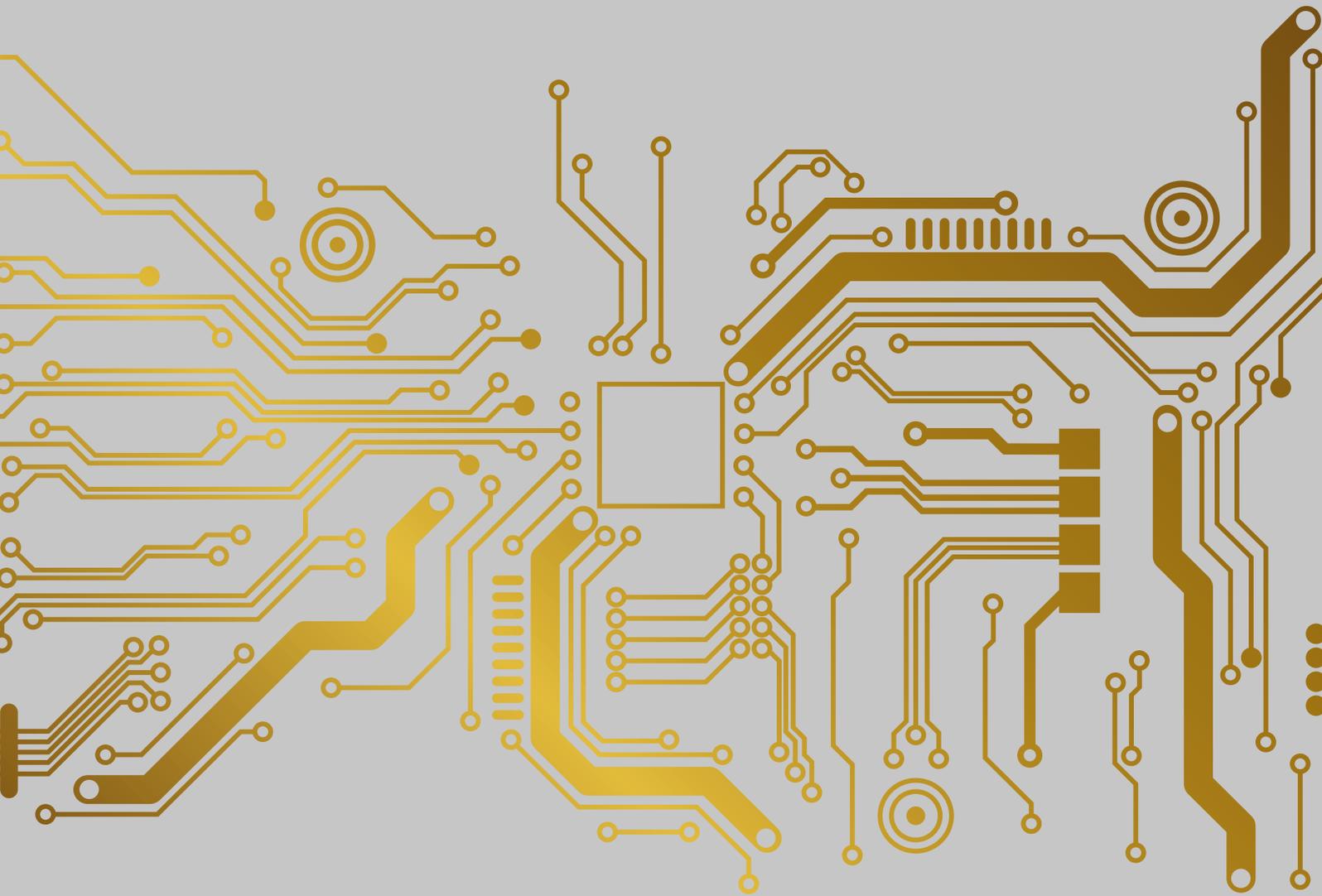
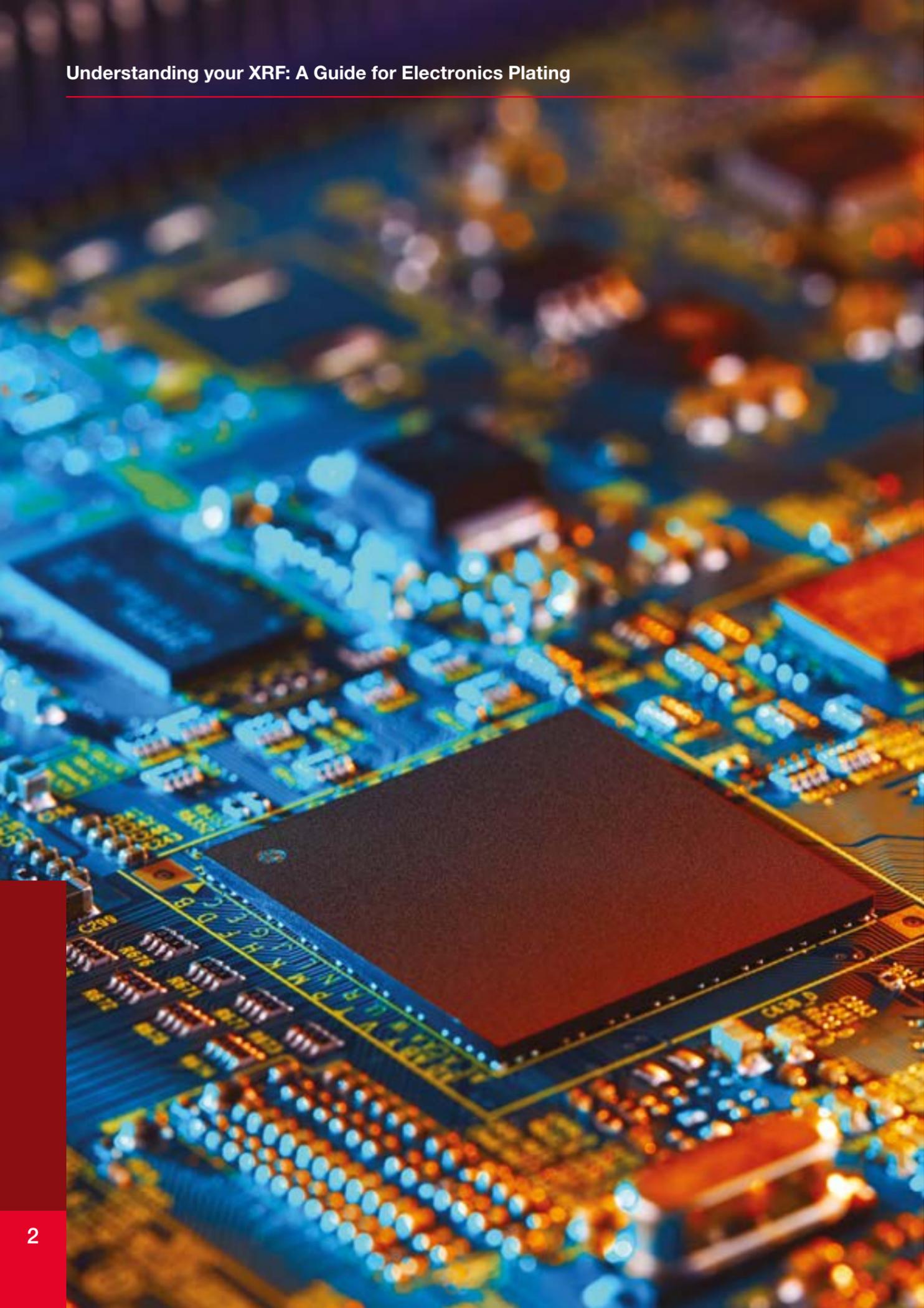


# Understanding your XRF: A Guide for Electronics Plating





## Purpose of this guide

**XRF analysis is a long-established technique for verifying the thickness and composition of coatings for a whole range of industries. Its fundamentally non-destructive nature, coupled with fast measurement times and compact benchtop instruments, means that analysis can be done on-site with immediate results.**

While XRF is known for being an easy technique, it is possible – as with any analytical technique – to get things wrong. Using your instrument incorrectly may result in poor accuracy and inefficient workflows. Plating thickness verification is also slightly more complex than other XRF applications, because the parts being tested are plated, and therefore the geometry of the instrument and the parts themselves play a role in the analysis.

With that in mind, the purpose of this guide is to be an all-in-one reference manual for everything to do with XRF for plating. If you're interested in how XRF works, then we've explained it here. If you want to know how to implement best practices to reduce your process time without losing precision, then we cover that in the productivity section. And if you're not getting the results you expect, then a quick look at things that can introduce error will give you a good place to start.

At Hitachi High-Tech, we've been designing XRF analyzers for electronics manufacturers for over 45 years. Over that time there have been advances in both plating technology and XRF instrumentation. We hope that with the help of this guide, you can be sure your products meet the strict specifications that today's applications demand.

## Why are things coated?

Why do we coat components? It might not be something we think about too often, but when we're interested in checking the integrity of a coating – which is why we use XRF – understanding the role the plating will play is useful.

Broadly speaking, coatings are either functional or aesthetic. A single component can have more than one layer, with each layer carrying out a different function. For example, PCBs have layers that are conductive, and then further layers that protect the conductive coating from the atmosphere. These are some of the main functions of plating:



**Corrosion resistance:** Coatings are used to prolong the life of components where the underlying material or substrate would corrode or oxidize within the expected lifespan of the part. For many components, protection from the atmosphere is necessary, and for some applications, such as wearables, specialized coatings may be applied to protect exposed connectors and components.



**Temperature resistance:** Some components are exposed to extremes of temperature, examples of these would be within an engine or furnace. Specialist coatings are used to protect components from corrosion at elevated temperatures.



**Wear resistance:** Coatings are applied to protect parts against various types of wear, such as friction sliding, abrasion or impact. These specialist coatings are especially useful for lightweight substrate materials, as the coatings can compensate for the lack of hardness in these materials.



**Conductivity:** Within electronics, the main function of the coatings is to create contacts that are highly conductive. Resistance creates heat, so reducing resistance with highly conductive coatings becomes especially important when dealing with connectors and mounts for electrical components.



**Biocompatibility:** For specialist medical devices destined for implanting into the body to repair bones or replace hips, specialist coatings are applied to help the body accept these parts. Coatings are devised that increase the likelihood of the body accepting the part and to reduce the risk of infection after the procedure.



**Decoration:** From jewelry to household appliances, decorative finishes are applied to make pieces look appealing and, in the case of costume jewelry, to keep costs down.

## Why is thickness tested?

Why check coating thickness at all? There are a number of reasons, often a question of balancing functionality with cost. This is why we often have a minimum and maximum plating thickness – it's not just a question of ensuring the plating is thick enough. There are five basic reasons why you need to test coating thickness:

**Meet basic functionality:** If the reason for the coating is functional, then there will be a minimum thickness below which the functionality will start to fail. For example, the part won't be protected from corrosion or high temperatures, or the conductivity will be too low. Because of this, most coatings applications have a minimum specified limit at the very least for good functionality.

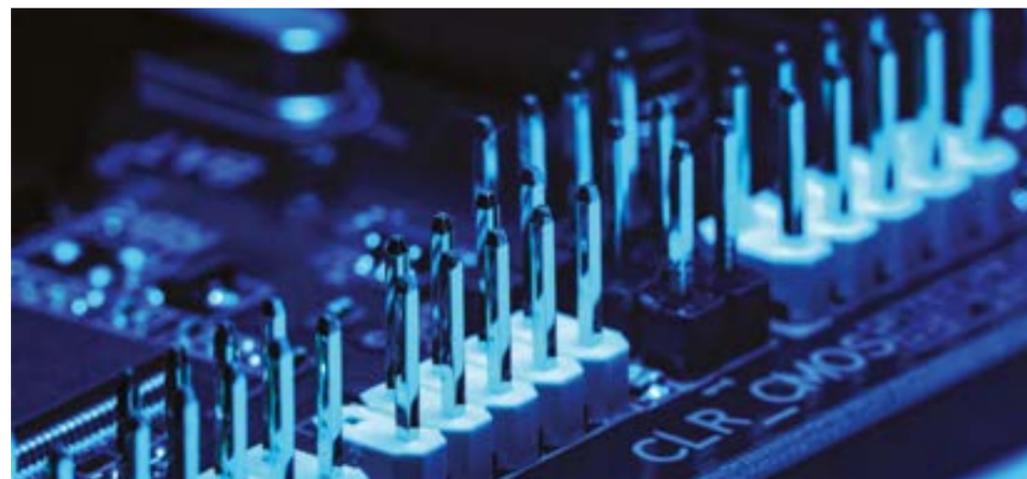
**Avoid premature defects:** In some cases, you can expect some wear of the coating over the lifetime of the part. This can be especially the case for moving parts that make contact with other components; here you'll need to meet the minimum thickness to avoid premature defects and meet quality standards throughout the expected lifetime of the component.

**Good mechanical fit:** Many plated parts form part of a complex system of components that must fit together. The acceptable tolerances in an engine, for example, are very tight and the plating thickness must be below a certain limit. This is one reason why over-plating, which makes the part too thick, can be as problematic as under-plating.

**Minimize costs through reduced waste:** Making the plating thick enough and no thicker helps to avoid overspend on chemicals. It also helps to minimize energy costs and makes the coatings process more efficient by increasing throughput.

**Proper visual appearance:** For decorative finishes, too thin a coating will result in the plating wearing off very quickly, spoiling the appearance of the object. Too thick can also be problematic for items such as cutlery and jewelry, as this results in loss of definition of the design.

This is why when verifying coating thickness with XRF, you'll want your plating thickness to be within lower and upper limits to ensure best product quality and performance, at maximum cost-effectiveness.



## Main industries for coatings and plating

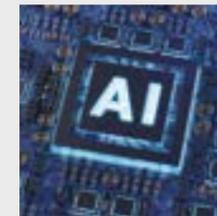
We've seen that there are many different reasons for plating components, and these tend to be dictated by the industry served. Here we'll look at the main markets for coating and what challenges they face.



### Mobile Communications

Mobile phones and tablets – and the associated accessories, such as smart watches – are at the forefront of PCB miniaturization. The drive to upgrade these devices every year or so is great for plating suppliers, as it drives a huge industry in boards for smartphones. However, the pressure to fit more in a tiny space produces many challenges for verifying PCB integrity.

It's not just the device in your hand that feeds the plating industry either. The mobile infrastructure requires specialist plated components too. The current development here right now is the rise of 5G. Conspiracy theories aside, the real challenge for coatings for 5G infrastructure is the need for thick printed circuit boards.



### Digitalization

Industry 4.0, analytics, artificial intelligence and machine learning are leading the most dramatic changes to society. A seemingly endless amount of data is being collected from mundane to highly specialized devices in an effort to anticipate and respond to changing stimuli more quickly and without the need for human interaction.

Electronics are being incorporated into more devices in widely varying applications, transmitting the collected data back through server farms, fed through AI systems and back to the device or the user. All the devices in this chain need to become smaller, more efficient, faster and increasingly resistant to environmental conditions.



### Transportation

Automotive, aerospace and maritime together make up a huge market for coatings. Platings for corrosion, wear and heat resistance are commonplace, as are plating on decorative components. However, the industry is evolving fast.

As advanced automation, safety and entertainment features are being included in new vehicles and with the push for electrification, electronic components comprise an ever-growing portion of the materials used in manufacturing vehicles.

## Common plating materials

### Gold

High conductivity and excellent corrosion resistance, solderability and weldability make gold extremely useful in the electrical industry for connectors, ICs and PCBs. However, its cost, softness and relatively low melting point means that gold use tends to be limited to those applications that need it most. Gold plated jewelry is known for its non-allergic nature, and brass pieces are often plated with gold.

### Silver

Silver has many positive qualities, including good corrosion and chemical resistance, good electrical conductivity and an appealing appearance. These properties, plus the rising cost of gold, has increased the demand of silver in the electronics industry in immersion silver coatings. Other applications include coatings for chemical storage containers and decorative items, such as tableware and jewelry.

### Tin

Tin is extremely versatile and alloys readily with other metals. It's non-toxic and has good solderability and corrosion resistance. Major uses of tin coatings are for food preservation containers and as coatings on electronics components. Tin-lead forms an alloy which is used to protect steel against corrosion, is etch resistant and again used for soldering.

### Nickel

Nickel coatings help to improve a component's strength and ductility. Electrolytic nickel coatings fall into two categories: Type I that produces a porous, ductile coating good for electronics components, and Type II that produces a bright, decorative finish that's good for wear resistance. Type II components include automotive grills that need a decorative finish.

### Electroless Nickel

For parts that are irregular in shape or those that need good corrosion resistance, electroless nickel is the coating to choose. This method of depositing nickel is used on aluminum to provide a solderable surface and for use with dies to improve lubrication. Nickel coatings are used extensively in transportation and mobile communications from bearings to heat sinks.

### Copper

Copper is used for its excellent heat transfer and conductivity. However, it's rarely used alone as the surface tends to corrode. Therefore, in applications such as PCBs, copper is used as an under-plating, with more inert metals deposited above it. It's also used extensively in plumbing fixtures and wiring.

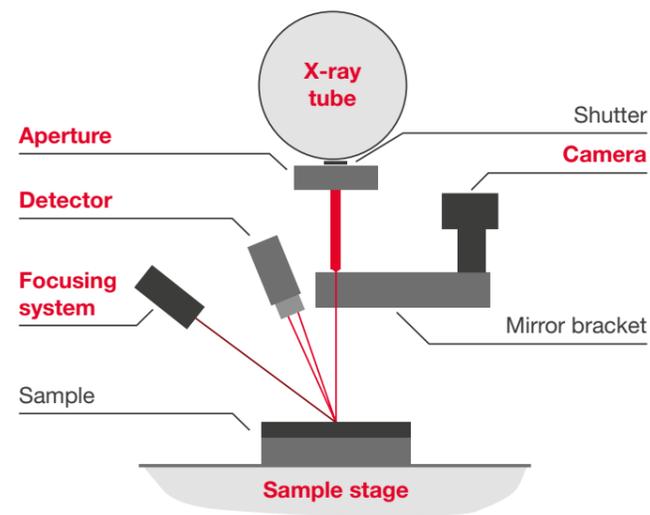
### Titanium

Titanium carbide and titanium nitride coatings provide good wear resistance and are used to coat hardened steel tools, extending the lifetime of band saws by up to five times. Porous, rough titanium coatings are used for medical implants as it's durable and provides a good surface for bone cells to grow. Titanium coatings are usually deposited with chemical vapor deposition (CVD) or ion plating.

# What's under the hood of your XRF analyzer?

Before we get into a discussion on how to get the best from your analyzer, it's a good idea to go over the main parts of a typical XRF instrument.

This diagram represents the main components within an XRF analyzer:



The components highlighted in red are the ones that we'll discuss further in this guide. Here's a brief explanation of what each one is:

**X-ray tube:** The part of the instrument that generates the X-rays that are directed at the sample.

**Aperture:** The aperture is the first part of the setup that directs the X-rays towards the sample. The aperture within the XRF instrument will determine the spot size – getting this right is crucial to precision and measurement efficiency.

**Detector:** This, along with associated electronics, processes the X-rays emitted from the sample: it detects both the energies of the X-rays and their intensity. There are different types of detector and we'll discuss these further in the guide.

**Focusing system:** This ensures that the geometry between incident X-rays from the X-ray tube, the part and the detector is consistent and measurable. If it isn't, the results won't be accurate.

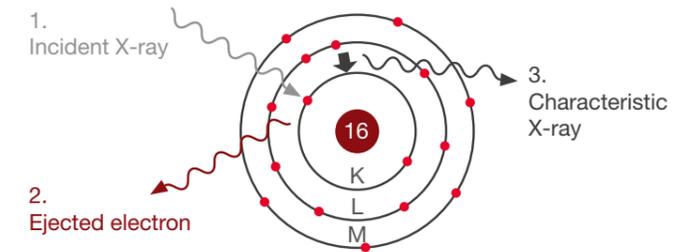
**Camera:** Enables the user to pin-point the area for measurement. In some cases, the camera feeds information to an automated operation module, and might include magnification options to pinpoint the precise location of the area you need to measure.

**Sample stage:** Your sample will sit on the stage, which can either be fixed or movable. Macro and micro movements are necessary to first find the feature, and then focus on the exact area to measure. The precision of your table is a factor in the positioning of your parts, and therefore the accuracy of your instrument.

## XRF Basics

XRF stands for X-Ray Fluorescence and is a technique for identifying the types and amounts of specific elements within a sample. For coatings analysis, the instrument converts this information into a thickness measurement.

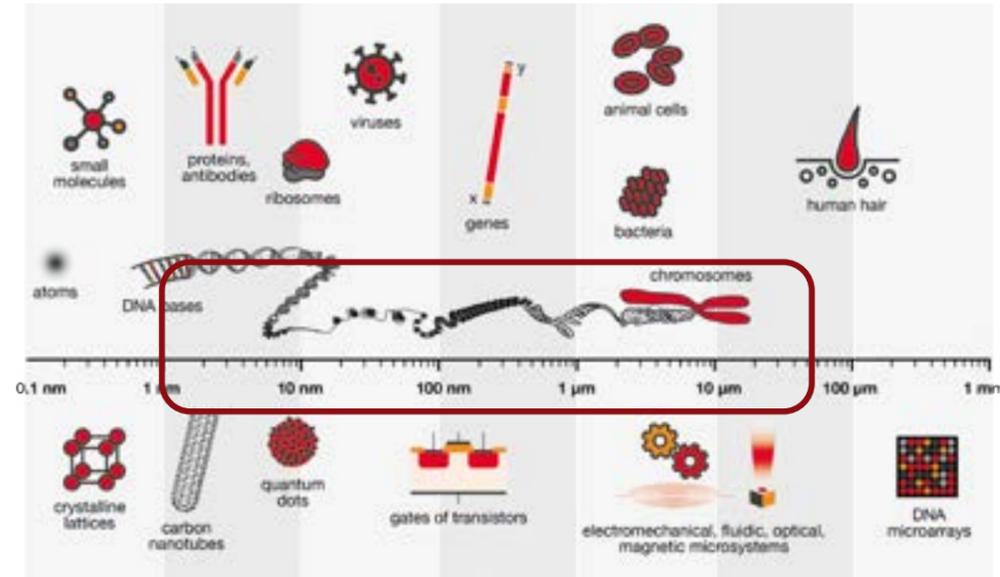
When you take a measurement, high-energy X-rays from the tube are focused through the aperture and hit the sample over a very small area (this area is your spot size). These X-rays interact with the individual atoms of the elements within the spot. This is explained in the following diagram:



The diagram represents a single atom, with a central nucleus in yellow and red electrons sitting in orbits. When you run an X-ray analysis, an incident X-ray knocks one of the inner electrons out of its orbit. Almost immediately an electron from the next orbit up will fall into the inner orbit to fill up the space. In doing so, this electron loses energy in the form of X-ray radiation and it's this characteristic X-ray that is picked up by the detector. Because the energy of the characteristic X-rays is unique to each element, the instrument can use the detected energy to tell us the type of atom the X-ray came from. And the intensity of X-rays detected at each energy level correlates to the amount of that element within the sample. This information is used to calculate the thickness and composition.

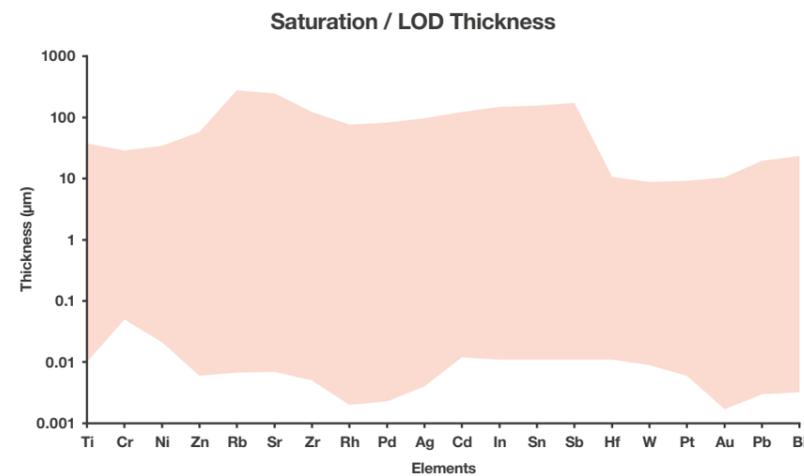
**XRF thickness range**

The following diagram gives you an idea of the workable thickness range of the XRF technique.



The minimum workable range at about 1nm is the minimum detection level of the XRF technique. Below this, the characteristic X-rays get lost in the noise and cannot be identified. The maximum range is around 50 μm. Above this, the coating is so thick that X-rays emitted within the atoms cannot escape the sample and reach the detector. This means that any further increase in thickness does not result in more X-rays reaching the detector, so the thickness appears to plateau.

The following graph gives you an idea of maximum and lower limits for different elements:



**Aperture**

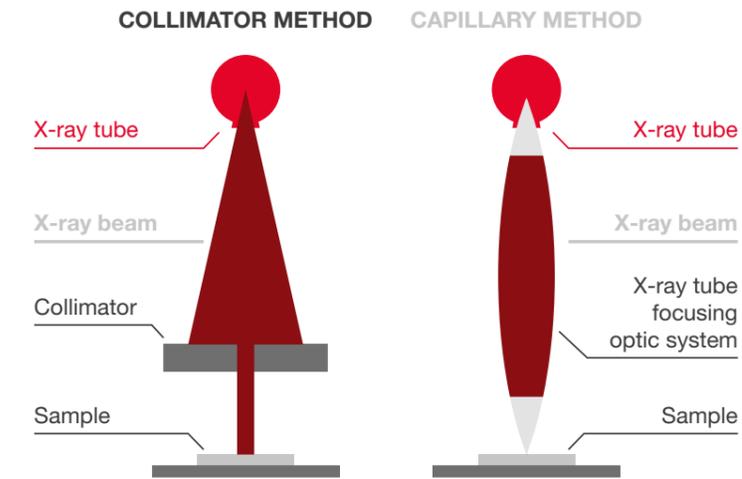
The spot size generated by your instrument needs to fall within the size of the features you need to measure. If the spot size is larger than the area you're focusing on, your results will be inaccurate because the analyzer will take the composition of the surrounding area into account. Even if this is just the air, your results will be off. There are two main aperture technologies that direct the X-rays toward the sample and set the spot size: mechanical collimation and capillary optics.

**Mechanical collimation**

A collimator is basically a metal block that has a precisely drilled hole through it. This blocks a portion of the X-ray signal, only allowing a small amount to pass through the hole and reach the sample. Collimators are typically useful for measuring features 100 μm (4 mil) and larger. Many XRF instruments come with a range of collimators of different sizes that you can choose when you set up a measurement. This ensures you can optimize collimator size for the best precision for each measurement (this is discussed more fully later in this guide).

**Capillary optics**

Polycapillary optics uses a bundling of specialized glass tubes to collect nearly all the X-ray tube output and focus it to a very fine spot. Compared to collimators, using polycapillary optics results in significantly higher intensity at the measurement location which can provide better precision on thinner coatings on smaller parts or features. Polycapillary optics are typically used for measuring features that are 10 – 50 μm.



**Aperture size vs spot size**

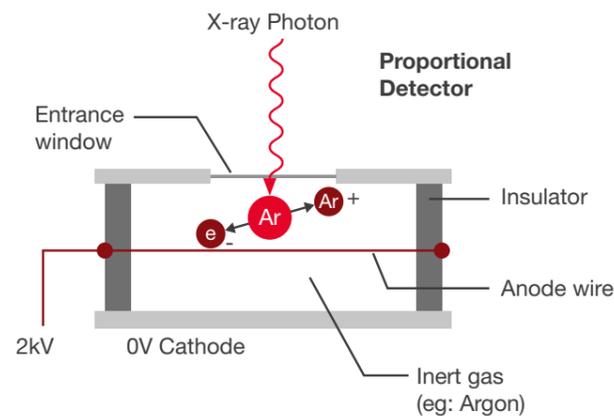
With either technology, there's some beam divergence as the X-rays pass from the outlet of the aperture to the sample surface, and you'll need to account for that when making your choice. Beam spread is typically greater with collimators than with capillary optics.

## Detector choices

There are two main types of detectors within XRF instruments: proportional counters and semiconductor-based detectors, such as an SDD. They both have advantages and which one you choose will depend on what you need to measure.

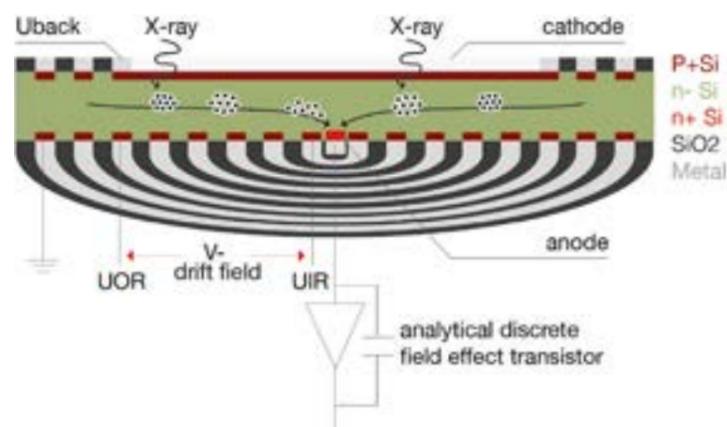
### Proportional Counters

These are cylinders of inert gas that ionizes when bombarded with X-rays. The ionized gas creates a signal that is proportional to the energy absorbed. They were used in the earliest coatings analyzers and are still widely used today.



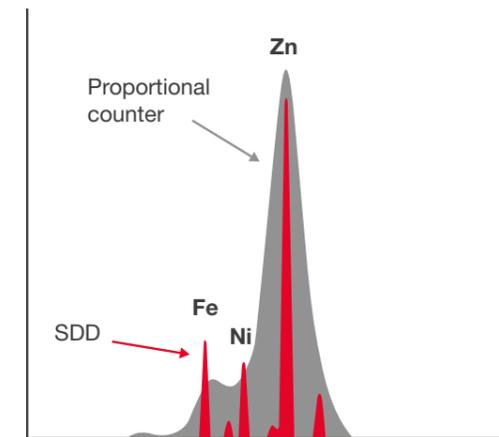
### Silicon drift detectors

There are several different kinds of semiconductor detector, but we'll consider the silicon drift detector, or SDD, as it's one of the most common. When the SDD is bombarded with X-rays, the detector material ionizes, creating a specific amount of charge. The amount of charge correlates to the element in the sample.



### Which detector to choose?

Essentially, proportional counters (PCs) are very effective for simple analysis where you have few elements. They can offer improved sensitivity for high-energy elements like tin or silver, especially when measuring with small collimators, whereas for phosphorus, SDD is better. PCs are lower cost than the SDD type. However, SDD offers better resolution – which means that it's easier to see results. This becomes important when you have several elements in the sample. The diagram below demonstrates the difference:



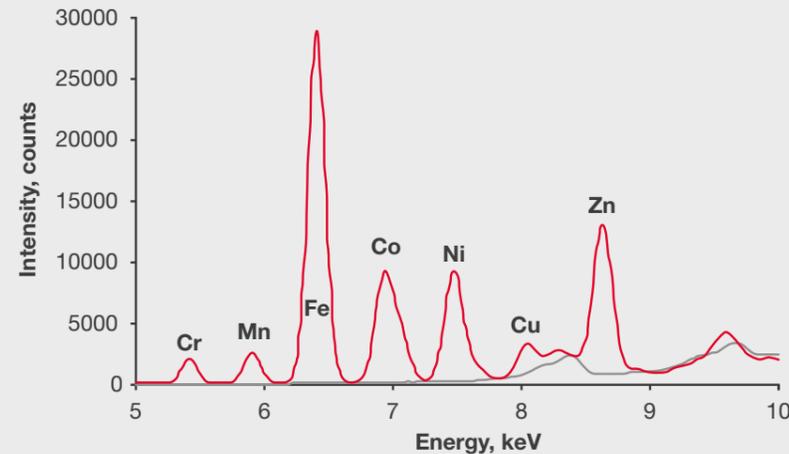
In the diagram, the red peaks are results obtained with the SDD; the gray is the same sample measured with a proportional counter. SDDs are also not affected as significantly by changes in atmospheric temperature as PCs. This is important when detection limits are very low. So, for very thin or complex coatings, SDD is the best choice.

#### A note for PCB manufacturers:

IPC-4552B (ENIG), IPC-4553A (immersion Ag), IPC-4554 (immersion Sn) and IPC-4556 (ENEPIG) do not specify a type of detector for compliance. In many cases, however, a silicon drift detector (SDD) may be preferable to achieve analytical performance targets or help you operate closer to your plating specifications.

## Understanding a spectrum

We've touched on how XRF works and what information it gives us. It's worth taking a closer look at the output of the instrument and how to interpret this information.



The graph above is a typical outcome from an XRF measurement. You can see peaks at different energies that correspond to the different elements present in the sample. The height of the peaks is the intensity of each energy level, i.e. how many readings at a given energy were detected. The intensity is used to calculate how much of a specific element is in the sample. For coatings analysis, this intensity correlates to the thickness or composition of the coating on the sample. Your analyzer will take this information and return the actual thickness and composition of the coatings. We'll go into the importance of calibration and how to ensure reliable thickness measurements in a later section.

For thin layers, you will get readings for the plated material and readings for the underlying substrate too, as the incident X-rays are able to penetrate the outer coatings and the emitted X-rays from the substrate are able to pass through the coating and reach the detector. However, as the coating thickness increases, you'll see a reduction in intensity of the substrate as the coating prevents transmission of X-rays from deeper within the sample.

## The basics: how to choose the right measurement techniques

### XRF

Metal and metallic coatings applied in the range of 0.001 – 50  $\mu\text{m}$  (0.05 – 2000  $\mu\text{in}$ ) to nearly any substrate material – including metals, polymers, ceramics and glass – can be accurately measured with XRF using one of two form factors: benchtop and handheld. Benchtop XRF instruments are designed to measure coating thickness and composition of single- and multi-layer coatings on small parts or individual features and specific areas on large parts. This is accomplished using an aperture that reduces the size of the X-ray beam size used to measure your parts. Handheld XRF instruments are designed to measure coating thickness and composition on large parts where it may be preferable or necessary to bring the instrument to the parts instead of bringing parts to the instrument.

### Differences between benchtop and handheld XRF

- | Benchtop XRF analyzers can be configured with features including a motorized precision sample stage and alignment tools for repeatable positioning, adjustable lighting and zoomable camera for clear sample imaging, as well as hardware and software for automating measurement tasks.
- | Handheld instruments, besides their inherent portability, allow you to measure parts that are too large or heavy to fit in a benchtop chamber, including the ability to reach deeper into larger assemblies to take measurements. They are also ideal for taking along for in-service inspection work and supply chain audits.
- | Due to the geometry of the X-ray tube and detector, benchtop XRF instruments can typically measure thicker coatings than handheld instruments and are better suited for complex, multi-layer coatings.
- | For textured surface finishes, a benchtop XRF should be fitted with a motorized stage to allow the instrument to scan an area on the part to provide an average thickness value. A handheld, with its larger spot size, may be able to provide an average in a single measurement.

Coatings analysis in accordance to ASTM B568, ISO 3497 and DIN 50987 can be achieved by XRF, regardless of the form factor of the instrument or the aperture technology.

### Capillary optics v. collimator

Aperture technologies available for benchtop XRF instruments are classified as either mechanical collimators or polycapillary optics. The selection is determined by the size of your parts or features and the thickness of the coatings you need to analyze.

### Collimators

Suitable for features as small as approximately 100  $\mu\text{m}$  (4 mil), circular and rectangular collimators are offered at multiple sizes for optimized precision and rapid analysis. Collimators providing spot sizes on the order of 1-3 mm can be found in some handheld XRF analyzers.

### Capillary optics

For features less than 100  $\mu\text{m}$  (4 mil) and coatings in the sub-nanometer (microinch) range, capillary optics are the best choice. With polycapillary optics, specialized glass tubes are clustered together in a tapered configuration. This advanced technology can achieve the smallest spot sizes and direct more X-rays at the parts, giving better precision on smaller areas.

## The basics: how to ensure your instrument is performing properly

### Routine instrument checks

XRF analyzers come with one or several ways to ensure the instrument hardware is performing as expected. These check samples can monitor characteristics like X-ray intensity, detector resolution and detector gain – a measure of the stability of the detector. When the instrument identifies minor changes, the results of the instrument check are used to automatically adjust the system and compensate for the changes. If significant deviations are identified, the instrument will issue an alert, letting you know to contact the manufacturer for support. Performing this instrument check at the recommended intervals is critical for getting consistent results. If the check is not performed frequently enough, your results might drift over time. If the check is performed too frequently, the instrument can become overcorrected and introduce errors. The manufacturer will provide guidance on this topic.

### Verifying calibrations

After running the routine check, it is recommended that you verify your calibrations before measuring any parts to ensure your instrument is under control. This can be done using stable, known production parts or with reference materials (standards). Reference materials are a good choice because they can be traceable to accredited bodies. It is typically recommended to verify calibrations on the day you expect to use the instrument.

### Certifying calibration standards

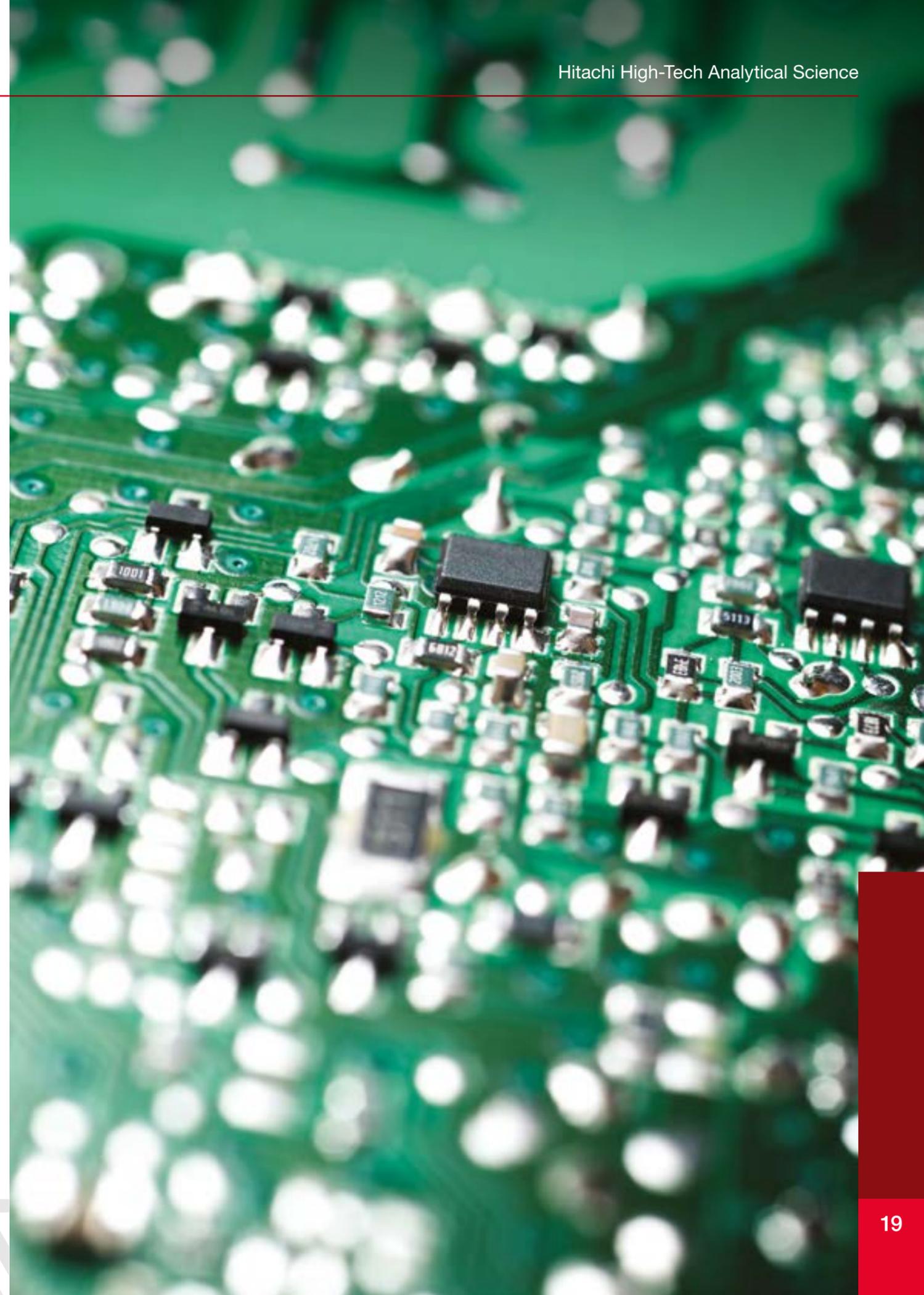
If purchased from an accredited facility, calibration standards arrive with a calibration certificate that indicates when and where the certification was performed, the known value and the measured uncertainty of the thickness and/or composition of the standard. It is good practice to have your calibration standards recertified by an ISO 17025 accredited lab on a regular basis that aligns with your internal quality program. This will ensure your standards are in good condition and are suitable for continued use or alert you that it may be time to replace them.

### Calibration standards: foils or hard-plated?

Standards can be individual foils that are mounted on a frame or hard-plated coatings applied to a substrate. Both are useful, and which you use depends on how you will use them. Foils offer an advantage in flexibility since you can have foil standards for your plating and place them over any substrate to create many calibrations. Hard-plated standards have an advantage in that they more closely resemble your actual parts and do not require the XRF to compensate for small air gaps between the foils and the substrate when they are stacked together. Hard-plated standards can be more robust since they are a solid piece, as opposed to thin foils that have risk of punctures or tears. On the other hand, foil standards can also offer an advantage when intermetallic layers can form on plated materials – since the foil standards are separated from the base, there is no risk of these boundary effects.

### Instrument certification

For reasons similar to why you get an annual health checkup or have your car inspected, it is recommended to have your XRF re-certified by the manufacturer to ensure that the analytical components (eg. X-ray tube, detector), electronics and mechanical components are behaving as expected. A trained engineer will review the instrument, run diagnostics, perform an analytical check and give the XRF a passing grade or make recommendations about components that may need some attention.



## Next level: things that can introduce error

**XRF is a comparative analytical technique, meaning that to get a result, it compares data collected from an unknown sample to data collected from reference materials on the instrument and compares that with established physical principles. While the technology is forgiving and users are trained on proper use, there are circumstances that can affect the results and introduce errors.**

### **Not using sample focusing**

This is a critical step in preparing a part for measurement. Focusing aligns the X-ray tube, part and detector in a consistent and measured geometry and distance. X-rays lose intensity with distance, so having the X-ray tube and detector unexpectedly farther from the part results in measurements that appear too thin. Positioning the tube and detector closer than expected results in measurements that appear too thick. This situation is exacerbated for multi-layer coatings, where the changing geometry is interpreted incorrectly.

### **Improper part orientation**

For flat parts, the angle of rotation is not a concern as the XRF signal is not affected. However, for curved parts, it is important to align the part in the same axis as the X-ray tube and detector. This makes it easier and more reproducible to align the part so that the X-ray beam hits the top of a convex part or bottom of a concave part, and not the side walls. Similar to focusing, measuring off-center changes the tube-sample-detector geometry. In extreme cases, having the part mis-aligned could prevent all XRF signal from reaching the detector.

### **Changes in the substrate**

Depending on the coating and substrate materials, the elements in the substrate can affect the XRF characteristics of the coating layers. These are well-known effects, so creating a calibration using materials similar to the parts you will measure eliminates any concern. If the base material of your parts is different from the calibration, the results could have errors. For example, consider parts that have nickel (Ni) and gold (Au) plating on a bronze (CuSn) substrate. Tin (Sn) in the brass substrate can act almost like a secondary X-ray source that creates more XRF signal for the coatings. If the calibration was made using a substrate of copper (Cu), the re-fluorescence effect is not properly modeled and the results for nickel and gold will be incorrect.

### **Measuring outside the range of the calibration**

The relationship between coating thickness or composition and intensity (XRF response) is linear over small ranges but is curved over larger ranges. Calibrations are therefore optimized to work over a finite range of thickness and composition, not over the entire range where analysis is possible. This optimized range is determined by regression settings and the reference materials that were measured to create the calibration. Work with your XRF manufacturer to understand the working limits of your calibrations and then set up warnings in your software if results fall outside of this range.

### **Not running routine instrument adjustments, or running it too frequently**

The XRF includes one or multiple ways to monitor the condition of the instrument and automatically correct for small changes in the characteristics of the X-ray tube, detector and electronics. It is important that these routine instrument adjustments are performed at intervals that are recommended by the manufacturer. If validation is recommended once a day, but is only performed once a month, the instrument could have been changing incrementally for that entire period. When the validation is run, there could be a step change in the results. Running the validation check more frequently than recommended can have a different effect – there is a risk that the instrument tries to make many small, unnecessary changes that add up to noticeable changes. This is called “overcorrection”.

### **Poor environmental conditions**

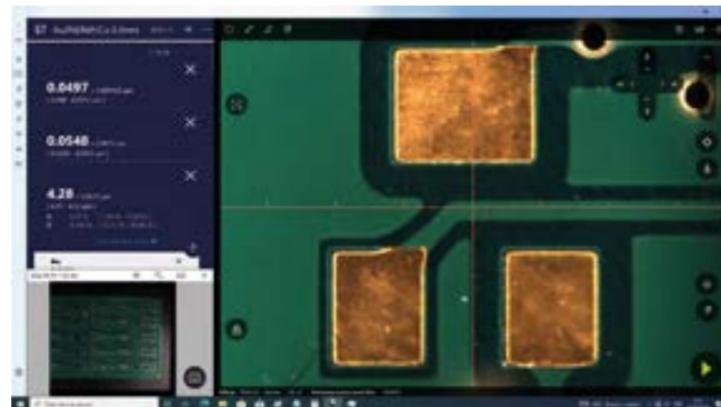
In addition to changing temperature and humidity near the analyzer, there are other environmental conditions that can affect the performance of an XRF. Dust and caustic chemicals in the atmosphere can interfere with XRF results and can prematurely degrade electrical components in the instrument itself and the PC that controls the instrument. The mains power to the XRF can affect the performance of electrical components including the X-ray tube power supply and detector electronics, which may introduce errors. In areas where the line power is not stable, it is recommended to install a line conditioner or an uninterruptible power supply. As much as possible, keep the analyzer in an environmentally controlled space with steady, reliable power and maintain some distance away from other equipment in the facility to keep people, parts and moving equipment from bumping into the equipment.

# How to increase productivity from your XRF testing program

In this section, we'll cover practical things you can do in your daily analysis to increase the speed of your testing, while ensuring you maintain the precision and accuracy you need.

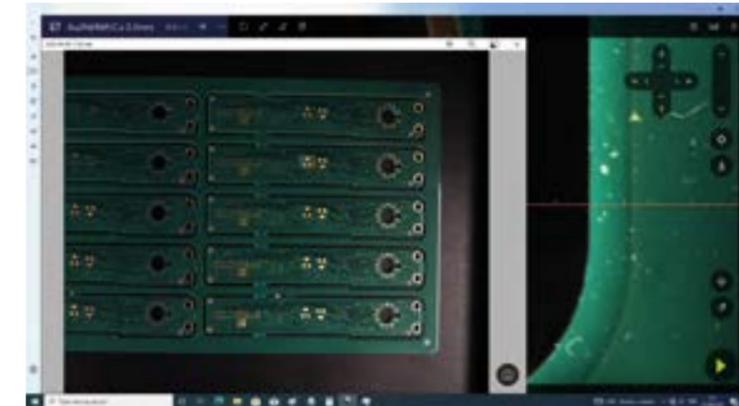
## Using a wide-view camera

This is a technique that's really useful if you're measuring large parts or loading several parts into the chamber for automated analysis. The issue with large parts is that you can't always see the whole component on the camera view. Here's an example of a typical view with a standard-view camera showing a 7.1 x 5.3 mm area.

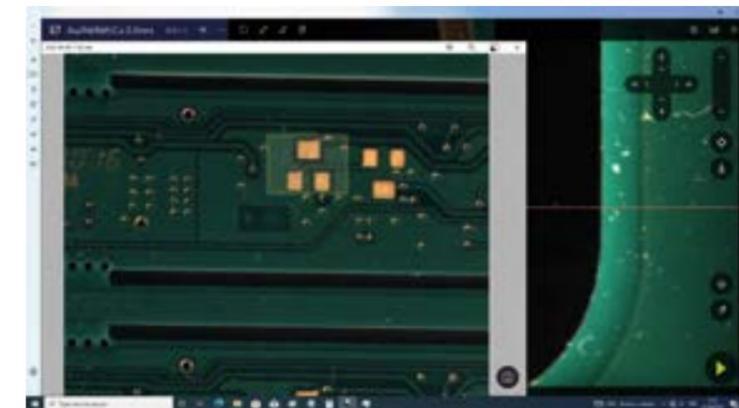


Fine positioning with standard sample camera image

This means that you have to spend time hunting around the part until you've found the feature you need to measure. The solution is to use a second, wide-view camera that allows you to see the whole board at once. It's then a simple job to find the area of interest and then zoom in to make fine adjustments. The image on the top of the opposite page is using a wide-view camera with a field of view of 250 mm x 200 mm. The image below the wide-view image is the same board but zoomed in for finer details. This saves time and operator frustration.



Wide-view image



Wide-view image, zoomed in on target measurement area

### Wide view camera speed test

To see just how much time you can save when implementing the wide-view camera technique, we carried out a simple test. Using a large board as a test sample, we asked the operator to set up a program to measure 5 points – each of the four corners, and one in the center. The operator completed the task first with the standard, narrow-view camera and then with the wide-view camera and we compared the time taken.

**Time taken with narrow-view camera: 73 seconds.**

**Time taken with wide-view camera: 59 seconds.**

**This equates to a 20% saving for each program and could save up to 12 minutes each day. In one year, you could save 40 hours on this operation alone.**

## Automated parts program routines

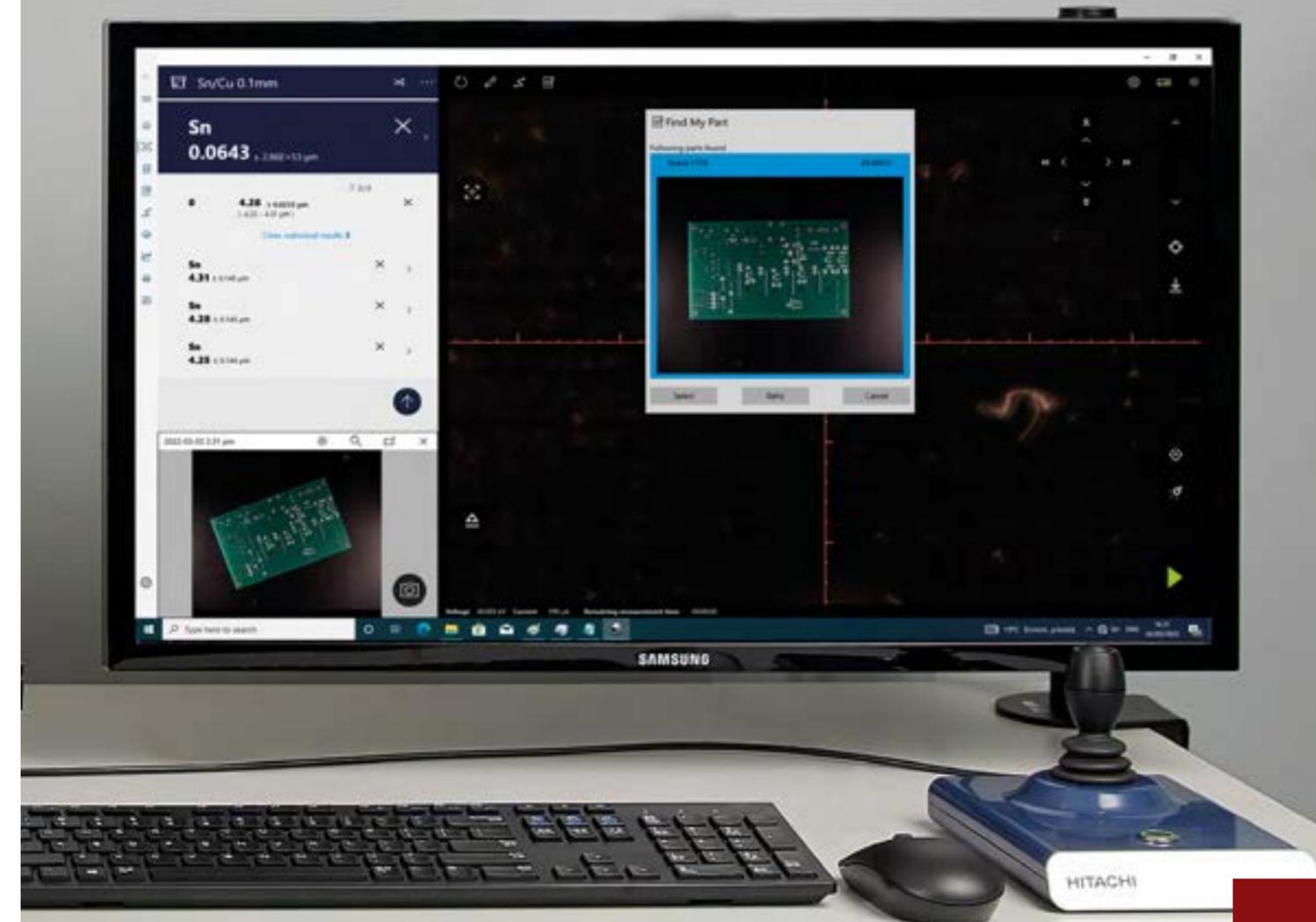
Analyzing routine parts means the operators repeat the same setup tasks throughout the day. They need to find the measurement locations, select the appropriate calibrations, choose the collimator size that best fits the area, set the prescribed measurement time, and define the data handling requirements. This all takes valuable time, and each step introduces the possibility of making a mistake. Each of these decisions or work instructions can be assigned to parts programs to create automated routines that simplify and streamline measurement setup.

One way these routines can be started is by using machine vision. The operator loads a part into the sample chamber and runs the parts program. The instrument uses an assigned camera to grab an image of the part and searches for it in the instrument's library. When a good match is found, the operator simply confirms the identified part and the instrument handles the rest – measurement locations are identified, the right calibrations are loaded, appropriate collimator sizes are selected, the analysis times are set, and the data export or report creation rules are loaded.

**Starting a measurement using machine vision can be 72% faster – or quicker – than setting up a measurement manually, reducing the setup time from minutes to seconds.**

Not all parts are complicated and may involve fewer decisions. Automated parts program routines can help here too. In addition to using machine vision, parts and their associated applications or measurement routines can be loaded using a simple text search or by scanning the QR code or barcode from a traveler. These routines do not use the instrument's cameras and require a bit more input from the operator, but they make key decisions including loading the right calibration, collimator size and measurement time.

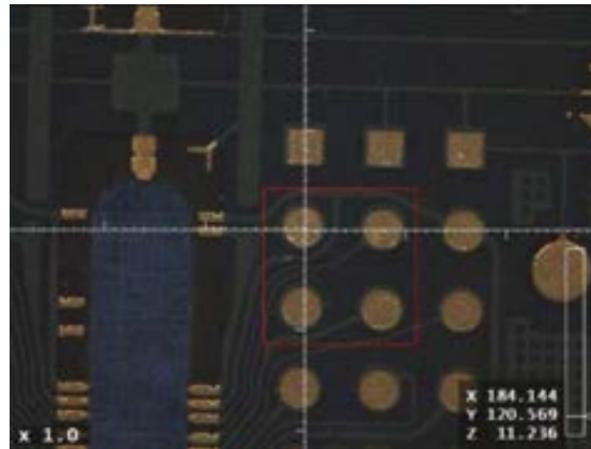
Whether using machine vision, part name searches or QR or barcode scans, automated parts program routines simplify your XRF setup, reduce mistakes, improve operator utilization and help you make quicker decisions.



## Automation with pattern recognition

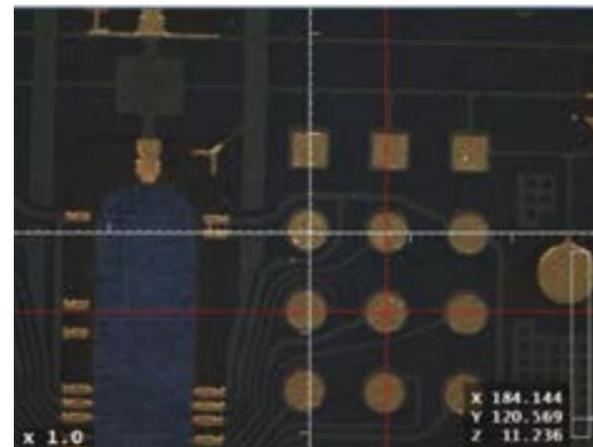
We've already seen that it takes time to find the right measurement location on large samples. If you are measuring a high volume of the same sample, you can get the software to do a lot of the work for you. Image processing software recognizes patterns on the sample and will automatically position the sample for measurement. This is extremely useful when you are routinely measuring large and complex parts where you have to locate minute features within a large area. Here's an example of how this works:

### Step 1: Set up the area of interest



Select area of the part that identifies that pattern (red rectangle)

The first step is to teach the software to find the right location. It does this through pattern recognition, so all you need to do is place the right pattern in the field of view and tell the software that this is the reference. Then, you select the exact measurement location within the image. In this case, the pattern is the group of four pads highlighted in the red square and the measurement location is the center point of the bottom-right pad in the group. You can also define the tolerances at this stage.



Select exact measurement area (red crosshairs)

### Step 2: Take the measurements

When it's time to take measurements on the actual samples, all the operator needs to do is place the pattern (in this case, the group of pads) into the image view and the software automatically moves to the centered measurement area. In parts with irregular geometry, the part doesn't even have to be in the right orientation, as the software will correct for sample rotation.

This saves the operator time as they don't have to pick out exactly the right location. It's easier and faster and ensures the right area is measured each time.

This technique can save significant amounts of time when measuring many parts in a batch. For example, this is a test fixture for loading many contacts.

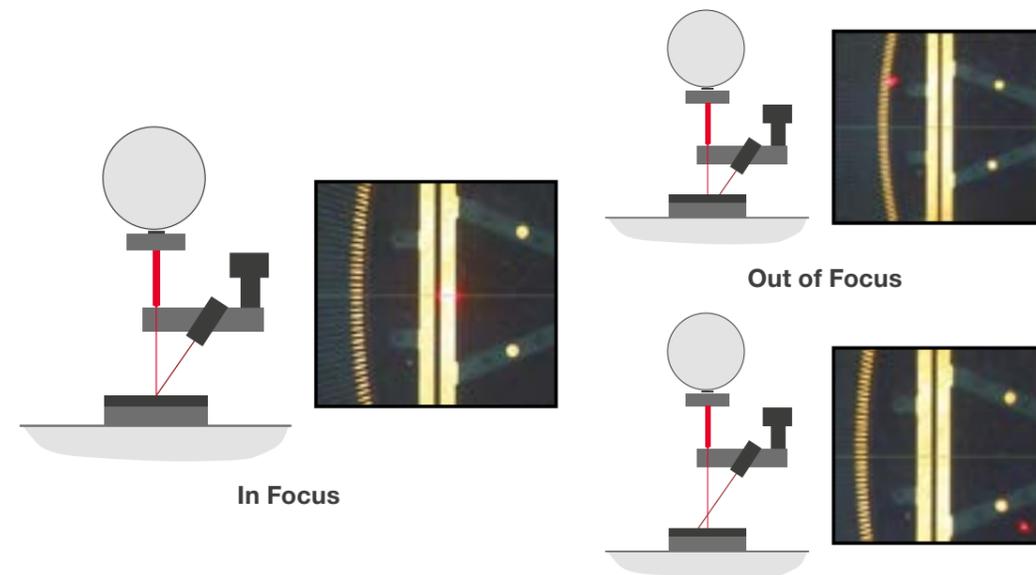


This would save the operator a huge amount of time and ensure measurements are taken in the right location every time.

## Focusing techniques

Focusing is important because the distance from the X-ray tube to the sample and then to the detector affects the XRF results. The instrument will expect this distance to be a certain value. If the distance is less than expected, the coating will appear too thick, and if the distance is too large, the coating will appear too thin. Maintaining the right distance is a fundamental technique and all instruments will have methods of doing this which will be a variation of the following:

### Manual laser focus for simple shapes



For simple components that are basically flat, a simple laser focusing technique is sufficient. In this case, a fine laser is shone onto the surface of the part and the operator moves the tube and detector up and down until the laser is positioned on a focus line. You can see this in the images above where the left-hand image is in focus and the right-hand image is out of focus. This technique is effective but can be time consuming if parts are complex and it does require the operator to make some decisions.

### Auto approach focusing

The movement of the tube and detector can be done automatically on some instruments. In this case, the desired distance is set during calibration. Then, during a measurement, the instrument uses a sensor to measure the distance and automatically moves the head into the right position. This is faster than the manual approach and is good when measuring samples of different heights.

### Auto approach speed test

To demonstrate the time saved with auto approach, we conducted a speed test that pitched auto-approach vs manual laser focus for the analysis of six boards with different heights. We asked the operator to create a multi-point program to measure all six parts using the two techniques.

**Time taken with laser focus: 44 seconds.**

**Time taken with auto approach: 29 seconds.**

**This equates to a 33% saving for each program and could save up to 12 minutes each day. In one year, you could save 40 hours in this operation alone.**

### Dealing with complex geometries with auto focus

This focusing method doesn't require the analysis head to move at all. Auto-focus measures the distance from the tube to the sample to the detector and updates the instrument's calibration to account for the new distance.

This is the best method for dealing with complex geometries, allowing you to measure parts of different shapes and sizes and even into recessed areas.

### Auto focus speed test

Once again, we put the auto-approach feature to the test and compared it to the manual laser focus. The operator was asked to set up a multi-point program for six boards of different heights, and the time taken for the set up noted.

**Time taken with laser focus: 44 seconds.**

**Time taken with auto focus: 17 seconds.**

**This method saves a huge 62% in time and is by far the fastest of the three techniques. Over the course of a year, this time saving could add up to 76 hours.**

This is the technique to choose if you are measuring high volumes of complex shapes.

## Securing parts of irregular shape

Given that the distance from the sample to the X-ray components is crucial in getting reliable results, you need to make sure that your sample isn't going to move around when in the analyzer. For flat, simple shapes, it's not a problem; you just place them on the sample stage. But for the majority of parts, the component is not flat and will certainly move around without some kind of fixture. These brackets are a typical example of the type of component that will need fixing during a measurement.



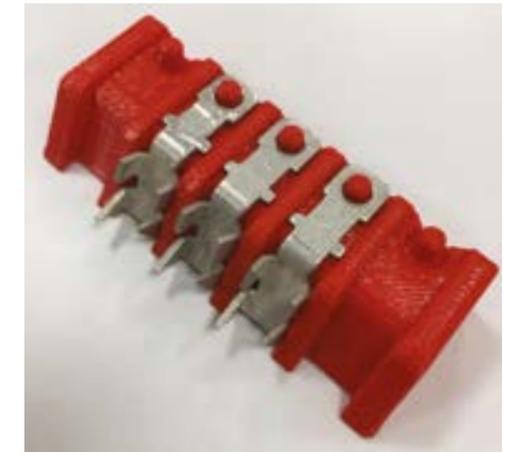
These kinds of components pose a challenge. There are many edges that will need checking, but no obvious way to stand the part so those areas are nice and perpendicular to the X-ray beam. There are two ways we can address this, one rather more advanced than the other.

### Ball of clay method



This is perhaps not the best way, but it does provide a fast way of getting a measurement done in the absence of any other type of holder. It's basically a ball of clay that you press the part into. You have to check as best you can whether the part is completely level, but once it is you can load it into the XRF analyzer and take your measurement. It's fast and cheap and probably not as accurate as we'd like.

### 3D printed part method



The ability to 3D print sample parts has been a massive benefit for making sample holders for irregular shapes. As you can see from the photograph above, with 3D printing it's relatively easy to make sample holders that ensure the components are presented flat to the XRF instrument. You can use this kind of setup whether you have a motorized or manual stage and it's great for getting repeatable results every time.

## Plating bath analysis

XRF is a versatile, non-destructive technique that's capable of measuring solids, liquids, powders and pastes. This makes it ideal for testing plating bath chemistry, making XRF a viable alternative to complex atomic absorption spectroscopy (AAS).

### Measuring plating bath chemistry with XRF

It is extremely easy to test the plating bath solution. All you do is pour a small amount of the solution into the sample cup (shown below). Simply place the cup in the analyzer and within a minute you can verify the composition of one or more elements.



### Typical calibration range and performance

The table below presents precision values for three different plating bath chemistries.

	Sn	Ag	ZnNi / Zn	ZnNi / Ni
Concentration	10 - 50 g/l	15 - 35 g/l	0-15 g/l	0 - 3 g/l
Error	<10%	<10%	<10%	<10%
Precision	0.11 g/l	0.10 g/l	0.08 g/l	0.06 g/l

It's important to note that the way coatings XRF analyzers are set up makes them less than ideal for detecting trace elements within plating bath chemistries. They are great for measuring the main chemicals, but if you need to test for trace elements, such as Cu within Ni baths, you'll need a dedicated XRF instrument. You'll still get the time and cost-saving advantages over the AAS method, and you'll be able to test much more frequently for better process control.

## XRF: A simple alternative to AAS

Atomic Absorption Spectroscopy has similarities to XRF as a technique – it uses the characteristic behavior of electrons within atoms to identify the elements present in a sample. Instead of X-rays, AAS uses the fact that different elements absorb light in a characteristic way. By analyzing which wavelengths of light have been absorbed by the sample, AAS can determine which elements are present.

### Sample preparation

AAS is great for analyzing solutions – which is why it's so widespread in plating bath chemistry analysis. But there is a lot of complex sample preparation required. Unlike XRF, you can't just pour the bath into a holder and test it. The exact process depends on the type of AAS carried out, but often you'll need to use concentrated acid to digest the bath solution over a period of time, using specialist equipment. The sample preparation phase of AAS is critically important for getting an accurate result.

It's this time-consuming process – and the fact that you have to send samples off-site for testing – that makes AAS quite a laborious technique. It certainly does give excellent results, but those results can often be verified faster with an on-site XRF instrument.

## Effect of aperture size and measurement time on precision and cost savings

We've discussed several methods of improving the efficiency of your testing. The last aspect of this is the measurement time itself. The precision (standard deviation) of your instrument is strongly related to measurement time and the size of the collimator you choose. And the precision you need depends on the tolerances you're prepared to accept on your coating thickness. We'll explain how all this links together before discussing how to choose the best parameters.

### Aperture size and XRF precision

We've mentioned above that the best aperture to choose is one that fits your parts. If the spot size is too big, then the X-rays will excite the surrounding areas and your results will include elements outside your target area, giving you incorrect results. If you are purchasing a new XRF, you need to decide if collimation or capillary optics makes the most sense for your parts. If you choose an instrument with collimators, or if your existing XRF has multiple collimators, one option is to choose a very tiny collimator that fits well within all the features on your samples. But the smaller the collimator, the longer you'll have to measure to get the precision you need. For example, using a 0.15 mm (6 mil) round collimator instead of a 0.3 mm (12 mil) one takes four times as long to get the same precision. This can have a significant effect in testing throughput.

### Measurement time and XRF precision

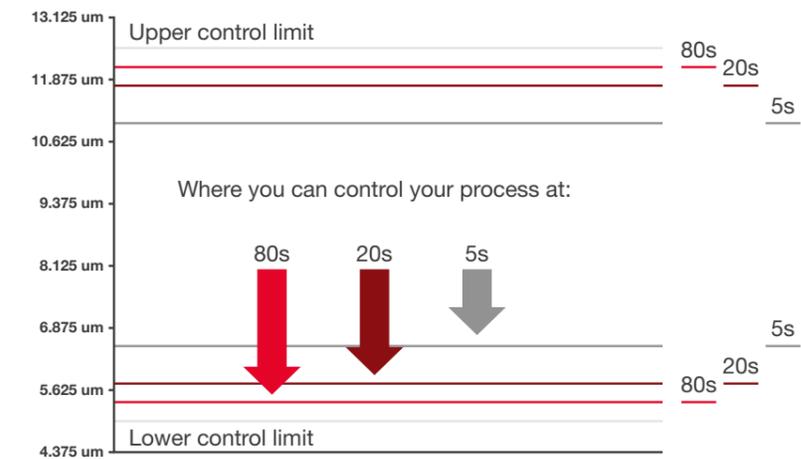
The longer you measure a single point on your sample, the more information you get and the better the precision, i.e. your standard deviation is closer to the average value. But this is not a linear relationship. If you want to improve the precision by half, you'll need to measure for four times as long. This is illustrated in the following table:

Time	Precision	3σ (99% confidence)
5s	0.5 μm (20 μin)	1.5 μm (60 μin)
20s	0.25 μm (10 μin)	0.75 μm (30 μin)
80s	0.125 μm (5 μin)	0.375 μm (15 μin)

So, you have three related parameters, collimator size, measurement time and precision. Collimator size is the easiest place to start because it has to be just smaller than your smallest feature. Then, you can work with measurement time to give you the precision you need. And that precision is often a business decision on whether throughput or material costs are more important to you.

### How to decide the right measurement time

Given a fixed collimator size, the right measurement time depends on the precision you need. The diagram below is a visual representation of how measurement time affects how close to your control limits you can operate.



Using the information above, if your XRF measurement time is 20 seconds, you'll get a precision of 0.25 μm (10 μin), which means that you are 99% confident that your XRF measurement is within +/- 0.75 μm (30 μin). Increase the measurement time to 80 seconds and you'll be 99% confident that your measurement is within +/- 0.375 μm (15 μin). If your lower control limit is 5 μm (200 μin), then at 20 seconds you'll need to aim for a thickness of 5.75 μm (5 + 0.75) [230 μin (200 + 30)], compared with a thickness of 5.375 μm 215 μin at an 80 second measurement.

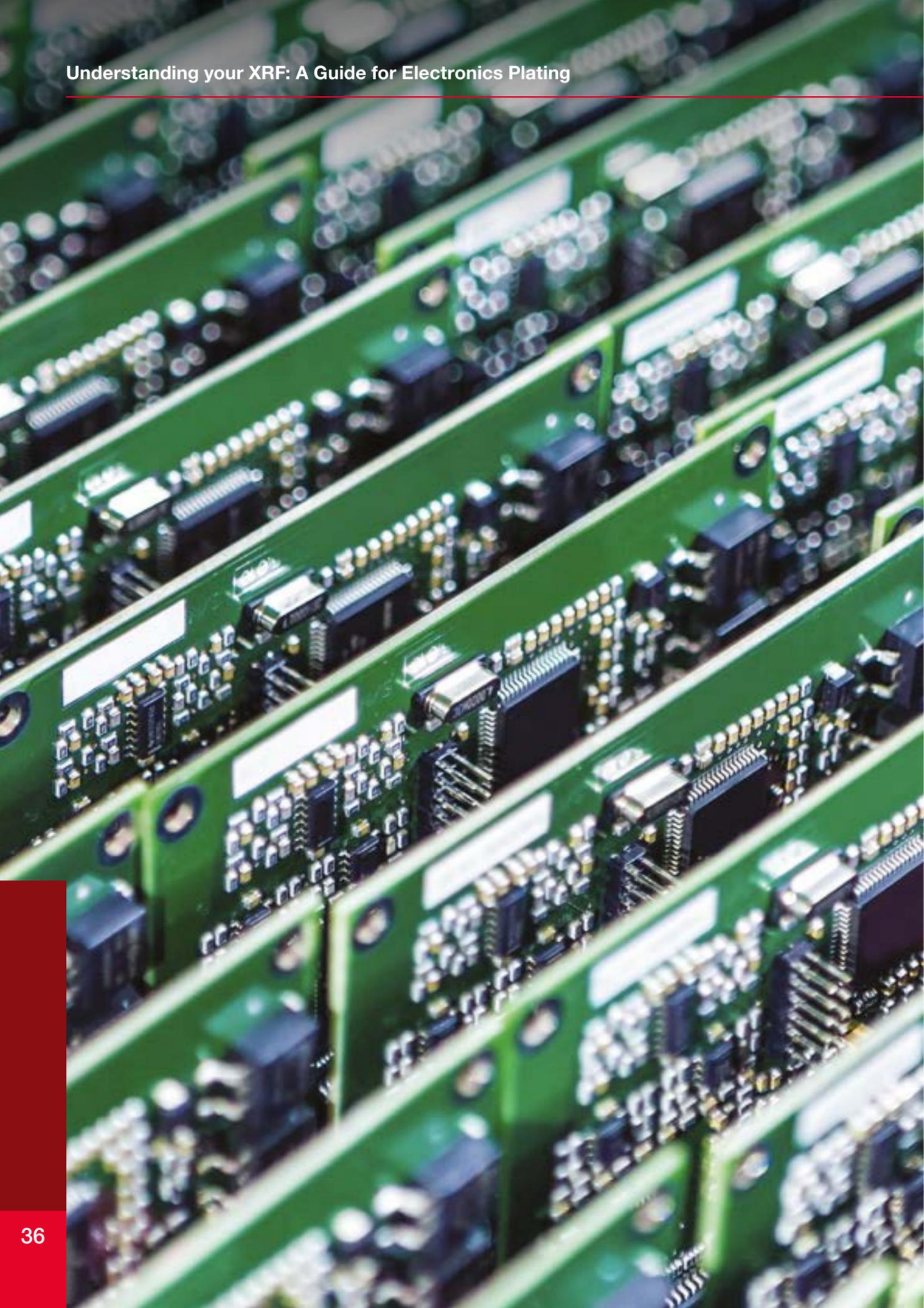
**This is a 7% saving on material costs, which could be significant if you're working with expensive materials.**

Conversely, throughput might be more important to you. In that case, you can plate well above the lower control limit and bring the measurement time right down.

**Using polycapillary optics at relatively short measurement times can offer similar precision improvements and cost savings as using longer measurement times with a collimator. The up-front acquisition cost of an XRF using polycapillary optics may be higher, but you can take advantage of the material cost savings throughout the lifetime of the instrument.**

### How long should you measure for?

There are practical limits to how short or long a measurement time can be taken. On the short side, in addition to the precision getting worse, the XRF needs enough time to collect a meaningful (or statistically significant) amount of data in order to report a usable result. There are also mechanical and electrical processes – such as setting Xray tube power, moving the shutter and calculating results – that take time. Typically, a coatings XRF measurement taken in less than 2-5 seconds is not recommended. On the long side, you need to balance measurement time, analytical precision and sample throughput. In the preceding example, we saw how increasing the measurement time from 20s to 80s resulted in the precision improving by half from 0.25 μm (10 μin) to 0.125 μm (5 μin). To get another similar precision improvement from 0.125 μm (5 μin) to 0.0625 μm (2.5 μin), the measurement time needs to be increased from 80s to 320s. In most cases, tying up the instrument for an additional four minutes is not worth that precision gain.

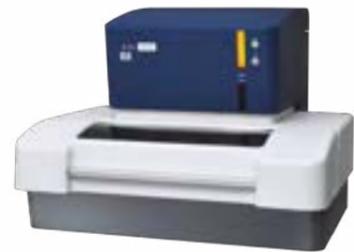


## Our solutions for electronics analysis

We specialize in high-tech analysis solutions, designed to help electronics manufacturers maintain quality of their coatings in a high-throughput environment. In our 45 years of supplying the coatings industry, we've developed a range of instruments that support quality control and RoHS programs.

## Coatings XRF Analyzers

Our range of XRF analyzers help to ensure consistent and accurate coatings for plating suppliers in high-throughput environments.



### FT160

**FT160: Microspot XRF for when 1 nanometer can be the difference**

Designed for tiny features and ultra-thin coatings analysis, the FT160 meets the challenges of the increasingly miniaturized world of electronics.

**The FT160 offers:**

- | Polycapillary optics and a high sensitivity SDD detector
- | Measurement of features smaller than 50 µm
- | Superior performance to meet the challenge of semiconductor wafer technology
- | Fast results and simplicity of use to increase productivity
- | A large door and stage to speed up sample presentation



### FT230

**Advanced features for high-volume testing**

Designed to simplify and accelerate testing of components and assemblies, the FT230 makes it easier to measure more parts in less time. Let your XRF make decisions for you.

**The FT230 offers:**

- | Find My Part™ smart recognition for quicker start-up times
- | Automated sample focusing for increased throughput and ease of use
- | Optional second, wide-view camera for easier feature locating
- | Flexible connectivity for sending results to SCADA, QMS, MES and ERP systems, and diagnostics to Hitachi
- | A large-area, high-resolution SDD for high precision on thinner and more complex coatings



### X-Strata920

**X-Strata920: XRF with your choice of analysis chamber**

Designed to analyze samples of a wide variety of shapes and sizes, the X-Strata920 is ideal for many applications, including PCB surface finishes, connector coatings and more.

**The X-Strata920 offers:**

- | A high resolution SDD option for complex coatings analysis
- | Four configurations to fit samples of any shape
- | A slotted chamber for small or long and skinny samples
- | An optional mini-well chamber for taller parts
- | An optional automated motorized stage for measuring several locations on a single component



### CMI Series

**CMI Series Gauges: Simple copper thickness measurement**

Our range of handheld and bench-top gauges use eddy current or microresistance technology to measure coating thickness on contact and are ideal for measuring copper on PCBs.

**The CMI Series offers:**

- | Surface copper thickness probes with user-replaceable tips
- | Thru-hole copper thickness probes with temperature compensation
- | Gauges for measuring thickness of Cu foil or laminate
- | Digital gauges with instantaneous readings
- | Factory calibrations that are ready to measure right out of the box

## RoHS Conformance Equipment

Our range of analyzers designed for RoHS (Restriction of Hazardous Substances) analysis are quick and easy to use and have the flexibility to adapt as regulations change.



### EA1400

#### EA1400: High throughput XRF analysis for RoHS

The EA1400 benchtop XRF analyzer uses advanced detection technology and innovative X-Ray optics design for rapid analysis of RoHS substances.

##### The EA1400 offers:

- | High performance detector boosts the count rate for improved resolution of trace elements from the bulk material
- | Ultra-fast cadmium screening enables high throughput testing
- | Innovative detection system gives superior measurement ability for lighter elements
- | X-ray optics alignment optimized for detecting impurities on rough surfaces and buried beneath the surface
- | Built-in failure analysis for investigation into unusual or above-limit impurities



### EA1000A III

#### EA1000A III: Dedicated XRF analysis for RoHS

Designed to speed up and simplify RoHS testing in high-volume production environments, the EA1000 series is compliant with current directives and allows you to update criteria as new legislation emerges.

##### The EA1000A III offers:

- | Analysis of a wide range of elements, including RoHS and halogens
- | Ability to accommodate a range of sample sizes, from large components to thin wires
- | Enhanced halogen analysis for accurate results
- | Fast analysis time with ability to measure up to 12 samples at a time
- | Advanced analysis software for differentiating between Hg and Zn



### HM1000

#### HM1000: Quick and simple phthalate screening

Designed for low-cost, rapid screening of phthalates, the HM1000 uses thermal desorption technology to screen for hazardous substances in PCBs and other electronic devices.

##### The HM1000 offers:

- | Screening for phthalates: DEHP, DIBP, BBP, DBP
- | High sample throughput, with typical analysis taking less than 10 minutes
- | Simple operation, with intuitive software and at-a-glance presentation of results
- | Auto-sampler can measure up to 50 samples at once
- | Low running costs with inexpensive sample holders and no need for helium gas



### X-MET8000

#### X-MET8000: Rapid and reliable XRF analysis on the move

In addition to our benchtop XRF analyzers, the handheld X-MET8000 provides fast and non-destructive coatings analysis, RoHS screening and alloy identification.

##### The X-MET8000 offers:

- | Powerful XRF technology in an easy-to-use handheld analyzer
- | Analysis results displayed on the large touch screen in seconds
- | Up to 12 hours of use on a single battery charge
- | Robust design tested to the MIL-STD military grade standard for robustness
- | Lightweight design of only 1.5kg for minimizing fatigue when used for long periods

## High-sensitivity Thermal Analyzers

Our range of thermal analysis equipment is optimized to detect and visualize the smallest reactions, while being robust, reliable and easy to use.



### NEXTA DSC

#### NEXTA DSC: High accuracy materials characterisation

Designed for accurate determination of melting point, glass transition and crystallisation temperatures, our NEXTA DSC range of differential scanning calorimeters deliver excellent sensitivity and baseline flatness.

#### The NEXTA DSC range offers:

- | High sensitivity and baseline performance, with unique furnace design for accuracy
- | RealView® camera system that allows you to watch material behaviour on screen
- | Intuitive, easy to use software, with advanced functionality for specific applications
- | Reliable auto-sampler testing and auto analysis function for faster testing
- | High degree of flexibility, allowing for addition of options after installation



### NEXTA STA

#### NEXTA STA: Complete quantitative thermal analysis

Designed for complete thermal analysis of materials, including thermal resistance, decomposition temperature, melting point and specific heat testing, the NEXTA STA range combines DSC and TGA to deliver TGA applications and more within a single analyzer.

#### The NEXTA STA range offers:

- | Ultimate accuracy and precision even when measuring trace amounts of material
- | Superior heating technology that meets the most advanced applications of TGA
- | Cp measurement in a wide temperature range
- | Unique, RealView® camera system for viewing material behaviour on screen
- | Easy to use with automated features, intuitive software and simple report creation



### TMA7000

#### TMA7000: Versatile thermal analysis of mechanical characteristics

The TMA7000 range can carry out a range of measurements within a single instrument – from precise TMA analysis, including thermal expansion, glass transition and softening, to DMA testing and creep measurement.

#### The TMA7000 range offers:

- | High accuracy with a high sensitivity, low noise TMA signal over a wide measurement range of up to +/- 5 mm
- | Ability to carry out TMA, DMA, stress-strain, creep and stress-relaxation measurements
- | Capability to measure minor changes of low-expansion material and thin films
- | Versatility for a range of applications due to superior control technology and a complete range of measurement probes
- | Improved thermal efficiency with auto cooling systems that reduce operating costs and increase throughput



### DMA7100

#### DMA7100: Optimal flexibility for an extensive range of materials and analyses.

For measuring storage and loss modulus which allows the measurement of glass transition ( $T_g$ ) as well as secondary transition ( $T_{\alpha}$  and  $T_{\beta}$ ). A wide range of measuring heads are available to measure soft and stiff samples over a wide temperature and frequency range.

#### The DMA7100 range offers:

- | The RealView® camera system lets you see the material behavior live on screen and recorded with your thermograms to help you understand and share your results
- | Flexible and intuitive software which includes sample analysis wizard for optimal results every time
- | Equipped with Lissajour monitor which allows the validity of the results in real time and post measurement
- | The ability to work as a thermomechanical analyzer (TMA) which allows measurements such as CTE, stress-strain and creep recovery

## Additional Instruments for Materials Analysis

Hitachi's full range of instruments for reliable and accurate materials analysis are available to help plating shops optimize their operations.



### ZA3000

#### **ZA3000 Series\*: Atomic absorption spectrometry**

Designed to measure major elements and contaminants in plating baths to ensure proper chemistry is maintained throughout plating operations.

#### **The ZA3000 Series offers:**

- | High sensitivity for trace element analysis
- | Background correction for all elements for high reliability
- | Enhanced basic performance for achieving high accuracy



### TM4000

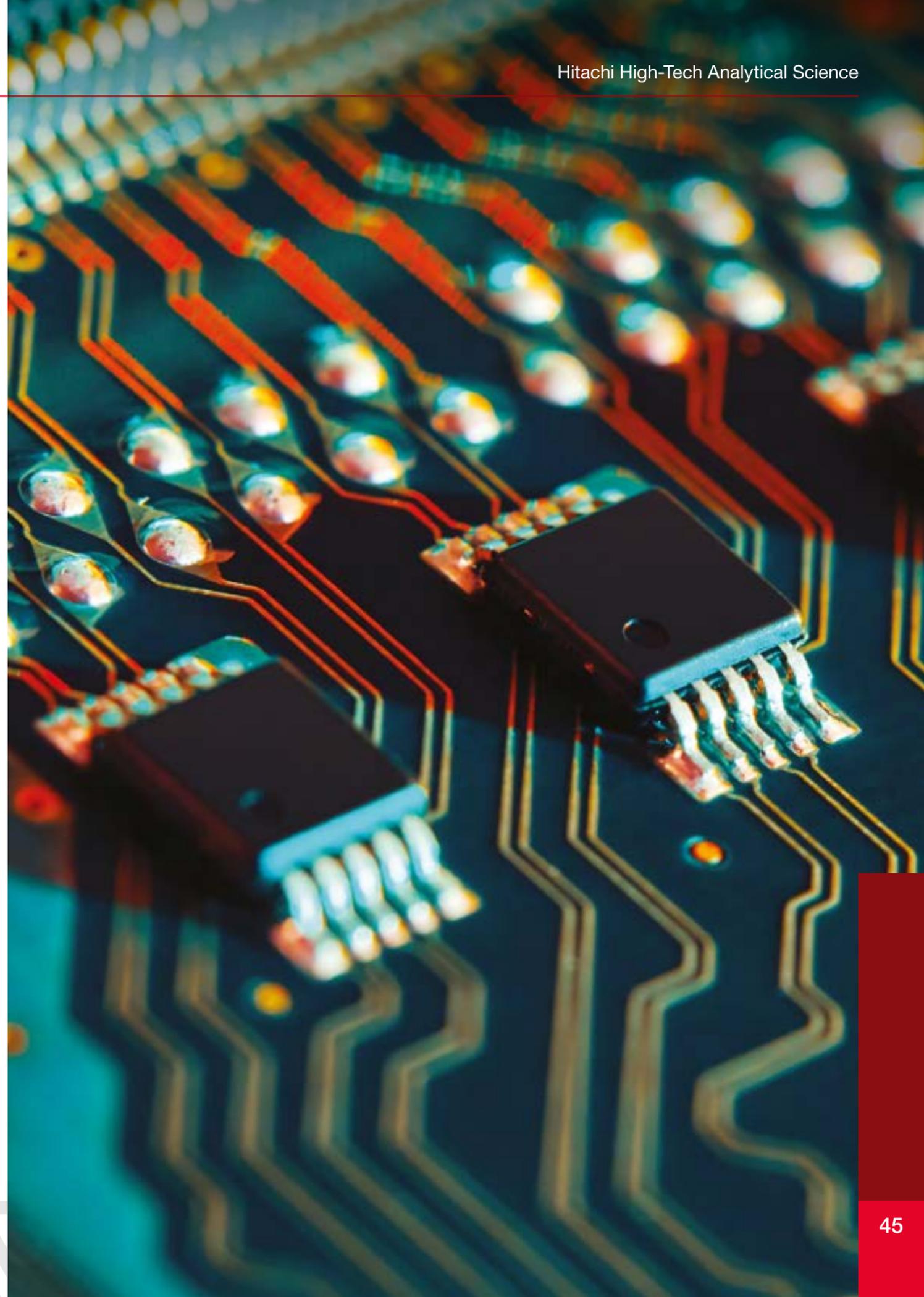
#### **TM4000II Series: Tabletop electron microscopes**

The TM4000II Series features innovation and cutting-edge technologies which redefine the capabilities of a tabletop microscope, providing sharp images of sample surfaces and inter-layer boundaries to support quality testing and R&D efforts.

#### **The TM4000II Series offers:**

- | Simple image acquisition for easy operation by staff
- | Zigzag function for stitching together multiple images
- | High accelerating voltage for high-speed EDS analysis
- | Elemental mapping overlays for determining plating consistency and identifying contaminants

\* Please inquire for distribution other than Asia.





## Support Services: Keeping you Running

From the moment your Hitachi analyzer is installed, you'll receive expert-level support from our service team to ensure you get the best from your Hitachi equipment. Our aim is to provide consistent, high-quality support that keeps your costs low and your uptime high.

Your service agreement is created to deliver the level of support you need yet be as cost-effective as possible. In other words, you don't have to pay for services you won't ever use.

Delivered by a global network of service centers and distributors, our support services include:

- | Extended warranties
- | Rapid response repairs
- | Remote support for instant troubleshooting
- | Notification of upgrades when they become available
- | Recertification in line with industry standards at our recalibration centers
- | Rental equipment to keep production going
- | Training to get the best from your analyzer

From installation day onwards, we're always on hand to offer advice, training and troubleshooting when you need it.

Find out more about XRF analyzers  
for electronics coatings analysis,  
visit **[hhtas.net/electronics-plating](https://hhtas.net/electronics-plating)**

Contact one of our experts today at  
**[contact@hitachi-hightech.com](mailto:contact@hitachi-hightech.com)**  
to arrange a demo.

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