Photonic Science

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X-RAY IMAGE STAR CAMERA

The X-Ray Powder Diffraction method is one of the few non-destructive methods that permit the identification and the elemental analyze of materials.

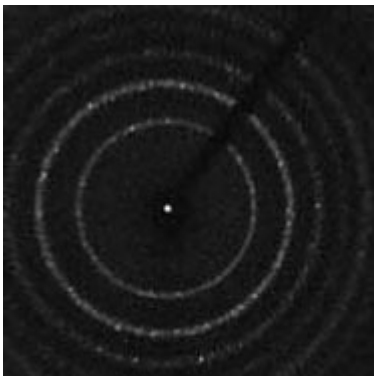
As the X-Ray diffraction pattern of a crystalline substance is unique, it is possible to characterize and thus to identify any polycrystalline substance (phase).

In order to understand the diffraction pattern, either the incident beam is monochromatic or the X-Ray detector is able to resolve the energy from the Kα1, Kα2 doublet to the Kβ1 line. Alternatively, Sollers slits / optics can be used in order to select the corresponding angular range.

A resolution better than 450eV is necessary (FWHM of the measured Cu Kα1, Kα2 doublet).

Diffraction patterns consists of rings, high intensity spots due to crystallized materials, which are mixed to the existing phases are averaged over continuous sample rotations. Intensity integration over those rings allows pattern indexation.

Near photon counting sensitivity maybe required for standard laboratory X-ray sources whereas high brilliance sources such as microfocus / synchrotons will require good dynamic range: typically 15,000:1 and large area 100 x100mm. One to two megapixel detectors with spatial resolution of 60-120 microns is usually sufficient.



Powder Diffraction

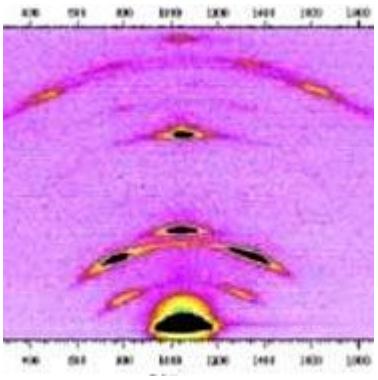
SAXS / WAXS technique is used to reveal order / disorder at large, micro or nano scale in non-crystallized materials: i.e. polymers, proteins in solutions, oil, colloids, and plastic.

A typical experimental set-up requires a highly collimated X-ray source and a detector with photon counting sensitivity as the intrinsic process behind small angle x-ray scattering is very inefficient. Ideally both small angle and wide angle detectors are combined in order to characterize simultaneously short and longer ranges of scattering vectors.

For instance, WAXS will be used to determinate the degree of crystallinity of polymer samples. SAXS is capable of delivering structural information of macromolecules between 5 and 25 nm with averaged particle sizes, shapes, distribution, and surface-to-volume ratio, of repeat distances in partially ordered systems of up to 150 nm. USAXS (ultra-small angle X-ray scattering) can resolve even larger dimensions.

SAXS WAXS patterns consist of low intensity patterns acquired over minutes of integration requiring very low background noise and good signal discrimination. Coexistence of bright and very bright signals on the same image could require dynamic range up to 106:1 using multiple exposures.

Large area detectors up to 200x200mm and 16 megapixel resolution are used in synchrotrons whereas smaller input size detectors: typically 60 to 90mm and 1 megapixel resolution are used with laboratory sources.



SAXS / WAXS

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Small Molecule and Protein Crystallography technique helps engineering of future drugs and chemical formulas produced by the pharmaceutical and chemical industry.

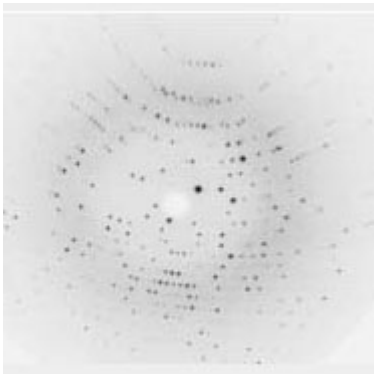
Small molecules (unit cell containing 100 atoms or less) and macromolecular (unit cell containing 10000 atoms or more) are crystallized and exposed to high brilliance X-ray beam on a synchrotron or X-ray lab source.

The experimental set up consists of gradually rotating the samples over 0.1 to 0.25 degrees in order to record Bragg reflections from each orientation of the crystal.

A good dynamic range is required, typically > 15,000:1 with potentially the possibility to read and expose at the same time in order to be able to rotate the sample at continuous speed over fine angular ranges: this is the fine Phi slicing technique.

Depending on beam delivery conditions as well as crystallization quality, the data collected can reveal conformal properties of a materialin addition to its electron density that will shed some light onto binding mechanisms of enzymes or proteins.

Large area detectors up to 270x270mm and 16 megapixel resolution can be used in synchrotrons, whereas 165mm diagonal detectors are more commonly used with laboratory sources.



Small Molecule and Protein Crystallography

X-ray Absorption Spectroscopy is used to determine which elements are present in an unknown sample.

Only discrete photon energy can be absorbed by the sample, this corresponds to the characteristic binding energy of electrons in the material that is excited. It will unveil its local composition as well as its electronic state.

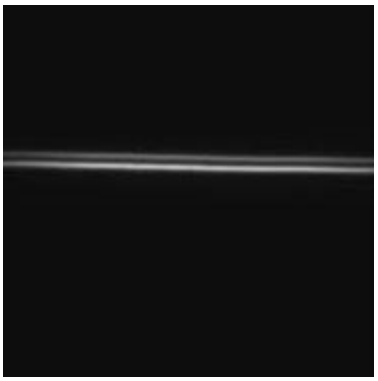
Tuneable X-ray sources are required in order to identify discrete K absorption edges of complex or multiple ionized materials presence within a given structure.

Integrating intensities over a 2D detector allows a rapid mapping over large areas.

Very good spatial resolution is required for matching the microbeam dimensions that are available in both synchrotrons and laboratory sources.

This application requires detectors that can ideally offer simultaneous energy resolution down to 150 eV and 2 dimensional mapping response with no read out dead period.

Detector format of 13x13mm are already available with energy response covering the Vacuum UV, the water window up to 8 keV. Typical duty cycle achieved: 163ms per frame.



X-ray Absorption Spectroscopy

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X-RAY IMAGE STAR CAMERA

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

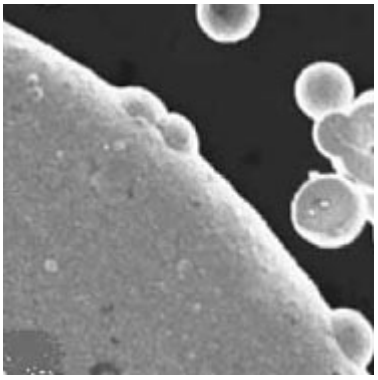
Wavelength region: 2.3 - 4.4 nm, corresponding to photon energy region of 0.28 - 0.53 keV is where the carbon atom (main element composing the living cell) and the oxygen atom (main element for water) deliver good imaging contrast.

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

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 IMAGE STAR CAMERA

Streak Camera read out.

Streak Cameras are used for characterization of fast temporal events down to femtosecond range, and routinely down to picosecond range. A temporal profile of a light pulse is converted into a spatial profile, by time-varying deflection of the light across the width of camera.

National Ignition Facilities, Synchrotrons, telecom industry as well as well the plasma physics and ultras fast spectroscopy community are using streak cameras with direct fibre optic coupling CCDs in order to record streak patterns directly from the streak tube.

Excellent spatial resolution, must be delivered by the CCD read out in order to exceed traditional film performance. Streak tubes usually have 1,000:1 dynamic range, therefore cameras must also have good dynamic range. With MCP image intensification, the low light levels may be amplified few 100 to 1000 fold, hence the requirements to cope with overexposure in case of saturation artefacts.

In the absence of MCP, the camera must have good sensitivity. Fibre optic coupling with no demagnification is then the best possible option for collecting the light emitted of the streak tube phosphor screen.

Streak Camera read out