3D and 4D X-ray imaging techniques for comprehensive microstructural properties of materials: from medicine to geosciences

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Imaging techniques play an important role in several research fields: medicine, biology, material science, geosciences and archaeology. Optical and scanning electron microscopy techniques are widely adopted 2D imaging technique for the investigation of the texture and morphology in a large range of materials. Imaging techniques based on hard X-rays are also of particular interest and microradiography has proved to be a precious tool for clinical diagnostics and for the 2D visualization and analysis of dynamic phenomena in different materials. In recent years, great interest has been posed on X-ray computed microtomography (μCT) techniques, employing microfocus sources and the unique possibilities offered by third generation synchrotron radiation sources. Synchrotron X-ray μCT measurements produce three-dimensional (3D) or 4D (dynamic μCT) images of the internal structure of objects with a spatial resolution at the micron- and submicron- scale. Investigations performed directly in the 3D domain overcome the limitations of stereological methods usually applied to microscopy-based analyses and a non-destructive approach is more suitable for further complementary analyses and for precious or unique samples (fossils and archeological finds, in-vivo and in-situ imaging, etc …). Moreover, the huge potential of phase-contrast imaging for medical diagnostics and materials characterization has been realized for quite some time as documented by numerous studies, and synchrotrons represent an ideal source for this imaging modality.
An intriguing challenge is to extract directly from 3D images quantitative parameters related to the physical, chemical and structural properties of the studied materials. Porosity and specific surface area as well as anisotropy, connectivity and tortuosity are interesting descriptors of a 3D model. However, accurate image processing and analysis methods for an effective assessment of these parameters are still an open issue in several applications [1]. Recent scientific studies performed by using advanced hard X-ray imaging techniques will be presented in this talk. Examples of results obtained at Elettra from the 3D textural characterization of geomaterials [2] as well as the quantitative analysis of fine morphological features in modern [3, 4] and ancient [5, 6] biological samples will be illustrated.

References:

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