Photonic Science

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X-RAY FDI CAMERA

Wavelength Dispersive X-ray Spectroscopy is used to count the number of X-rays of a specific wavelength diffracted by a crystal.

The single crystal, the specimen and the detector are mounted precisely on a goniometer with the distance from the source of X-rays (the specimen) and the crystal equal to the distance from the crystal to the detector.

The technique is often used in conjunction with EDS, where the general chemical make-up of an unknown can be learned from its entire spectrum.

WDS is mainly used in chemical analysis, in an X-ray fluorescence spectrometer or in an electron microprobe.

The detector geometry must allow good angular coverage for mapping all wavelengths in a single acquisition without having to move the detector.

Detectors with 80x30mm active area can be offered with both linear scanning or area scan modes, 100% duty cycle, optimum sensitivity and dynamic range. Temporal resolution down to <100 nanoseconds with 30KHz repetition rate can be offered for pump probed experiments.

Wavelength Dispersive X-ray Spectroscopy

Transmission X-ray Microscopy produces contrast using the difference in absorption of soft X-ray in the water window region.

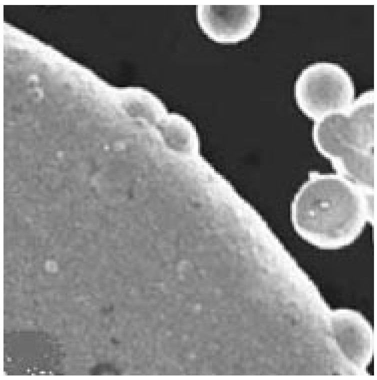
Wavelength region: 2.3 - 4.4 nm, corresponding to photon energy region of 0.28 - 0.53 keV is where the carbon atom (main element composing the living cell) and the oxygen atom (main element for water) deliver good imaging contrast.

A typical set up consists of polychromatic source used with condenser optic that relays the radiation onto the sample and a Fresnel zone plate is used in order to magnify the image onto the camera. The latter is a very high resolution cooled high sensitivity CCD camera coupled to a state of art scintillator using high NA lens with 1.4 micron effective pixel size.

An alternative solution using direct exposure of the CCD to soft X-ray is also available with 13 microns pixel size.

An other technique, known as lens less coherent diffraction imaging is emerging as a potential technique for enhancing resolution down to 1.5 the radiation wavelength. It also enables to eliminate a low transmission FZP.

Combined with XANES (by taking an image above and below the absorption edge of an element), the camera can unveil information about the chemical state of components in the sample.



Transmission X-ray Microscopy

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X-RAY FDI CAMERA

X-ray Topography reveals cracks in single crystal substrates using X-ray beams that have been Bragg-diffracted by a crystal to image it.

X-ray topographs will show the distribution of various singularities that affect the Bragg reflection used in particular crystal defects such as precipitates, individual dislocations, stacking faults, domain or phase boundaries.

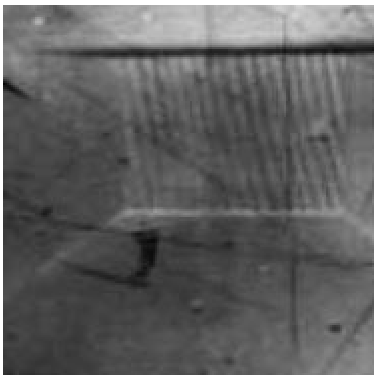
Topography relies on the fact that singularities or inhomogeneities can affect the spatial distribution of diffracted intensity and hence result in contrast.

In its usual meaning, topography can only be performed on single crystals, or on single grains within a polycrystal.

There is a wide range of variants: in transmission or in reflection, with a monochromatic beam, 8keV or with a white beam up to 100 keV, with a divergent beam or very well collimated beam, depending on the sample thickness and material.

A high resolution detector is necessary in order to record intensity changes produced by subtle diffracted beam path differences.

Scanning over large areas such as with Silicon wafers requires the use of detectors with good sensitivity, 100% duty cycle in order to maintain good inspection throughput.



X-ray Topography

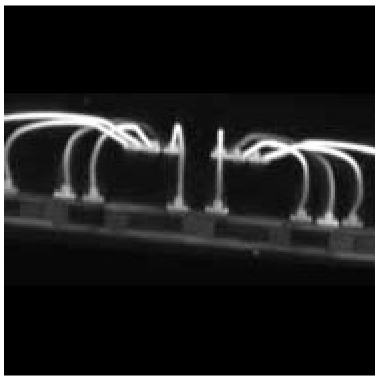
X-ray Micro and Nano Tomography allows a 3D reconstruction from a series of radiographs for different angular positions of the sample down to sub micron resolution.

Typically a full tomographic data set will require in the order of few hundreds to a few 1000s radiographs using a 3D reconstruction Feldkamp algorithm. Optical Cone beam / fan beam reconstruction are used, with the sample rotating in a fixed plan / helicoidally around an axis perpendicular to the beam.

The total acquisition time is in the range of few seconds per frame, it depends very much on the source brilliance / geometry. 100% duty cycle detectors with simultaneous read out / exposure allows to save up to 50% of the scanning time.

Resolution down to a few hundred nanometers can be achieved by using a small focal spot source and reasonable geometric magnification. The recorded data is often several Gigabytes and can be processed using the massively parallel calculation capacity of GPUs.

Microtomography can be combined with phase contrast imaging, either in a qualitative way (“edge enhancement”) or, more quantitatively, including phase retrieval (“holotomography”). Very high resolution cameras allows the build of scanners with sub micrometer spatial resolution whilst keeping compact dimensions and good sensitivity.



X-ray Micro and Nano Tomography

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X-RAY FDI CAMERA

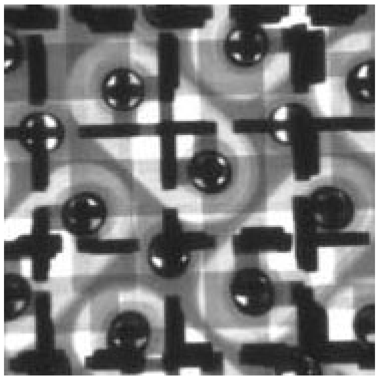
Industrial PCB X-ray Inspection / Digital X-ray Radiography are used to detect porosity, inclusions, cracks and even grain structure within a variety of cast components and in welded joints.

With the increasing production of many new types of components such as BGA and flip-chip devices, it is important to produce good quality real-time X-ray images to isolate dry joints, bridging/shorts, voiding, misplacement / misalignment problems down to few microns or less resolution.

A high resolution camera is used in conjunction with high geometric magnification in order to keep a compact system that includes moving stages. The same kind of set up can be used for inspection of the latest ceramic, plastic and composite structures as well.

The cameras required for this kind of routine exposure time of < 500ms per frame and good enough resolution: typically better than 25 microns minimum feature detection capability in order to keep the geometric magnification requirements.

This keeps the overall instrument dimensions as low as possible. Simultaneous read out and exposure cycles are usually necessary for keeping duty cycle as close as possible to 100%, thus enabling higher board inspection throughput.



Industrial PCB X-ray Inspection / Digital X-ray Radiography.

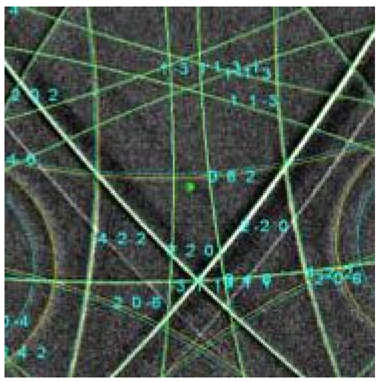
Scanning Electron Microscope EBSD / KOSSEL Imaging.

EBSD can be used for crystal orientation mapping, defect studies, phase identification, grain boundary, morphology studies, regional heterogeneity investigations, material discrimination, microstrain mapping, and using complimentary techniques, physico-chemical identification.

Experimentally EBSD is conducted using a SEM equipped with a backscatter diffraction camera that records faint Kikuchi bands. This corresponds to each of the lattice diffracting planes and can be indexed individually by the Miller indices of the diffracting plane which formed it.

The bands formed can also be analysed to show the deformation present within the material: pattern blurring gives an indication of the plastic strain within the crystal and small rotations of the pattern (compared to a perfect crystal at this orientation) indicate elastic strain.

Cameras with good sensitivity are required for performing a fast acquisition duty cycle over 100 fps. Reduction in beam current / increased duty cycle can be achieved with optimized camera coupling and scintillator absorption. EBSD cameras can be upgraded to digitize Kossel diffraction patterns that will lead to subsequent structural / strain analysis.



Scanning Electron Microscope EBSD / KOSSEL Imaging

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X-RAY FDI CAMERA

Plasma Diagnostic.

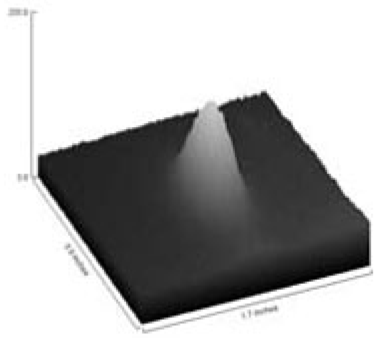
EUV / VUV detectors are used for calculating the fractional abundance of ions for hot plasmas with different electron temperatures and electron densities. They are used to characterize wavelengths and emissivity versus temperature of the brightest spectral lines emitted by the ions wavelengths longer than 45 Å.

ITER plasmas will be analyzed in selected EUV lines, similar to the space-based instruments routinely used to study temperatures, emission measures and motions of 0.1–2 keV solar coronal plasmas.

It is important to match the detector yield over the entire spectral range whilst maintaining good spatial as well as temporal resolution. It is possible to use direct and indirect detection.

Direct detection is achieved by selecting back thinned CCDs in order to optimize quantum efficiency in the range of 100 eV and above. With a band gap of 3.5 eV on average, each photon is well discriminated, however coping with bright signals can be issue.

Indirect detection can be used with either a MCP or phosphor screen assembly read out by a CCD detector with better compromise on dynamic range.



Plasma Diagnostic

EUV / DUV Lithography, Source, Optics and Resin Characterization.

The semiconductor industry roadmap uses shorter wavelength light sources to produce smaller feature sizes on processors as well as on memory components. Wavelength ranging from 248 nm to 193 nm are currently used to produce feature sizes < 100 nm. The next generation includes EUV sources which use 13.5 nm for printing feature size as small as 32 nm.

A source with very good brightness is needed for maintaining production throughput similar to that of DUV techniques. Therefore, EUV and UXV CCD detectors with good UV sensitivity and good dynamic range are necessary to cope with pulsed sources that are used to characterize resin, prior to mask manufacturing.

EUV sources can produce an important amount of debris so it important that that the CCD detectors withstand over exposures without saturation / bleeding artefacts as well as potential contamination from debris coming from the plasma generation.

Large area cameras from 13x13mm up to 24x36mm can be used with frame rate up to 5ps at full resolution.

EUV / DUV Lithography, Source, Optics and Resin Characterization

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X-RAY FDI CAMERA

Astronomy / Diffraction limited CCD Imaging.

Recent technological changes in CCD cameras now permit short exposures to be taken with negligible read out noise, allowing a high speed stream of images to be captured. This can result in thousands of quick short exposures being saved for subsequent post processing.

This technique uses a bright star nearby the object to be observed, and calculation of the Strehl number of the reference star in each image taken. A selection algorithm drops images that fall below the minimum and those images that meet the selection criteria are used and this may be as little as 1% to 10% of the data stream.

These selected images are combined by shifting and co-adding the sequence to produce diffraction limited image of the object being observed. The resultant image has been corrected for the turbulence of the atmosphere. This technique has also been called " LUCKY IMAGING".

Associated techniques are “speckle interferometry”.

Astronomy / Diffraction limited CCD Imaging

Single Molecule Fluorescence Imaging.

Single Molecule emission spectra, lifetime, and intensity deliver specific information about the molecule location. The physical properties of materials such as lateral or rotational diffusion, conformational studies including protein folding can be studied using single molecule fluorescence technique.

Combined with a confocal microscope set up, SMF is capable of mapping both the location and orientation of single molecules, observing orientation and intensity changes over time down nanometer range.

It is important for the detector to record fast sequences at low intensity as the emission from single fluorescent molecules could be weak and changing rapidly over time.

Subtle intensity changes are usually recorded over a large background, this translates into good dynamic range requirements for the camera on top of high sensitivity, fast shuttering capability and rapid image transfer to a host PC.

Single Molecule Fluorescence Imaging