RIKEN KEIKI

PR-E-0490

Photoemission Yield Spectroscopy in Air (PYSA) AC-2S Series

Product Guide

Contents

Product Concept

As the latest model,

More compact size
with the same ease-of-use of the AC-2

This is the **AC-2S** .

Previous model

AC-2

Also… **Pro models with the addition of frequently requested functions**

+ AC-2S Pro α
AC-2S Pro β

in the model lineup!

Product Concept

Development concept:

Inspiration, Innovation, Evolution

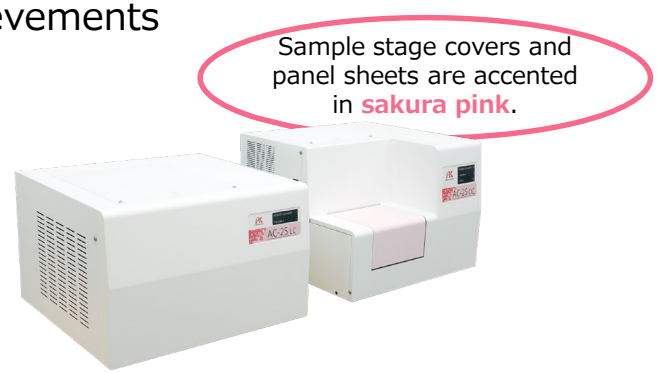
The models in the AC-2S Series reflect our hope that utilization of the AC-2S Series will create new value. To that end, we continue to develop products offering improved ease-of-use to meet the requirements of researchers.

◆ Why the AC-2S?

① The most widely used model “AC-2” with many achievements of academic articles.

② Significance of “S”
- **S**mart (highly functional)
- **S**akura (the sakura flower as a symbol of Japan)

Our wish to make the instrument made-in-Japan world-wide used for its compact size and advanced function.



◆ The AC-2S Series comprises three types:

AC-2S:	More compact, lower cost system with all-round functions of the previous model	☞ **For general analysis**
AC-2S Pro α:	Supports high light intensity (2,500 nW or higher)	☞ **For materials development**
AC-2S Pro β:	Micro light spot measurement capability	☞ **For device development**

AC-2S Series Features

AC-2S Series features

1. Allows easy measurement in air.

No need for vacuum; samples can be easily inserted and removed, measured in a short time.

2. Minimal damage to samples, high measurement repeatability

Detects minute photoemission levels by subjecting samples to low intensity UV radiation for minimal damage to samples and high measurement repeatability.

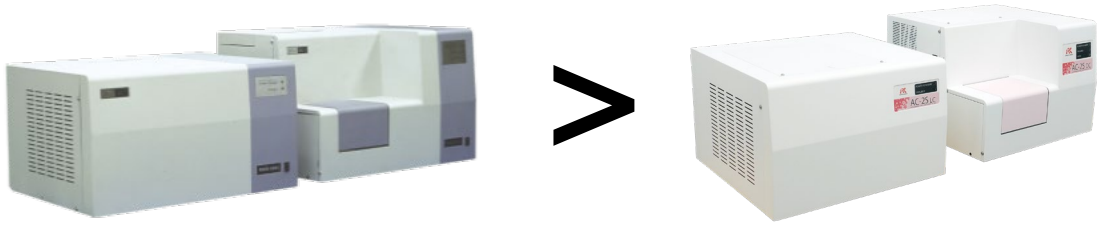
3. Backed by extensive track record of the AC Series

Adopted by universities and research institute worldwide; cited by over 2,000 academic articles.

About the AC-2S

AC-2S features

1. Major size reduction from the previous model



Width: **21 %** smaller
Weight: **38 %** lighter

2. Lower price makes the purchase easier

Significantly lower price than the previous model. Please contact Riken Keiki for more information.

3. Ease-of-use with the same functionality

Completely updated measurement and analysis software for ease-of-use.

About the AC-2S

Comparison to the AC-2 (previous model)

- Function difference

	AC-2	AC-2S
System configuration	Separate type	Separate type
Measurement range	3.4 - 6.2 eV	3.4 - 6.2 eV
Measurement steps	0.05 eV	0.05 eV
UV lamp	D_2	D_2
Lamp service life	1,500 hours	1,500 hours
Light intensity	1 - 500 nW	1 - 500 nW
Spot size	Smaller than 4 × 4 mm	Smaller than 4 × 4 mm
Measurement time	Standard time: approx. 5 minutes	Standard time: approx. 5 minutes
Repeatability	Work function (standard deviation) 0.02	Work function (standard deviation) 0.02
Operating system	Windows 98 (Windows 10)	Windows 10
Communication port	RS-232C 9pin	USB 2.0
PC software configuration	Combined measurement/analysis	Separate measurement/analysis
Data extension	MDB file	Text file
Data export	Clipboard	CSV
Repeated measurement function	N/A	Yes
Multi-point measurement function	N/A	Yes
Clipboard	Yes	Yes (enhanced)
Self-diagnosis	Yes	Yes (enhanced)
Temperature range	15 – 35 °C	15 – 35 °C
International*	CE, UL	CE, UL (pending)

Software now even easier to use!

About the AC-2S Pro

New AC-2S Pro features

AC-2S Pro α/Pro β

The AC-2S Series lineup includes **<Pro specifications>** models incorporating various new features not available with the previous model.

<High-temperature measurement>
Capable of measurement at temperatures up to 100 °C

α β

A heated sample stage allows measurement at user-specified temperatures up to 100 °C.
⇒ This makes it possible to evaluate characteristics at actual operating temperatures —for example, for new materials with temperature-dependent characteristics.

<New long-life, high-intensity light source>
Lasts approx. ten times longer than the previous model

α β

The laser-driven light source (LDLS) provides long service life (approx. ten times longer than the previous model), consistent measurements of materials requiring high light intensity (max. 2,500 nW: Pro α), and micro area measurement capability with easy spot focusing (Pro β).
⇒ The extended service life eliminates the need to replace the light source. It also allows measurements of a wide range of materials, including those requiring high light intensity.

<Micro light spot measurement>

β

Allows measurements of small spots (not larger than 0.4 mm square).
⇒ Small spot measurement capability allows measurements of semiconductors and other small-sized materials.

<Low-energy region measurement>

α

Capable of low-energy measurement as low as 2.0 eV
⇒ Allows measurements of new low-energy photoemission materials that previously could not be measured.

About the AC-2S Pro

Examples of applications using new AC-2S Pro α features

① High-temperature measurement capability (Visualizing temperature-induced changes in measurement samples)

Previous model: Measurement possible only at room temperature
AC-2S Pro α: Measurement possible at high temperatures by heating up to 100 °C
Examples of measurement: Catalysts, organic light-emitting diode functional materials, organic solar cell functional materials, fuel cell electrode catalysts, all-solid battery electrodes

② High light intensity capability

Previous model: Insufficient output with 500 nW
AC-2S Pro α: Irradiation possible up to 2,500 nW
Examples of measurement: Research on the charging characteristics of toner and other substances, surface concentration measurements of additives, etc.

③ Film thickness measurement capability

Previous model: Film thickness measurement not possible due to insufficient photoemission
AC-2S Pro α: High light intensity allows film thickness measurements.
Examples of measurement: Component surface coating thickness measurement, etc.

④ Low-energy region measurement

Previous model: Measurement possible only down to 3.4 eV (measurement not possible for anode materials below 3.4 eV)
AC-2S Pro α: Measurement possible from 2.0 eV ⇒ Allows anode measurement.
Examples of measurement: Organic light-emitting diode anode materials, organic solar cell anode materials

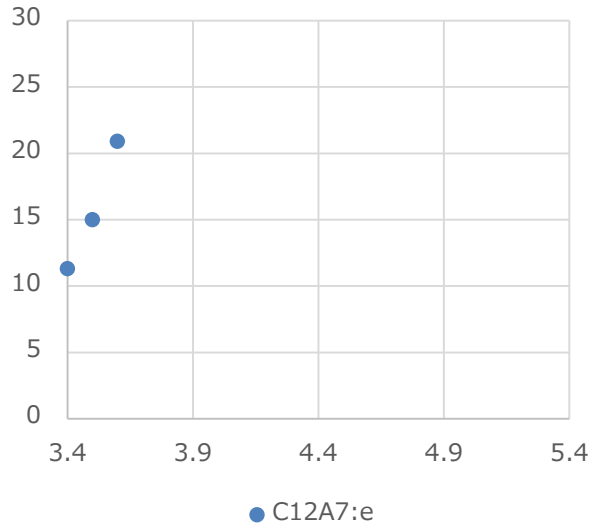
About the AC-2S Pro

<New AC-2S Pro α functions> Example of measurement using low-energy capability

Example of measurement: Anode materials for organic EL

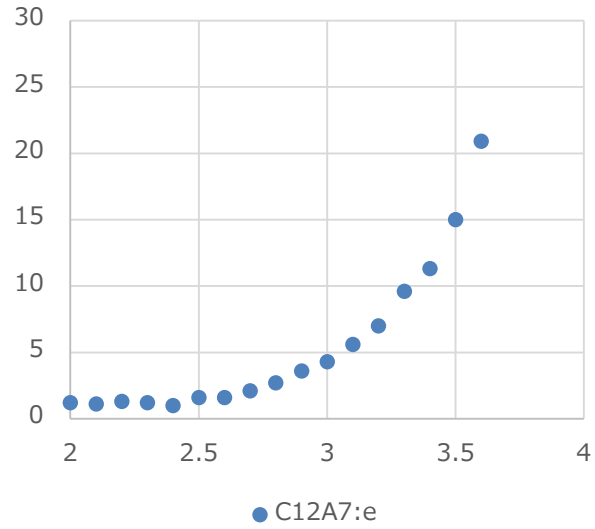
Previous model

Sufficient measurement data cannot be obtained due to inability to measure below 3.4 eV.



AC-2S Pro α

Measurements can be obtained due to low-energy range down to 2.0 eV.



About the AC-2S Pro

Examples of applications using new AC-2S Pro β features

① High-temperature measurement capability (Visualizing temperature-induced changes in measurement samples)

Previous model: Measurement possible only at room temperature
AC-2S Pro β: Measurement possible at high temperatures by heating up to 100 °C
Examples of measurement: Catalysts, organic light-emitting diode functional materials, organic solar cell functional materials, fuel cell electrode catalysts, all-solid battery electrodes

② Micro light spot measurement capability

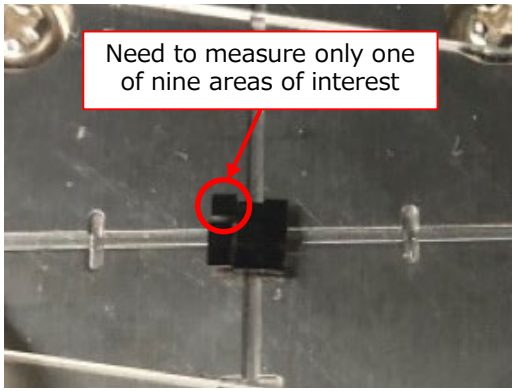
Previous model: 2 - 4 mm square spots
AC-2S Pro β: 0.2 - 0.4 mm square spots
Examples of measurement: Measurement of contamination/oxidation of electrodes and minute electrical components on PCBs, etc.

③ Film thickness measurement + micro spot capability for expanded measurement scope

Previous model: Spot cannot be focused on area of interest due to insufficient photoemission.
AC-2S Pro β: Areas of interest can be viewed using micro spot.
Examples of measurement: Small component surface coating thickness measurement, etc.

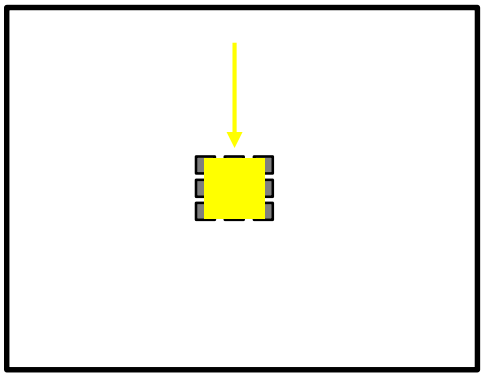
About the AC-2S Pro

<New AC-2S Pro β functions> Example of measurement using micro spot measurement capability



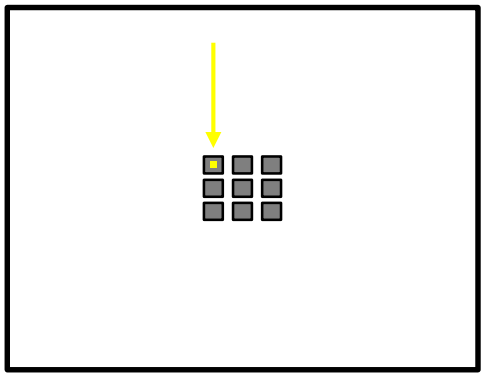
Previous model

Area of interest cannot be measured because the irradiation spot is too large.



AC-2S Pro β

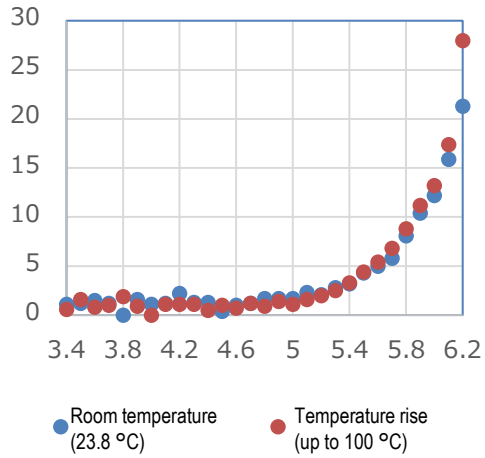
Micro spot capability (0.2 - 0.4 mm square) allows measurement of specific areas of interest.



About the AC-2S Pro

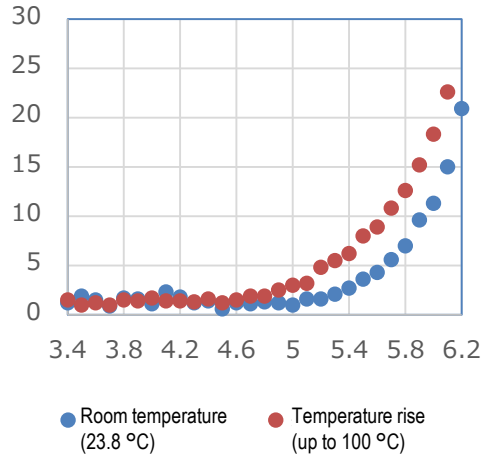
<Common to both AC-2S Pro α/β> Example of measurement using heated sample stage

Sample 1



Substance for which measurement results remain unchanged even when temperature changes

Sample 2



Substance for which measurement results change when temperature changes

⇒ **The AC-2S Pro α/β allows evaluations of temperature-dependent variations in substance characteristics.**

[Appendix] About the AC Series

[Appendix] About the AC Series

The first-generation AC-1 was developed **36 years ago!**

The AC Series consists of photoelectron yield spectroscopy in air (PYSA) that use the OPEN COUNTER developed with RIKEN to enable surface analysis.
The OPEN COUNTER count the individual low intensity photoelectrons emitted when the sample surface is irradiated with weak low-energy UV light in air. Compared to conventional surface analysis in which high-energy X-rays are passed through the sample in a vacuum, this analysis technique causes minimal damage to the sample. This technique is widely used around the world, particularly in the development of organic devices.

[Appendix] About the AC Series

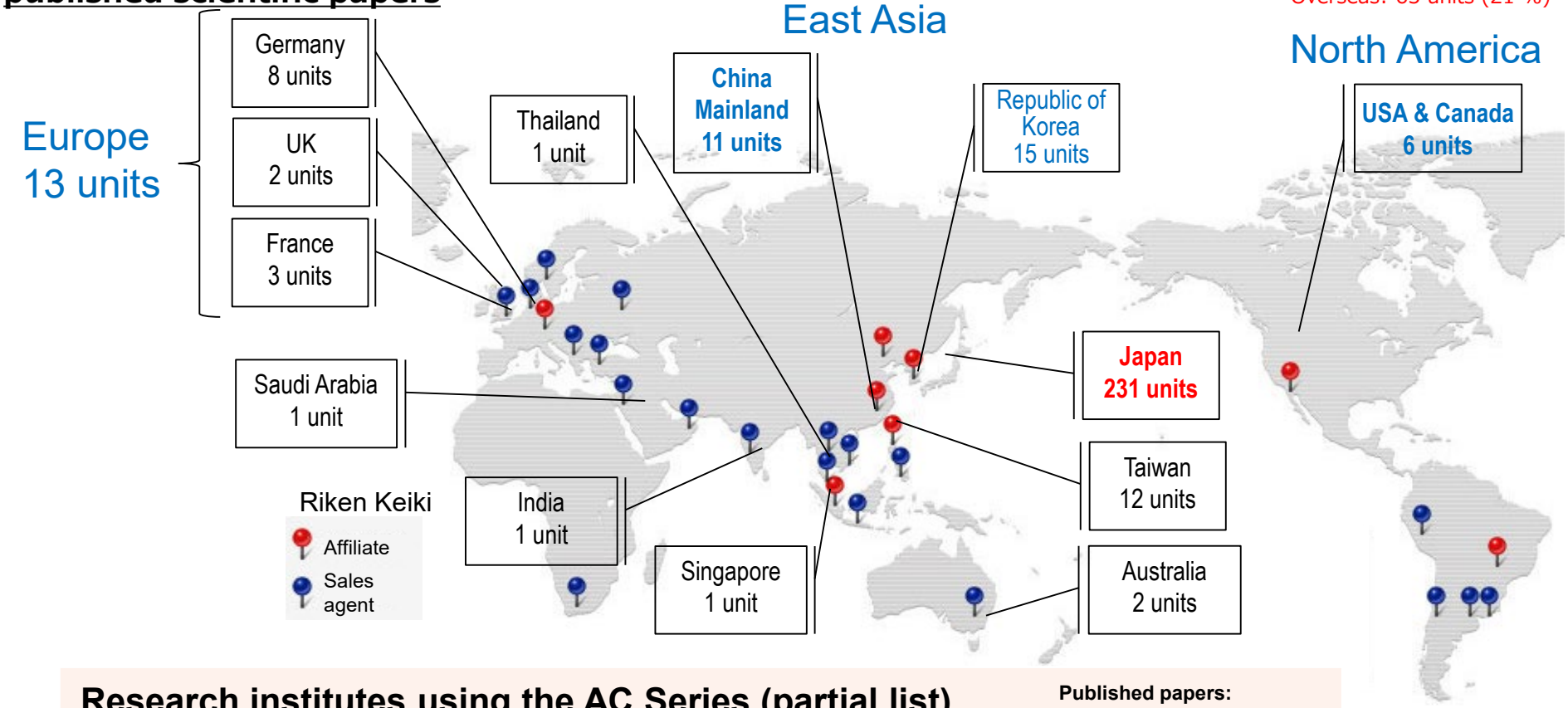
PR-E-0490

Figures as of March 2021

Sales, research organizations where adopted, published scientific papers

Total sales: 298 units

Japan: 235 units (79 %)
Overseas: 63 units (21 %)



Research institutes using the AC Series (partial list)

Published papers:
More than 2,000

University of Tokyo, Kyoto University, Nagoya University, Yamagata University, Kyushu University, RIKEN, National Institute for Materials Science, Tokyo Institute of Technology, Shinshu University, Stanford University (USA), Princeton University (USA), Strasbourg University (France), Fraunhofer-Gesellschaft (Germany), Humboldt University (Germany), Peking University (Mainland China), South China University of Technology (Mainland China), Industrial Technology Research Institute (Taiwan), Korea Electronics Technology Institute (Republic of Korea), Kyungpook National University (Republic of Korea), VISTEC (Thailand), IMRE (Singapore), CSIRO (Australia), KAUST (Saudi Arabia)
(*Based on numbers of papers published)

Measurement example

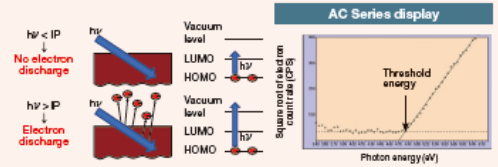
Material selection (screening)

Case study 1: Ionization potential measurement of organic electroluminescent materials

Manufacture of organic electroluminescent devices requires selection (screening) of optimum charge injection materials for charge injection into luminescent materials. Charge transfer at the material interface is important here, and ionization potential forms a key factor in evaluating materials. The AC Series are able to measure ionization potential quickly and easily in open air.

What the AC Series reveals (Explanation of phenomena)

Irradiating a material with UV radiation increases the energy of electrons exactly by the energy of the UV radiation ($h\nu$). Electrons are emitted from the material if the electron energy exceeds the vacuum level. The ionization potential (IP) can be estimated from the electron emission threshold energy.



Ionization potential of organic thin films

Ionization potential for metals differs between vacuum and in open air due to surface oxidation but is relatively consistent for organic materials. These are the results of measuring organic materials in open air and vacuum.

	In open air	In vacuum
Alq3	5.84eV	5.8eV
a-NPD	5.50eV	5.4eV
CuPc	4.99eV	5.2eV

*In open air: AC Series
In vacuum : Measured using ultraviolet photoelectron spectroscopy

Indices for new material development

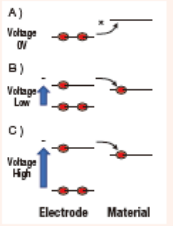
Case study 2: Searching for fuel cell materials (energy)

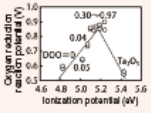
A breakthrough in the performance of renewable energy devices such as artificial photosynthesis, solar cells, photocatalysts, fuel cells, and storage batteries has become a pressing need to curb global warming. This has produced strong demands for development of new materials differing from conventional materials. For example, searching for materials to replace platinum for the cathodes of fuel cells traditionally involved wide use of CV measurement. Using the AC Series which are capable of measuring solid materials enables efficient material searching.

What the AC Series reveals (Explanation of phenomena)

Electron transfer from electrode to material causes a chemical reaction. You can see the following using the AC Series.

A) Electrode HOMO < Material LUMO
==> No electron transfer
B) Apply voltage (low) to electrode
Electrode HOMO > Material LUMO
==> Electron transfer (High efficiency example)
C) Apply voltage (high) to electrode
Electrode HOMO > Material LUMO
==> Electron transfer
(Low-efficiency example requiring high voltage)





Correlation between ionization potential and oxygen reduction reaction voltage (E_{ORR}) of fuel cell

A. Ishihara, M. Tamura, K. Matsuzawa, S. Mitsushima and K. Ota, J. Fuel Cell Sci. Technol, 8 (3), 031005

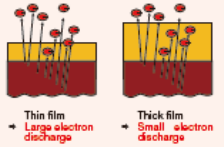
Material surface film thickness measurement

Case study 3: Silicon oxide film thickness measurement

Semiconductor materials require confirmation of film thickness uniformity. However, steady improvements with integration in recent years have resulted in thinner films, making thickness measurements by conventional methods (FT-IR) difficult. The AC Series can measure film thicknesses at an angstrom level by using the electron permeability of thin films. And it also allows film thickness evaluation in high integration.

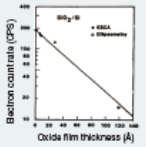
What the AC Series reveals (Explanation of phenomena)

The volume of electrons discharged from a material varies depending on the thickness of the silicon wafer.
With thinner films, a greater volume of electrons is discharged; with thicker films, the surface film forms an obstruction, and a smaller volume of electrons is discharged. Measuring the electron discharge for a known film thickness at a constant ultraviolet intensity and plotting this on a graph enables determination of unknown film thicknesses.



Correlation between silicon wafer surface oxide film thickness and electron count rate

We see clearly that the electron discharge decreases as the oxide film thickness increases.
Allows measurement in open air even of films measuring just a few Å in thickness.



M. Uda, Jpn. J. Appl. Phys., 24 (1985) 284

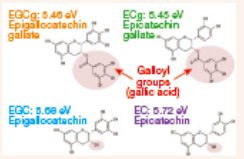
Electron state analysis of liquid samples

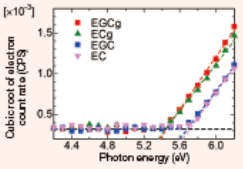
Case study 4: Measuring catechins in water

The AC Series are capable of measurements in open air, which allows electron state analysis for liquid and powder samples and presents applications across a wide range of fields, including food, chemicals, cosmetics, medicine, and pharmaceuticals. Catechins forming the astringent component of green tea are widely reported to exhibit biological activity. The following experiments show that catechins, which was reported to have a high biological activity, showed a low ionization potential.

What the AC Series reveals (Explanation of phenomena)

Biological activity including antioxidant, anticancer (suppressing cancer cell growth), antibacterial, and antiviral (deactivating) properties is generally reported to be higher in catechins with galloyl groups (gallic acid). If we use the value for standard bottled green tea as a guide, measuring the ionization potential of powdered catechins mixed with pure water reveals that catechins with galloyl groups have lower ionization potential. In practice, bottled green tea also contains chemicals in addition to catechins, which present issues. But using an Atmospheric Photoemission Yield Spectrometer provides information on electron states under normal daily life conditions.





D. Yamashita and A. Ishizaki, Anal.Sci., 32 (2016) 577

[Appendix] About the AC Series

AC Series products and market transitions

Product transitions

AC-1 (99 units) 1985 - 1998

AC-2 (128 units) from 1999

AC-3 (45 units) from 2005

AC-5 (5 units) from 2014

NEW AC-2S from 2021

1985 1990 1995 2000 2005 2010 2018 **2021** Present day

Main product markets

Photocopier market
1987 - 1995

Hard disk market
1986 – 1990

Organic device (organic light-emitting diode, organic solar cell) market from 1996
[Current status]
- Lively organic light-emitting diode markets in China/Taiwan/ROK
- Decarbonization business prominent in Europe and US

New materials market
Solar cells, fuel cells, artificial photosynthesis, oxide conductors, photocatalysts, quantum dots, carbon nanomaterials, etc.

New semiconductor device market
New memory devices (e.g., spintronics)

Storage battery market
Lithium ion batteries, all-solid batteries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