CHOOSING OF THE RIGHT MICROFOCUS X-RAY SOURCE AND DETECTORS.

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Of all non-destructive test methods, only X-ray technology enables visual detection beneath the surface of opaque components assemblies and finished products. This has made it an essential tool in multiple manufacturing sectors, including aerospace and automotive as well as in medical imaging.

A new generation of the technology centers around microfocus X-ray sources that offers much smaller spot sizes than more traditional alternatives while maintaining the necessary output power. In addition, advances in digital detection, such as CCDs, amorphous silicon and CMOS sensors have all begun to provide resolution comparable with the film. Such detection method significantly improve throughput and are less cumbersome than the more mature methods that utilize X-ray tools borrowed from medical technology. The improved overall performance of these new nondestructive test methods is based on how well the microfocus X-Ray source and designated detector work together, so proper selection is critical.

Advanced non destructive test systems are being used to detect minute flaws, such as microcracks in turbine blades in aluminum die castings. They are in even greater demand in the semiconductor and electronics industry for inspecting circuits, connections, solder balls and joins as well as for detecting inclusions of poor wetting.

The need for a test solution that incorporates the microfocus X-ray sources and flat panel detectors using CMOS technology is growing in parallel with the more stringent requirements associated with each new generation of electronic components. The volume of solder connections incorporated into printed circuit boards, for example has raised exponentially, requiring manufacturers to fabricate smaller packages with more joints.

Another rapidly expanding segment of the market is mobile phones and personal digital assistants. These devices often incorporate integrated circuits fabricated using micro ball grid array. Many microscopic connections are hidden beneath the surface of the components and require high resolution microfocus X-ray sources to nondestructively assess their quality.

Focus on Microfocus

The smallest feature that a microfocus X-ray system can detect depends on two factors: the detectors pixel and the minimum spot size of the X-ray source. Conventional megapixel detectors can easily image at magnifications as high as 2000X, but 100X is adequate for most electronics inspection applications. In either case, the level of resolution and magnification is determined by the focal spot size of the X-ray source which is linked to whether its anode is reflective or transmissive.

Image magnification derives from X2/X1 ratio, where X2 is the distance from the object to the detector and X1 is the distance from the X-ray source to the object. Sharpness is given by:

$$S=D*(M-1)$$

Where M represents magnification and D is the focal spot size. Maximizing magnification requires minimizing the X-ray factor, while optimal resolution requires the focal spot to be as small as possible. Important here is the type of anode. Most X-ray tubes operate by bombarding an anode with thermionic electrons, which decelerate to zero velocity and generate broadband X-ray radiation. Transmissive anodes enable shorter X1 factors measuring only 0.5 mm and producing 1 μm spot sizes but the physics of reflective anodes results in larger diameter beams and bigger focal spot. Microfocus X-ray sources provides the solution because they incorporate focusing disc in the tube to filter the electron beam throw a small pinhole. Keeping the disk at ground potential or zero volts prevents it from generating unwanted X-rays. Such tube designs enable reflective anodes to produce 5 μm and resolve features at 100x magnification.

More importantly, the microfocus X-ray source's small spot size does not effect its output power, which is important to maintain image capture rates in pace with manufacturing throughput. Output power helps increase image readout because more intensive X-rays reduce coupling time in the detector.

Detecting voids among 100 μm solder balls in a chip size package, for instance, requires 65X magnification and output of 80 kV. Conversely, detecting microtracks in an aluminum die cast requires only 10X magnification but 110 kV output. So a larger spot size with greater intensity can be used, thereby decreasing the data-acquisition time.

Digital selection

As in film based systems, digital configurations use a scintillator element to convert the X-ray radiation to visible photons, which can be coupled and read by detector's pixels. Then standard imaging software can either detect flaws automatically - similar to conventional machine vision systems or display the image on a computer monitor for visual interpretation. Early digital x-ray systems coupled CCD cameras to image intensifiers equipped with CsI photocathode that provided good detection efficiency for X-ray above 10kV. The bulky conversion and amplification elements in these intensifiers, however, required a large area on a lab bench (or inspection machine) and didn't lend themselves to in-line inspection applications. Also the number of elements in an image intensifier introduces mild image distortion which is more noticeable near the edges.

Recently, flatbed x-ray scanners have emerged in much smaller packages and footprints, comparable with VHS videocassette. Their control unit dimensions also have compact sizes.

These scanners apply different scintillation materials in one or several configurations:

- Direct deposition applies a scintillator – usually CsI- directly onto the detectors surface. This provides clear images but offers little protection against the X-ray radiation, reducing sensors lifetime. This method more poular in medical applications, where X ray energies are considerably low.

- Flipped scintillator plates apply CsI onto glass plate that is flipper over the CMOS imager. The glass improves the durability but can reduce the resolution and the low energy sensitivity.
- Structured scintillators, which confine light emitted by absorbed X-ray to narrow channels, deposited on a fiber faceplate. The scintillator can be CsI crystals that have a needle structure and produce a high resolution image or amorphous GdO2S which is lower in cost and resolution. In either case, these gaps deliver the converts light directly to the sensor's pixels rendering excellent images and durable sensors. The drawback is that these screens often entail complex, costly manufacturing methods.

CMOS Solutions

Amorphous silicon plates measuring 100X100 mm were considered as an alternative CCD**.** Their expansive area enables faster scanning over large areas, and the material also provides higher sensitivity. Unfortunately these advantages come at a relatively higher price. CMOS technology is a more viable option because it offers performance comparable to CCD sensors and amorphous silicon, but often at a lower price.

CMOS chips can be active or passive. Active chips incorporate microamplifiers into individual pixels, whereas passive chips amplify signals at the end of the column. Although active CMOS chips provide less image noise, passive chips are better suited for industrial inspection applications because of better uniformity and longer lifetime. Besides, it relatively low cost.

CMOS technolology's single-chip architecture integrates a large 12X12 cv active area developed from a single 300 mm wafer what has pixels measuring 50 µmX 50 µm. This kind of resolving power is particular useful for failure analysis but can be used in many applications that put the same or better emphasis on throughput, such as semiconductor wafer processing and electronics manufacturing.

For these and similar applications, CMOS chips pixel binning capability allows them to read single 100 µm square pixels or 4X4 units measuring 400 µv. Read singly, CMOS pixels provide high eight line pair resolution. Binned pixels reduce resolution but increase frame rate up to 30 fps.

The largest commercial CMOS imaging chips, measuring 18 x 22 cm, are truly advantageous in large area scan applications.

Further design innovations in both source and detectors configurations have reduce the dimensions, complexity and potential cost of these components This not only facilitates their integration into in-line, automatic inspection operations but also contribute their ease to use.

At the moment Japanese company **Hamamatsu Photonics** produces wide range of sealed and open type of microfocus X-ray sources with focal spot down to 5 µm which are able to expose flaws with greater resolution and clarity. From another hand we offers several models of flat panel sensors with pixel size 50µm X 50µm pixel size and photodiode area up to 120X120 mm which enable to resolve defects that are exposed by smaller focal spot Where necessary, pixel binning offers the option to dynamically switch between high resolution inspection and rapid large area scanning.

Further design innovations in both source and detector configurations have reduced the dimensions, complexity and potential cost of these components and discover new applications, where non destructive inspection is essential.

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