Featured Articles

Coating Thickness Measurement with High-performance for Latest Electronic Fine Components of Mobile Devices

—FT150 Series Fluorescent X-ray Coating Thickness Gauge—

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OVERVIEW: X-ray fluorescence analysis is widely used for measuring the coating and plating film thickness of electronic components and other products as it can perform non-destructive and non-contact simultaneous measurement of multi layer coatings. As the components to be measured become increasingly scaled-down, the X-rays used for this purpose need to be tightly focused. The FT150 series high-performance fluorescent X-ray coating thickness gauge meets this requirement. It realizes nanometer-level plating thickness measurement over an area of several tens of microns, by using polycapillary X-ray focusing devices, in place of the conventional collimator method, thereby increasing the intensity of X-rays to which the sample is exposed by around 1,000 times. This article introduces some typical applications to describe the measurement precision performed by the FT150 series.

INTRODUCTION

X-RAY fluorescence analysis uses the fluorescent X-rays emitted from a sample by irradiating incident X-rays, and can perform non-destructive and non-contact measurement of the quantities of each element present in the measurement region. Utilizing this capability, the technique is widely used for measuring plating thickness. One important application for fluorescent X-ray plating thickness measurement is the plating thickness measurement of terminal parts such as electronic components, printed circuit boards, and connectors. As the plating of these terminals is an important technology for ensuring the reliability of electrical connections between components, it is routinely measured at production plants.

As electronic devices become smaller and lighter, so too are the components they use becoming smaller and more densely mounted, with the result that there is growing demand for the ability to measure plating thicknesses over areas of 100 μm or less.

Gold (Au) is commonly used as a plating for electronic components because of its excellent electrical and chemical characteristics. Au plating is expensive and is a critical factor in quality, so it is becoming increasingly important to control plating thickness. Recent years have seen numerous examples of plating thicknesses of 10 nm or less, and sites that deal with plating thickness control for the latest electronic components are demanding instruments that can easily and accurately measure platings with nanometer-level thicknesses over areas of a few tens of micrometers.

FT150 SERIES

Hitachi High-Tech Science Corporation developed the FT150 series high-performance fluorescent X-ray coating thickness gauge, which features simple operation and provides precision measurement of plating thickness processes at electronic component manufacturing plants. Fig. 1 shows a photograph of the instrument.

Product Range

The FT150 series is made up of three models with different combinations of sample chamber and polycapillary to suit different measurement applications (see Table 1). The X-ray irradiating system consists of an X-ray tube as X-ray source and a polycapillary X-ray focusing device and is available in a version that is optimized for nickel (Ni), palladium (Pd), or Au, especially for very thin, 50nm or less, thicknesses, another version that is suitable for a wider range of

PC: personal computer

Fig. 1—Exterior of the FT150.
From the left, the photographs show the exterior of the measurement head, stage controller, and PC used for operation.

Table 1. FT150 Series Product Range
Three models are available with different combinations of polycapillary and sample chamber.

	Sample chamber	Polycapillary
FT150	Standard	Characteristics suitable for thin Ni/Pd/Au platings
FT150L	Large	"
FT150h	Standard	Characteristics suitable for Sn and Ag platings

Ni: nickel Pd: palladium Au: gold Sn: tin Ag: silver

plating materials, including tin (Sn), silver (Ag), and for comparatively thick Pd or Au. The sample chamber is available in two sizes: the standard size of 300 mm × 400 mm, and a larger option specialized for large 600-mm-square printed circuit boards (see Fig. 2).

Fig. 2—FT150L with Sample Chamber Door Open.
The large sample space provides ample room for large flexible samples.

X-ray Irradiation System and Detection Intensity

The X-ray irradiation system in the FT150 series uses a polycapillary X-ray focusing device that enables precision measurement by focusing high-intensity X-rays on a very small area. The polycapillary on the FT150 and FT150L, which is optimized for thin Pd and Au platings, has a beam diameter of 30 μm for Au platings, while that on the FT150h has a beam diameter of 35 μm for Sn platings.

The FT150 series has also been optimized for X-ray detection sensitivity, using a silicon drift detector (SDD) that is able to withstand high X-ray intensities without saturating. Used in combination with the polycapillary X-ray focusing device, the FT150 and FT150L achieve two times higher Au X-ray fluorescence (XRF) intensity than conventional models, while the FT150h can perform measurements in the 20-keV+ range, which has traditionally been difficult to detect.

Ease of Operation

As fluorescent X-ray plating thickness gauges are used regularly at manufacturing plants, it is important that they be easy to use.

The FT150 series models were designed for ease-of-operation based on the following three concepts.
(1) Large samples can be easily set in the sample chamber because of its large space
(2) Easy to open and close with little force
(3) No structural parts located where they will obstruct the view of the measurement position

To prevent radiation leakage, the FT150L designed for the measurement of large printed circuit boards has a cover large enough to hold these large boards instead of the commonly used slit arrangement. In addition to a large door with a power-assisted hinge that is easy to open and close with one hand, the large space above the sample stage reduces the risk of scratching the sample, something that can happen when inserting it into slits (see Fig. 2).

To reduce operator workload, the FT150 series is also equipped with built-in calibration samples. It performs a warm-up run and periodical calibration automatically, without any user instructions.

PRINCIPLES AND FEATURES OF FLUORESCENT X-RAY PLATING THICKNESS MEASUREMENT

Overview of Fluorescent X-ray Plating Thickness Measurement

A sample exposed to primary X-rays in turn emits fluorescent X-rays with energies that are distinctive of the different elements contained in the plating material. As the amount of fluorescent X-rays emitted depends on the thickness of the plating on the sample, this thickness can be calculated from the fluorescent X-ray intensity. This technique is suitable for use in manufacturing plants because the exposure of the sample to X-rays and their detection are both achieved without contact with the sample plating (see Fig. 3).

In principle, the amount of fluorescent X-rays generated has a degree of statistical variation. Although impossible to eliminate, the relative amount of this variation can be reduced by increasing the number of X-ray photons detected. In other words, precise measurement is achieved by increasing the intensity of primary X-rays and by detecting more of the fluorescent X-rays by improving detector efficiency.

Techniques for Measuring Minute Areas

Fluorescent X-ray plating thickness measurement does not work correctly if the primary X-rays are irradiated outside of the measuring area. This means that the primary X-rays must be shaped into a narrow beam that matches the sample. Although X-rays are a form of electromagnetic radiation, just like visible light, they have a much lower refractive index and this makes it impossible in practice to focus them using an optical lens. A simple and common method for making a narrow X-ray beam is to use a collimator. A small aperture in a metal plate that is thick enough to block the X-rays, only allows X-rays to pass through the target area. Unfortunately, as the X-ray beam is made narrower, its intensity falls roughly in proportion to the area of the hole. As noted above, this degrades the measurement accuracy. Accordingly, the FT150 series models are equipped with polycapillary X-ray focusing devices so that they can expose small areas to high-intensity X-rays. A polycapillary uses total reflection on the inner surface of a hollow glass tube to guide the X-rays and achieve a focusing effect by orienting each individual glass tube so that they are directed at the same point (see Fig. 4).

The polycapillary focusing devices used on the FT150 can focus X-rays that excite Au fluorescence within a 30-μm region (see Fig. 5). The resulting

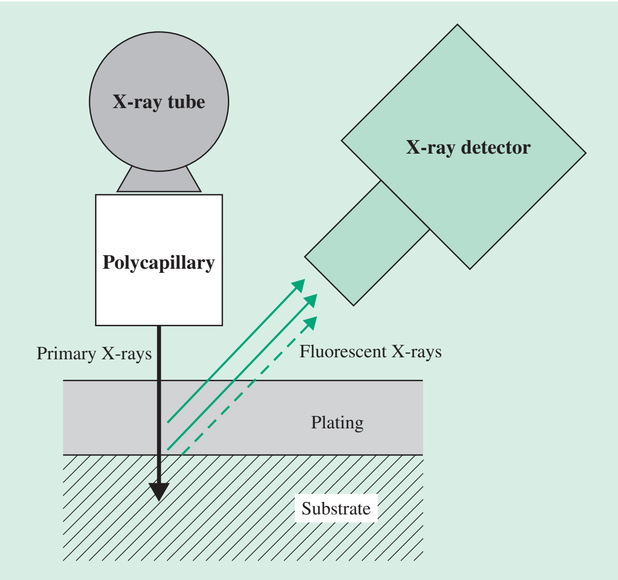


Fig. 3—Principles of Fluorescent X-ray Plating Thickness Measurement.
Non-destructive and non-contact measurement can be performed by detecting the fluorescent X-rays emitted by a sample exposed to primary X-rays.

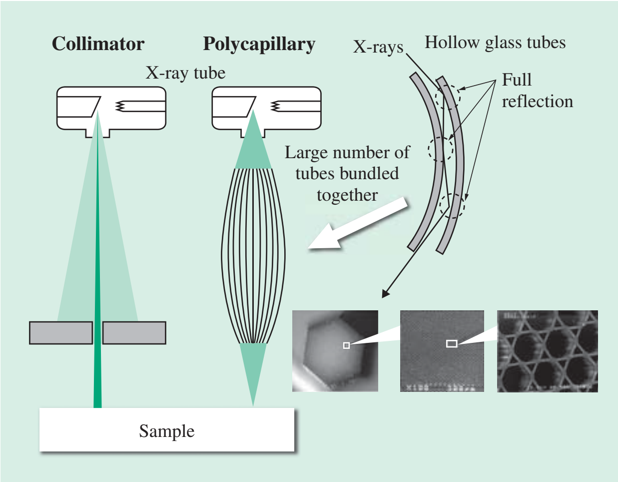


Fig. 4—How Collimators and Polycapillaries Work.
When a collimator is used to produce a narrow beam, most of the X-rays do not reach the sample, resulting in very low intensity. Because a polycapillary focuses the X-rays, it can deliver high intensities.

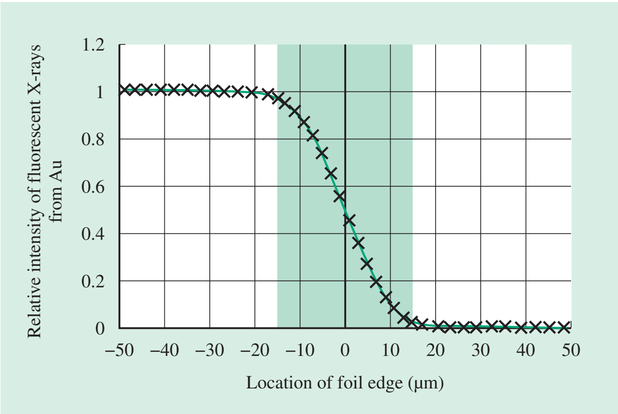
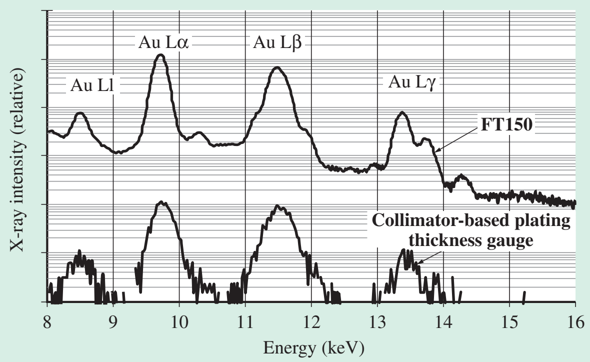


Fig. 5—FT150 Beam Diameters.
The graph plots the change in X-ray intensity as the beam is scanned across the edge of the Au foil. The size of the region of gradual change in intensity indicates that the beam diameter is 30 μm.



Mo: molybdenum W: tungsten
* The FT150 has a tube with an Mo target, 45 kV 1,000 µA, and beam diameter of 30 µm. The collimator system has a tube with a W target, 50 kV1,500 µA, and beam diameter of 90 µm.

Fig. 6—Comparison of Fluorescent X-ray Intensity on FT150 and Collimator-based Plating Thickness Gauge.
The graph plots the spectra measured by each instrument for a bulk sample of Au. The fluorescent X-ray intensity on the FT150 is roughly 1,000 times that of the collimator-based plating thickness gauge.

Table 2. Results of Repeated Measurements of Ni/Pd/Au Plating on Lead Frame
The table lists the mean and RSD obtained from ten 100-s measurements.

	Mean	RSD
Au	0.0062 µm	1.5%
Pd	0.0180 µm	1.9%
Ni	0.9045 µm	0.1%

RSD: relative standard deviation

Table 3. Results of Repeated Measurements of Ni/Sn Plating on Ceramic Capacitor
The table lists the mean and RSD obtained from ten 30-s measurements.

	Mean	RSD
Sn	4.32 µm	0.4%
Ni	2.46 µm	0.8%

intensity of fluorescent X-rays from the sample is about 1,000 times greater than that achieved by conventional instruments equipped with a collimator (see Fig. 6).

As this means that even very small areas can be exposed to high-intensity X-rays, a weak X-ray signal from a 1-nm Au layer can be distinguished from the background with only a 30-s measurement.

EXAMPLE MEASUREMENTS

The following chapter presents examples of using the FT150 for measuring two common types of samples: a lead frame and a compact multilayer ceramic capacitor.

Cu/Ni/Pd/Au Three-layer Plating

The FT150 was used to measure a three-layer Ni/Pd/Au plating on the lead frame used for an integrated circuit (IC). The measurement used a stack of Au, Pd, and Ni foil of known thicknesses on a copper (Cu) substrate as a reference.

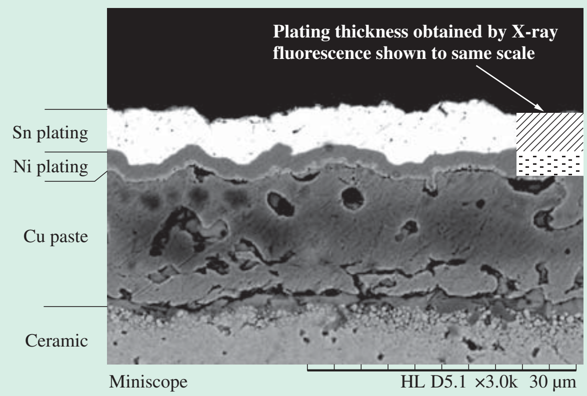
Ten 100-s measurements were performed and the mean and relative standard deviation (RSD) were obtained. The results demonstrate the ability of the FT150 to perform highly accurate measurements of even thin platings of 10 nm (0.01 µm) or less (see Table 2).

Multilayer Ceramic Capacitor

This example involves using the FT150h to measure the Ni/Sn plating on the electrodes of a commercially available multilayer ceramic capacitor.

The capacitor's two-layer Ni/Sn plating was measured without any sample preparation. The reference for the measurement was a stack of Sn and Ni foil of known thicknesses on a Cu substrate.

Ten 30-s measurements were taken and the mean and RSD were obtained. The results demonstrate the ability to perform highly accurate measurements with an RSD of 1% or less, despite such a short measurement time (see Table 3).



SEM: scanning electron microscope Cu: copper

Fig. 7—SEM Cross-section of Multilayer Ceramic Capacitor Measured by the FT150.
The plating thickness obtained by X-ray fluorescence is shown to scale at the top right of the SEM image. The results indicate good agreement.

Using a polishing machine, a cross-section of the capacitor was made. After cleaning the cross-section using an ion milling machine, the thickness of the Ni/Sn layer was observed by a scanning electron microscope (SEM), the plating thickness showed excellent agreement with that obtained by X-ray fluorescence (see Fig. 7). The ability of the FT150 to use X-ray fluorescence to make fast and accurate measurements of mean plating thickness over a small area exposed to X-rays enables non-destructive measurement without the need to prepare a cross-section. This makes it suitable for use in the control of plating thickness at manufacturing plants.

CONCLUSIONS

This article has described the rising demand for ways to measure very thin platings over small areas to enable control of the plating thickness of electronic components. It has also presented actual measurement data to demonstrate that the required measurement performance has been achieved by developing a measurement system based on the use of a polycapillary X-ray focusing device to provide a narrow, high-intensity X-ray beam.

Anticipating continued strong demand for scaled-down electronic components with a high level of added value, Hitachi High-Tech Science intends to continue development so that plating thickness measurement, too, can achieve smaller sizes and higher precision.

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