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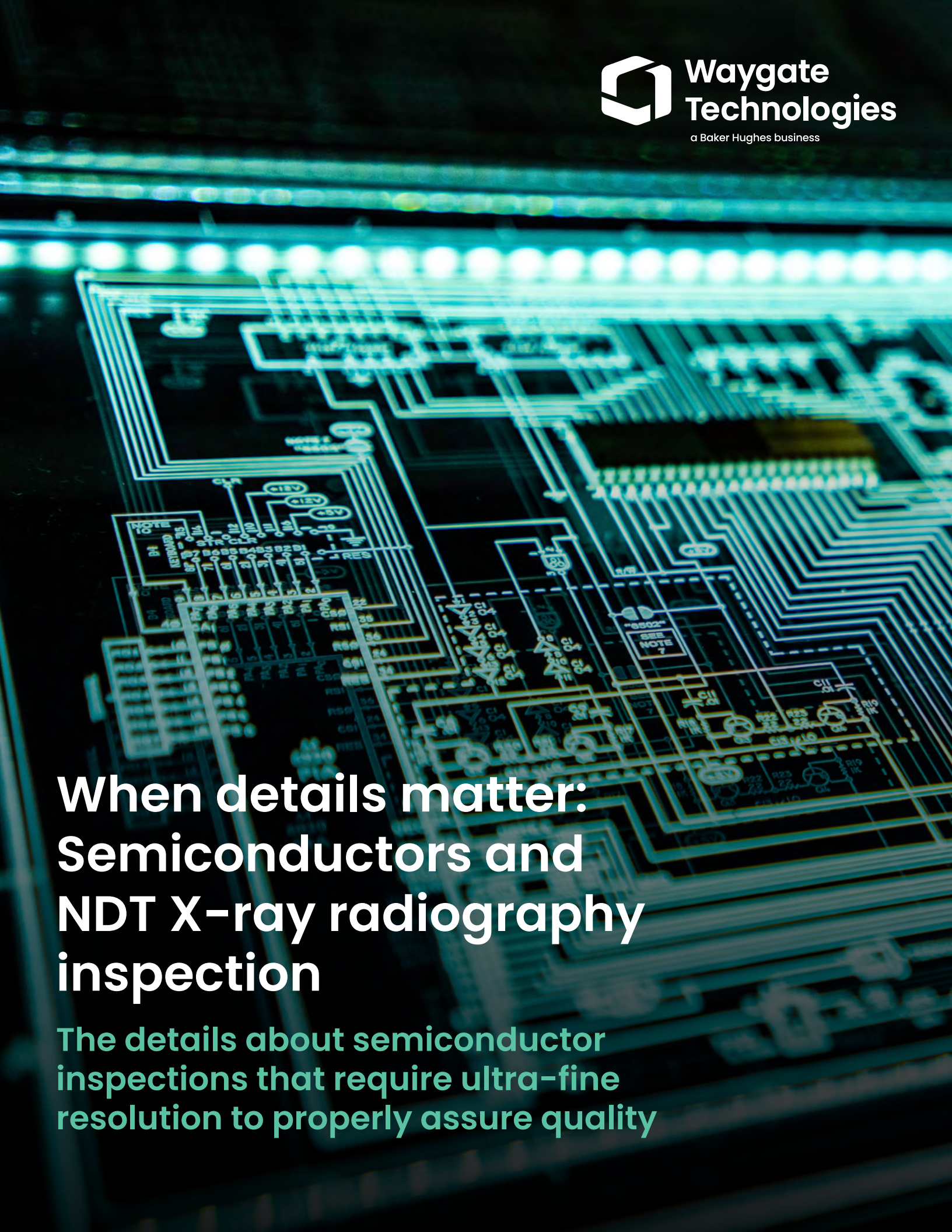


When details matter: Semiconductors and NDT X-ray radiography inspection

The details about semiconductor inspections that require ultra-fine resolution to properly assure quality

Executive summary

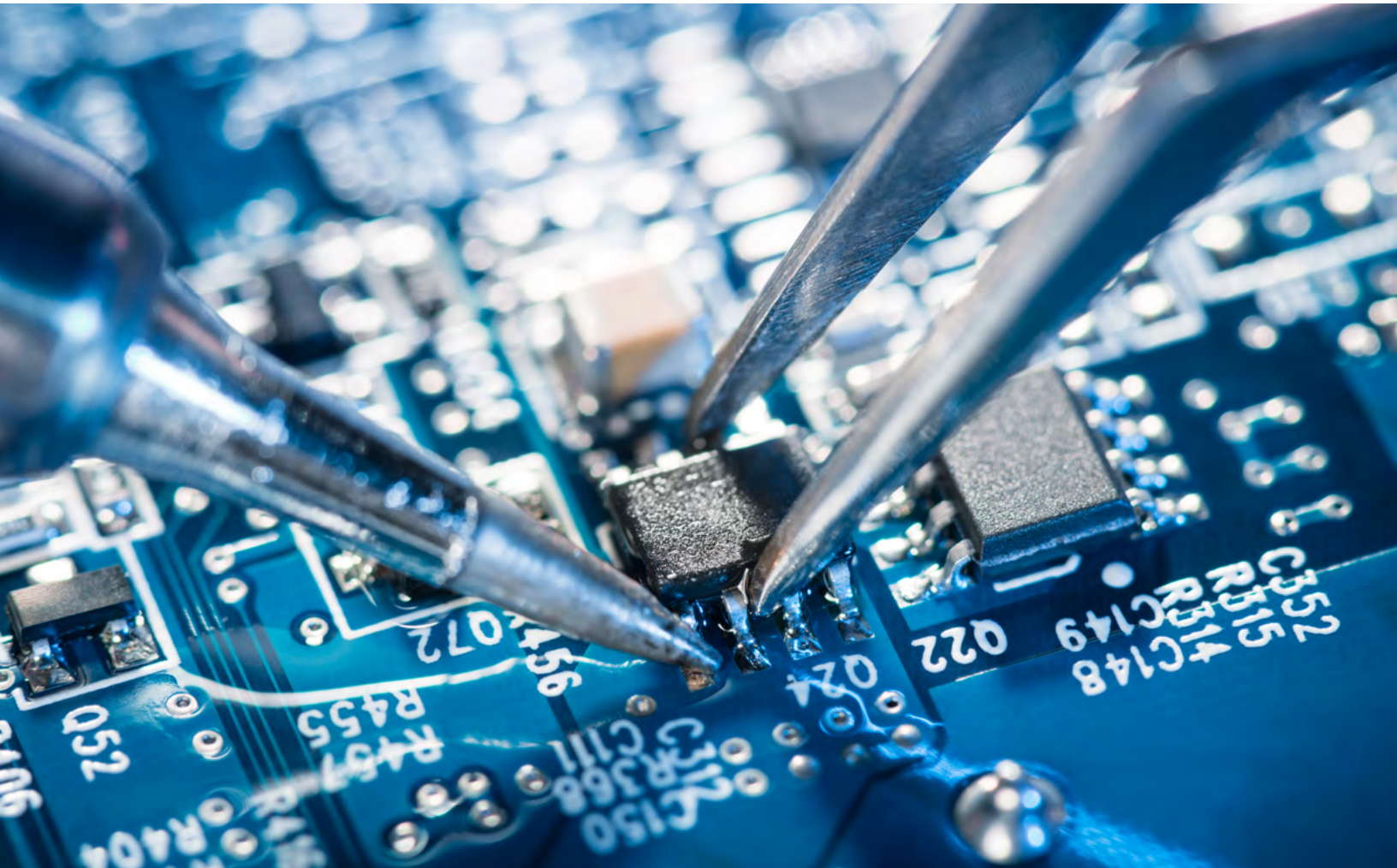
Around the world, semiconductors power our daily lives. Across smart phones, computers, automobiles, airplanes, etc., the world's reliance on semiconductors and small electronic components to catalyze connections and new innovations is skyrocketing. This increasing reliance also poses an increasing challenge for semiconductor manufacturers: to provide the best-in-class quality assurance of micro-sized semiconductors and small electronic components. Only then can we safeguard our collective wellbeing as we use our phones, drive our cars and fly in airplanes every day.

As semiconductors and small electronic components grow in use, however, so does their sophistication, while, concurrently, their size decreases. This trend elevates both the regulatory and technology requirements for detailed quality assurance.

To meet quality assurance standards, semiconductor manufacturers leverage non-destructive testing (NDT) X-ray radiography inspection to work at ultra-high levels of resolutions on all visible and sub-surface areas. However, as quality demands increase, ever-evolving inspection technology advancements are essential. Next generation radiography, engineered specifically for ultra-fine resolution semiconductor inspections, is now required to comprehensively ensure semiconductor quality.

New inspection technologies for semiconductor and small electronic solutions encompass best-in-class hardware, software and services with unparalleled resolution/ image quality, inspection accuracy, reliability and serviceability. It also connects Industry 4.0 capabilities. For next generation, best-in-class semiconductor NDT inspection, semiconductor manufacturers need a partner with deep expertise in high-resolution radiography who understands the details of semiconductor inspection.

On a daily basis, micro-level details can impact our collective wellbeing. For semiconductor manufacturers, the responsibility of consistent quality assurance at ultra fine levels is a tall order. The details matter greatly. Seeing those details with extraordinary clarity can make the difference between safe vs. unsafe operation of items such as smart phones, cars and airplanes upon which we rely each and every day.



1. New requirements for semiconductor quality assurance

Ever wonder what makes the world go around? It's semiconductors, of course. Our daily reliance on semiconductors and other small component electronics such as LED chips and diodes, is astonishing.

Because semiconductors are the ubiquitous "behind the scenes" enablers within so many devices and applications we use each and every day, the significance of their role may not be readily apparent. From cell phones to computers, the Internet, cars, airplanes, digital cameras, automobiles, washing machines, TVs, bank ATMs, trains and beyond, semiconductors and other small electronic devices, help to power our world, ushering in convenience and ease. So much ease, in fact, that many of us do not think about reliability and safety – we assume it. The responsibility for consistently assuring quality, reliability and safety, lies heavily with semiconductor manufacturers who must obsess about component quality at ultra fine levels of detail.

Semiconductors power innovation in net new applications

Today's applications have just begun to scratch the surface of semiconductor use and what is possible. Emerging competencies in new personal devices, autonomous vehicles, artificial intelligence and machine learning, for example, elevate semiconductor's role in our daily lives. Consider these examples:

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Wearables, moving beyond smart watches and fitness devices into **EKG and Blood pressure** monitors and even novel device applications like **DNA Nudge** that helps you optimize your grocery shopping selections based on your DNA profile.

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Electric air taxis such as **Lilium**, **Volocopter**

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Smart manufacturing is powered by semiconductors across operations, enterprises, and entire supply chains.

In fact, semiconductors are so central to emerging innovations that our digital transformations – including the journey to Industry 4.0 and beyond – **are not possible without semiconductors.**

Digital transformations are not possible without semiconductors.

Semiconductor usage rises in existing applications

In addition to growing in usage-breadth, semiconductor and small electronic device usage is also increasing in depth. The automobile is the perfect example. Today, automobiles can employ up to **5,000 semiconductors** to power new competencies and advancements, including those in autonomous vehicles.

While semiconductor usage, in both breadth and depth, is rising, so does the requirement for elevated levels of quality. The potential impact of small defects in semiconductors or small electronic devices can be far-reaching and significant. Public safety is now increasingly reliant on semiconductor quality for safe, reliable operation of cell phones, computers, cars, airplanes and a host of other devices.

Manufacturing productivity and profitability is also increasingly dependent on semiconductor quality. Industries are striving for zero defects, a lofty but worthwhile goal. In the automotive industry, for example, an auto manufacturer might produce 25,000 cars per day, each containing 5,000 semiconductors. With semiconductor quality levels at parts per million failure rates, that could create 125 cars per day with operational issues due to semiconductor quality.

Public safety increasingly reliant on semiconductor quality

In addition to the automobile example above, other semiconductor-rich applications are intertwined into our daily – and hourly – activities. Cell phone dependence, for example, is evidenced by **one study** that reveals, on average, cell phones are checked 96 times per day. Computers, appliances, airplanes and ATM's are used frequently. Because semiconductors are central to so many of our daily rituals around the world, public safety is increasingly dependent on their quality and reliability. That places much responsibility on the shoulders of semiconductor manufacturers.

2. Challenges of semiconductor quality assurance

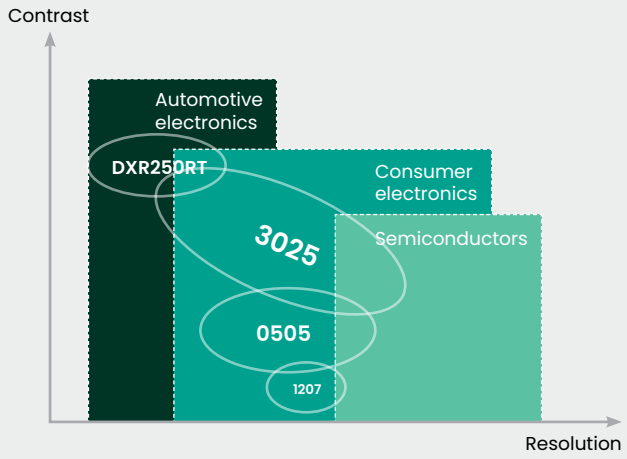
While crucial, comprehensive quality inspections of semiconductors and small electronic components is challenging. Inherently, semiconductor and component design leverages small size concurrent with big levels of sophistication and functionality. The continuing trend is to pack more and more sophistication into smaller and smaller designs, further magnifying the challenges of quality inspection. Additionally, many of the connection points, joints and bonds in semiconductors and small electronic components are sub-surface, obscuring them from surface or visual inspection techniques.

Experience dictates that inspection technologies for semiconductors and small electronic components must deliver two essential competencies:

1. Provide ultra-high detail detection/resolution at high contrast
2. Enable inspection on visible and sub-surface areas

Without these characteristics, the comprehensive inspections of semiconductors and small electronic components are not possible. The inspection technology that uniquely meets these requirements is non-destructive technology (NDT) via X-ray/radiography.

Why details matter in semiconductor inspections



That's why, when it comes to semiconductor quality assurance, the details matter. The semiconductor details in fact, can make or break functionality of much larger end-use devices, such as cell phones, computers, cars and airplanes. Thus, semiconductor manufacturers must adopt proper quality inspection approaches.

3. Must-have NDT inspection advancements

As semiconductor and small component design evolves dynamically and usage skyrockets, radiography and NDT inspection must adjust in-kind to ensure quality standards are met. Emerging next-generation characteristics in NDT radiography are raising the bar and setting new norms for inspection capabilities that provide a new suite of capabilities and benefits.

Capability	Benefit
Improve image quality and contrast at micro-levels of resolution	Product high resolution, high detail images for semiconductor inspections
Enable accurate inspection on visible and sub-surface areas	Enable comprehensive inspections to include all surfaces
Provide ease-of-use in semiconductor manufacturing processes	Designed for optimal handling of semiconductors and small electronic
Be highly reliable with unwavering consistency	Provide sample-sample inspection consistency
Utilize dose control to protect all types of components	Prevent sensitive devices from getting pre-damaged by X-ray

Hardware, software, services and industry 4.0 (4IR)

Advancements in NDT radiography to deliver these new capabilities, and beyond, require ever-evolving innovation across the three solution elements: hardware, software and services. A key enabler to innovations is a deep understanding and proven expertise in the details of radiography.

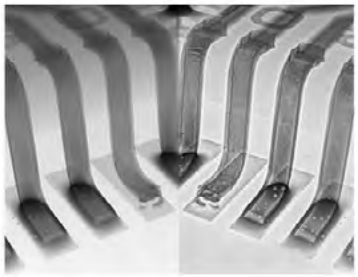
Hardware. Industrial X-ray radiography hardware is comprised of several elements that are engineered to define its' performance parameters. The major components and their primary role are:

- X-ray tube: An X-ray tube creates the X-rays
- Generator: A high voltage generator powers the X-ray source
- Detector: A detector records the X-rays that pass through the sample and produces the image
- Manipulator: A manipulator helps move and/or rotate the sample to the right position for inspection
- Control: A control panel is a centralized panel to set and control the whole process during inspection

Software. Radiography software is an oft overlooked, but key enabler to best-in-class industrial X-ray solutions, especially in the high stakes inspection of semiconductors and small electronic components. Smart software powers inspections, providing image enhancement and optimization, automation, measurement functions and programming capabilities.

Software makes a difference in X-ray details

Conventional Software



Enhanced software

Services. Expertise in industrial X-ray technologies help optimize solutions, enable joint problem-solving and provide test scans and on-going support for challenges and /or unique samples.

While each solution component must employ best-in-class technology to properly inspect semiconductors and small electronic components, the promise of Industry 4.0 (4IR) poses new requirements. Specifically, 4IR capabilities also demand connectivity to MES (Management Executive Systems).

For industrial X-ray inspection in semiconductor manufacturing, the stakes are high and the details matter greatly. Thus, manufacturers need more than a product, they need a partner, to help enable the quality inspections required to optimize operations and ensure collective safety across end-use applications.

Regulatory compliance

In addition to supplier mandates, governing agencies, such as IPC (The Association Connecting Electronics Industries), help to establish standards to guide quality levels for semiconductors and small electronic components. **IPC** classifications are level 1, 2, 3, and 3A and are selected primarily by end-use application type. These globally recognized standards help ensure consistency in quality, reliability and requirements.

5. Summary

It takes a global effort to ensure quality and safety across the breadth and depth of semiconductor applications that are front and center in our daily lives. Each day, we check our smart phones 96 times per day, drive in cars and fly in airplanes. It is the micro-level details within the semiconductors and small electronic devices powering our devices, appliances and vehicles which ultimately determine our large-scale, collective safety. In semiconductor manufacturing, adopting next generation NDT X-ray solutions that are designed to meet the unique demands of semiconductor quality inspections is the linchpin of quality. And that quality is in the ultra fine details. Providing a clear look at those details helps safeguard our daily lives as we enjoy the ease and convenience of smart phones, computers, cars and planes.

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