PHOTOELECTRON SPECTROSCOPY

Gas Detection for Life **Model AC-2**

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)
- Energy selectable UV source
- Low photo - excitation energy (3.40 - 6.20eV)
- Compact desktop type
- Easy sample introduction and removal
- Full computer control

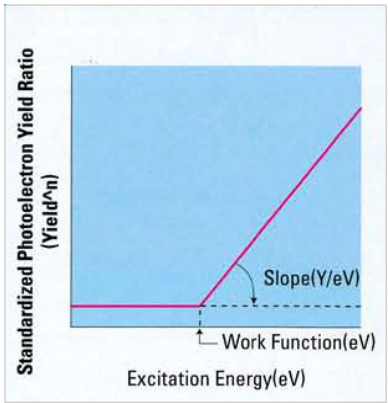
Characterisitics:

- Contact-free and non-destructive analysis of sample surface in air. Large samples and powders cannot be measured in a vacuum. However, these can be measured by the AC-2 since the AC-2 measures in air and no vacuum is used.
- Measurement of contamination or film thickness on sample surface in several A to hundreds of A.
- Measures Work Function and Ionization Potential by applying variable ultraviolet energy to the surface, which excites photoelectron and then measures the photoelectron energy released.
- Since the UV light energy is relatively weak, no change or destruction occurs on the sample surface.

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 (Yield^n, or Y), the result is a line with a specific slope of degree (Y/eV).



* 1 standardised photoelectron yield ration (Yield^n) 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.

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Basic Analysis Method:

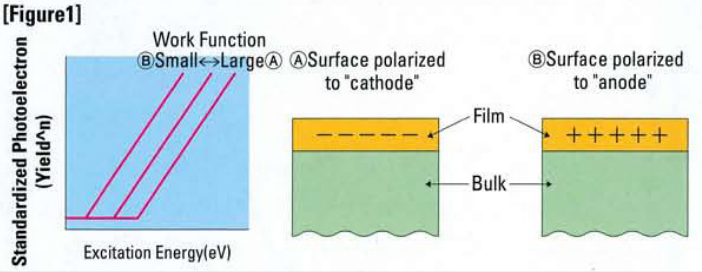
1. The Work Function is a particular value for each substance or material, and represents the valence belt maximum (ionization potential) of each substance.

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).

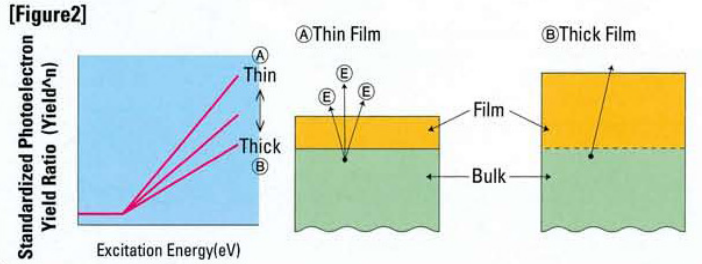
3. The slope is related to the quantum efficiency of the photoelectron emitting substance and the thickness of any film on the substance surface (within several hundreds of A).

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.

Program Contents:

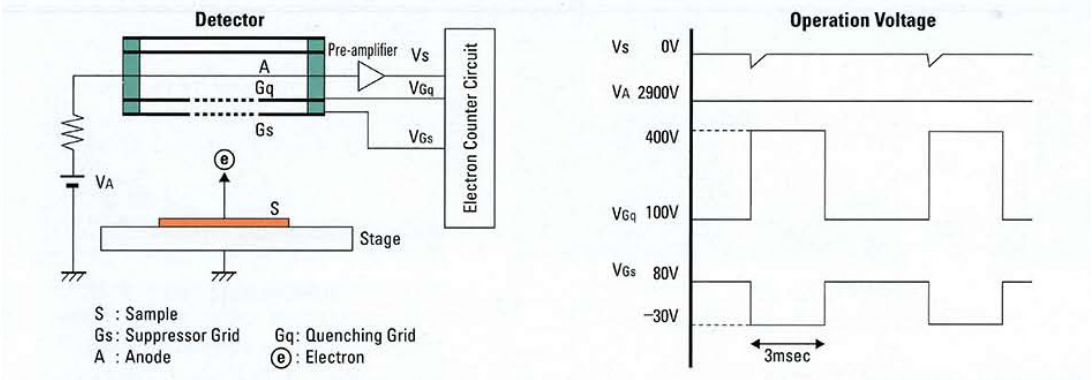
Measurement of Work Function / Ionization Potential
The photoelectron spectrum, number of emitted photoelectrons correlating to the energy of irradiated light, is measured. The Work Function and Ionization Potential are determined by the threshold where photoelectron emission first occurs.

Measurement of film thickness / contamination
Measurement of the fixed energy (number of photoelectrons emitted by irradiation with monochromatic light (fixed energy light) is performed. The number of emitted photoelectrons correlates to and converts into a measurement of the film thickness or contamination by applying the calibration curve.

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 which enters the spectrometer is controlled by the light adjuster, and it enters the spectrometer. The spectrometer selects the desired wavelength of UV light, and irradiates the test sample with this light through an optical filter (as energy selection *1). As a result, photoelectrons may be emitted from surface (several A to hundreds of A), due to photoelectric effect. (*2) The photoelectrons emitted are counted by the detector and low energy electron counter. The result is then printed or displayed on a CRT after analysis by the AC-2 software. This instrument is operated by a PC.

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

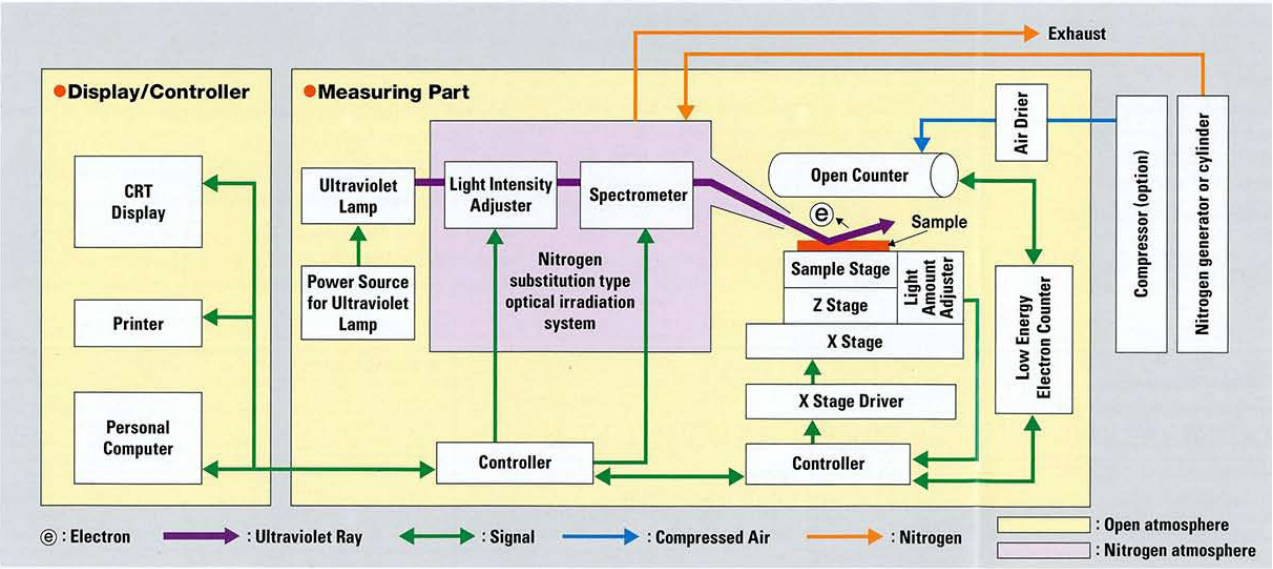
$$E_{(ev)} = \frac{h \cdot c}{\lambda} = \frac{1240}{\lambda\,(nm)}$$

λ : Wavelength h : Plank's constant

E : Energy c : Eight velocity

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

Structure:



Measurement Examples:

1. **Application: Measurement of surface condition (Measurement of surface wash of Si, GaAs, water, ITO film)**
   When a water surface is washed by acid or solvent, the surface condition changes depending on the method and elapsed time for treatment. As a result, the Work Function changes in accordance with the surface condition. The cleanliness, effect of the cleanser and stability of the surface after washing will effect the measurement.

2. **Application: Measurement of the Ionization Potential of material for photocopying**
   Sensitive materials and toner are used in photocopying. The sensitive material consists of conductive supporter, a charge-generating layer, and charge-transporting layer. The toner consists of pigment, charge controlling material, epoxy, and carrier (magnetic powder). Characteristics such as the relationship between the solution's oxide electric potential and the charging feature of these materials can be measured in either their powder or solid thin film form.

3. **Application: Measuring film thickness**
   If excitation energy is constant, the relationship between film thickness and conversion ration (CPS) is as follows, due to photoelectron decay in the film coating.

$$N = No \exp\left(\frac{t}{\lambda}\right)$$

N: Number of Photoelectrons emitted when film is thickness t
No: Number of Photoelectrons emitted when film is thickness 0
t: Film thickness
λ: Mean free path of electrons in film

When the film thickness on the bulk surface is actually measured, the free path of each film is not known, since the work function changes due to the film thickness and material. It is therefore necessary to create a "standard sample" measurement slope for comparison purpose.

Measurement Examples cont:

4. **Application: Measurement of lubricating film thickness on hard disc**
   On the surface of a hard disc, a thin lubricating film layer is applied in order to enhance abrasion resistance. Thickness of this lubricating membrane is typically several A to hundreds of A. The thicker the lubrication film layer, the more the electrons emanating from the hard disc will be stopped in the film. By measurement of a standard sample in advance to determine the relationship between film layer thickness and electrons emitted, the thickness of the lubricating layer on a specimen can be measured and determined within just a few seconds.

5. **Application: Measurement of SiO2 film thickness on Silicon**
   Photoelectron emission from silicon will be decreased by a film of SiO2 on the silicon. The thickness of the SiO2 layer can be determined by the amount of photoelectron energy emitted from the specimen surface.

Main Objects to Measure

Any sample that emits photoelectrons
- Metal (pure metal, alloy, material containing carbon etc)
- Semiconductors (mono crystal, multi crystal, Amorphous etc)
- Organic material, magnetic material, polarized material, catalysts, pigments, etc
- Ceramics (BN, ZrO2, etc)
- Power samples

Samples from which photoelectron emission does not occur
- Ceramics (SiO2, AL203, etc)

Main Applications

- Measurement of ionization potential of sensitive materials used in organic EL and photocopying
- Research of surface characteristics of hard discs and magnetic tapes
- Measurement of surface oxidation conditions of semiconductor and lead frames
- Inspecting quality of an MgO film on a plasma display
- Measurement and analysis measurement of work function of materials for Field Emission Display (FED)
- Inspection of contamination at molecular level of precision electronic materials

Specifications:

Model	AC-2
Measuring Principle	Low energy electron counter method
Energy Search Range	3.4 - 6.2eV (364 - 200mm)
Repeatability Precision (Standard Deviation)	Work function 0.02eV Logarithm counter ratio 0.03logCPC (at 2.7logCPS)
Measuring Time	Approx 5 minutes / 1 sample
Ultraviolet Lamp	Deuterium lamp
UV Spot Area	2 - 4mm square
Spectrometer	Grating type monochrometer
Sample Size	50mm square, Thickness 10mm, 1 sample measurement
Stage	X axis (automatic): 150mm, Z axis (manual): 10mm
Operating Condition	15 - 35℃, Less than 60% RH
Power Requirement	AC100V AC, 50/60Hz, 5A max
Outer Dimensions	AC-2LC1 (Light source Part): approx 600 (w) x 310 (h) x 450 (d) mm AC-2DC1 (Measuring Part): approx 600 (w) x 360 (h) x 450 (d) mm
Weight	AC-2LC1 (Light Source Part): Approx 40kg, AC-2DC1 (Measuring Part): Approx 50 kg

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