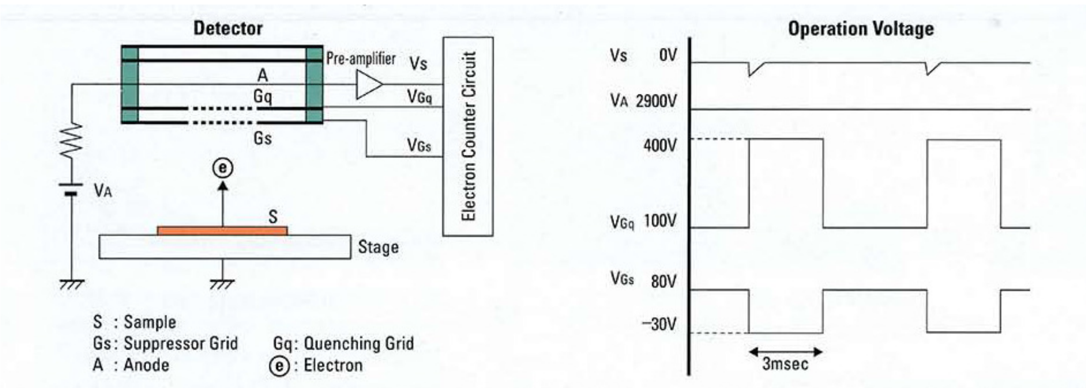
6. If the substance surface is damaged, the initiation point (starting point) of the Work Function becomes scattered.

7. Bulk materials like ceramic hardly emit photoelectrons. If the ceramic has a film that easily emits photoelectrons, the slope changes depending on the film thickness.

Measurement Principle:

An electron emitted from a sample surface moves several µmetres toward the detector (this is called the "Mean Free Path of electron in air"). After that, the electron attaches to an oxygen molecule, and it travels to Anode (A) through Suppressor Grid (Gs) and Quenching Grid (Gq). The intensity of the magnetic field is increased by high voltage . When the electron approaches the Anode (A), the speed is accelerated by the intensified magnetic field. Then, an electron slide is triggered. As a result, the energy from a single electron is amplified up to 105 - 107 times, and the discharge pulse signal is generated in the preamplifier output (Vs). When the low energy electron counter receives a discharge pulse signal it transmits the electron detection signal to the controller, and changes the Quenching Grid Voltage (VGq) and the Suppressor Grid voltage (VGS) as shown in the diagram below. The Quenching Grid erases the discharge by lessening the voltage gap to the anode (A). The Suppressor Grid captures the positive ion generated at discharge, and prevents the electron from entering into the detector as the discharge is erased.

Principle Diagram:



Operation

The intensity of light emitted from the ultraviolet lamp enters the nitrogen substitution chamber and then enters the spectrometer after being controlled by a light adjuster in the chamber. The spectrometer selects the desired wavelength (energy selection) (*1) of UV light, and irradiates to atmosphere through CaF2 window and is condensed to the surface of the sample. As a result, photoelectrons are emitted from the surface (several A to hundreds of A) of the sample, due to photoelectric effect. (*2) The photoelectrons are counted by an open counter and processed by personal computer. The data is then displayed on a CRT

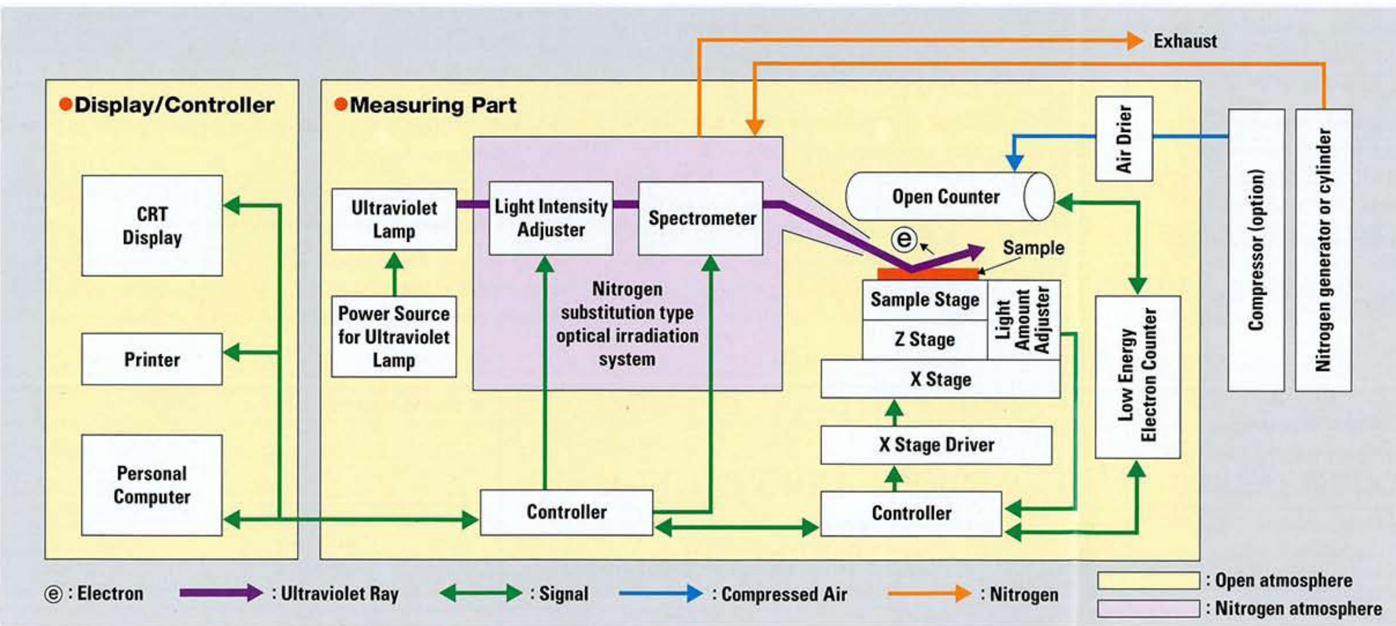
*1 Light that has one specific wavelength has one specific energy. The conversion formula is as follows:

$$E_{(ev)} = \frac{h \cdot c}{\lambda} = \frac{1240}{\lambda_{(nm)}}$$

λ : Wavelength h : Plank's constant
E : Energy c : Eight velocity

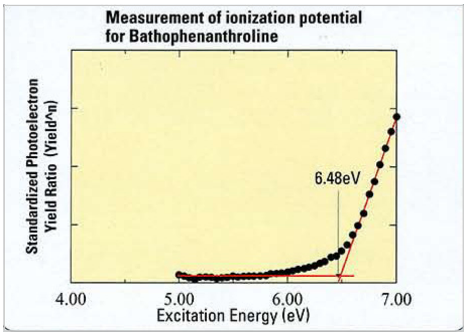
*2 Photoelectric effect: The physical phenomenon that causes some materials that absorb light to emit electrons from the surface.

Structure:

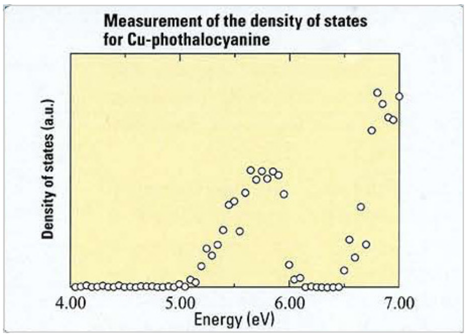


<u>Measurement Examples</u>:

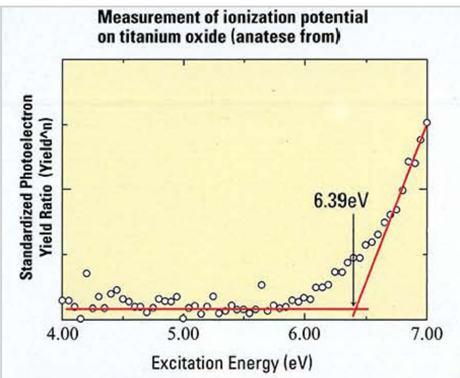
1. **Application: Measurement of HOMO level on materials used in organic EL and organic TFT**
   For charge moving devices such as organic EL, organic transistor, solar cell and photocopying drum etc, it is important to measure their Highest Occupied Molecular Orbital (HOMO) energy level. We have succeeded in expanding the limit of excitation energy up to 7.00eV (177nm). As a result of this expansion, the material which could not be measured with the AC-2 can now be measured.



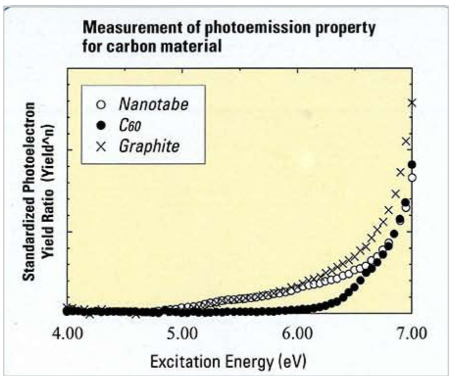
2. **Application: Measurement of Density State on work materials**
   Properties of many substances are lead from the Density of States (DOS) (the number of conditions for photoelectrons in some energy). This DOS is quoted from the differential value of photoelectron yield ratio. It is trying to understand substances of properties logically by comparing the measurement results for DOS with the calculation results of the molecular orbital.



3. **Application: Measurement of ionization potential on photocatalytic materials**
   The oxides to be used as photocatalyst and dielectric have a rather high photoemission threshold energy and they are difficult materials to measure with the AC-2. Now we can examine the behaviour of photoemission in a wide range with the AC-3, even in these materials.



4. **Application: Measurement of photoemission properties for carbon nanotube and fullerene**
   Carbon nanotube and fullerene are noted as the new electronic materials. The electron emission property is important to use the electrode for electron emission. The electronic states around the HOMO are also important to use for electronic devices. We can measure the emission property and the density of states of these materials with the AC-3.



Model AC-3

Specifications:

Model	AC-3
Measuring Principle	Low energy electron counter method
Electron Detector	Open counter
Ultraviolet Lamp	Deuterium lamp with lamp house
Spectrometer	Nitrogen substitution type grating method monochrometer
Energy Search Range	4.0 - 7.0eV (310 - 177nm)
Operating Condition	15 - 35℃, below 60% RH
Repeatability Precision (Standard Deviation)	Work function 0.02eV
Measuring Time	Approx 5 minutes (when measuring in 5.0 - 7.0eV energy scanning range with step 0.1eV)
Radiating Ultraviolet Rays	Spot size: 2 x 5mm (slit 1.00mm) Maximum intensity: above 100nW (at 5.9eV)
Sample Size	30 x 30mm max (max thickness 10mm), 1 sample measurement
Utility Required	Power source: 100 VAC, 50/60 Hz, 5A (max) Compressed Air: 0.5 - 0.6MPa, 5L/min Nitrogen Gas: 0.1MPa, 2L/min (while measured), 5L/min (while purging)
Software	AC-3 for Windows (functions to measure photoelectron spectrum, radiation light spectrum, threshold energy etc)
Approvals	CE
Overall Dimensions	Approx 740 (w) x 1080 (h) x 680 (d) mm (with casters)
Weight	Approx 120 kg

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