Investigations of complex structures by means of the x-ray computed microtomography method

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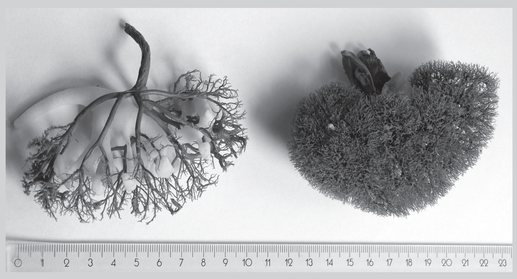
INTRODUCTION

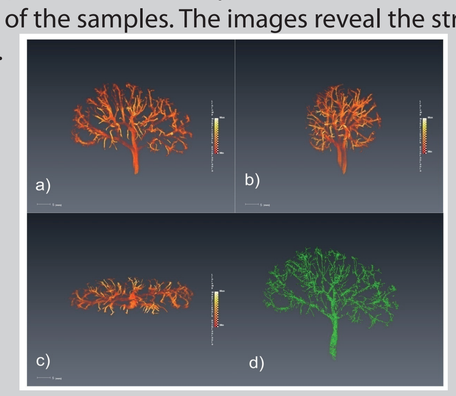
The poster presents investigations of several classes of complex structures by means of the X-ray computed microtomography method. The poster summarizes work carried out during participation in MP0601 Cost Action. On the basis of these results a doctoral thesis has been also created [1].
In this work geometrically complex biological systems such as human kidneys or human intervertebral discs as well as material-science structures (chemical-vapor-deposited (CVD) diamond and geological porous media) were investigated.
Investigations were performed with the use of microtomographic setup based on laboratory X-ray source. Results were compared with outcomes obtained with the use of a synchrotron beamline. Processing and analysis of the obtained microtomographic images was performed using modern coputational grid [2]. Comparison of the results obtained with the use of laboratory source-based system and the "TopoTomo" synchrotron beamline (ANKA Light Source, Karlsruhe Institute of Technology) is also presented.

BIOLOGY & MEDICINE

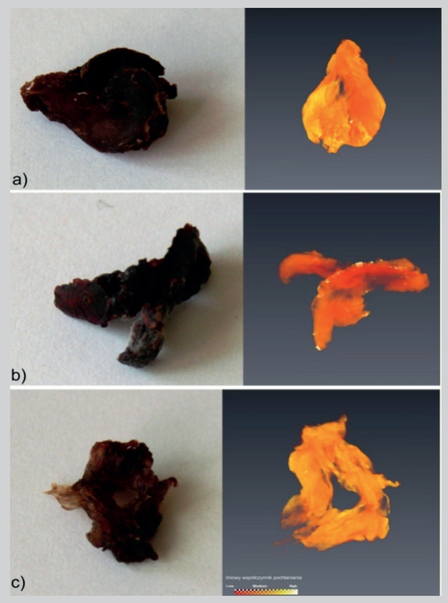
Microstructure of kidny endocasts specimens has been investigated at the Institute of Nuclear Physics Polish Academy of Sciences (IFJ) in Krakow with the use of the multipurpose X-ray microprobe [3]. Depending on the required radiation energy, the X-ray source can be equipped with Ti, Mo, Ag, or W targets. In this measurement Ag target has been used, providing energy spectrum adjusted for the samples composition.

The μCT measurements have been performed with the use of polychromatic radiation emitted from Ag target, however tomographic images are not affected by the beam hardening artifacts due to the low absorption of specimen's material. During experiments the acceleration voltage of the source was set to 70 kV and the tube current amounted to 20 μA. In order to improve signal-to-noise ratio as well as to shorten projections exposition time 4 x 4 pixels binning has been used. Microtomographic images have been reconstructed from 500 projections with the use of FDK (Feldkamp, Davis, Kress) algorithm [4] implemented into Octopus software [5]. Typical time of single projection acquisition was equal to 25 s. The projection images were subjected to flat field and dark images correction in order to reduce effects of the beam intensity inhomogeneities, the scintillator imperfections and the dark current effects. Figures below show photos and tomographic images of the samples. The images reveal the structure of main kidney vessels as well as microstructure of minor vessels.

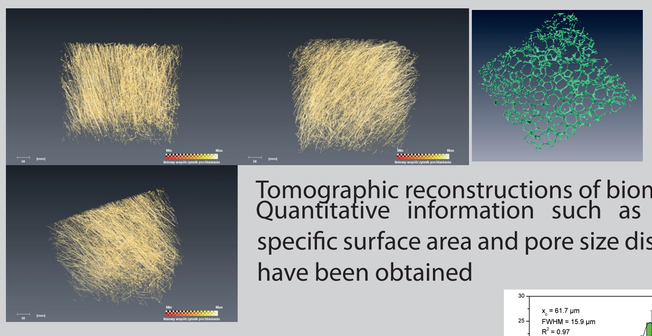




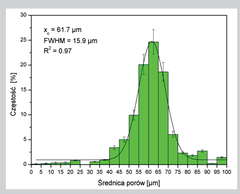
Back pain is a common problem of the modern society. About two thirds of adults suffer from low back pain at some time. 1-3% of these disabilities are caused by prolapse of intervertebral discs. In this case the pain is caused mainly by mechanical compression of the nerve roots.
Adverse changes in the proteoglycans (PG) – the basic macromolecules forming the intercellular matrix of the disc – play crucial role in the evolution of the intervertebral disc degeneration. The highly sulfated glycosaminoglycan (GAG) chains - linear polysaccharides belonging to PG, principally keratan and chondroitin - are among the main components of the disc responsible for its mechanical properties and possible pathogenic processes. The proportion and distribution of the components varies considerably with respect to region of the disc with the highest concentration in the nucleus pulposus .
In this work we present preliminary studies of structure of human intervertebral disc fragments by means of microCT measurement. The main goal was to work out procedure of samples transport, preparation and measurement. Investigation was carried out with a use of microCT facility at Institute of Nuclear Physics in Krakow. Due to the long time of the experiment and rapid loss of water from the sample (about 80% of mass during 7 hour) measurement of hydrated disc turned out to be impossible. MicroCT measurement of dry sample has been carried out with promising results.



POROUS MEDIA & MATERIAL SCIENCE



Tomographic reconstructions of biomaterials. Quantitative information such as porosity, specific surface area and pore size distribution have been obtained



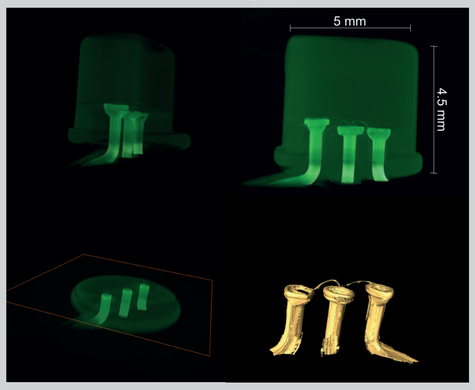
Pore size distribution of polylactic acid foam biomaterial

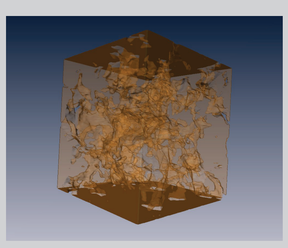
The study of microstructure and porosity, applied to investigations in the field of petroleum geology has been carried out. Moreover, simulations of fluid dynamics in void pore space have been performed in order to obtain the hydraulic permeability of investigated media.

The measurements of the microstructure, porosity and specific surface area of sandrock samples, extracted from a drill hole at 2680 m depth have been carried out using the X-ray microprobe at IFJ PAN, Krakow.

Basing on tomographic data obtained with the high spatial resolution, simulations of the fluid dynamic in void space of porous media have been carried out. Lattice Boltzmann Method (LBM) in 3DQ19 geometrical model has been used in order to predict the hydraulic permeability of the media. Computing power-consuming calculations have been performed with a use of modern grid infrastructure.

Non-destructive testing of electronic devices





Microtomographic image of sandstone rock microstructure

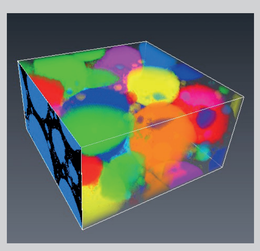
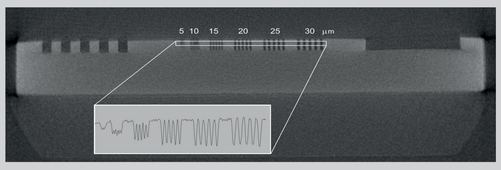


Image segmentation for pore size distribution assesment

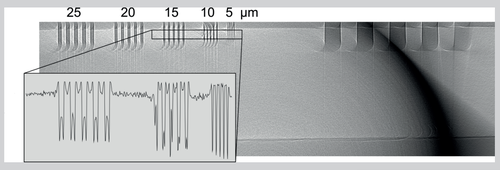
Comparison of resolution and artefacts appearance:

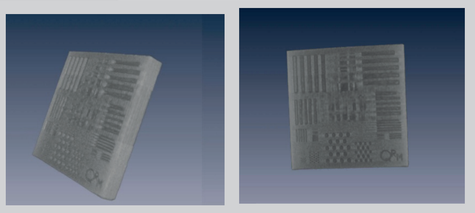
Microtomogarphic crossection of a resolution phantom

a) Microtomographic system based on a laboratory source (IFJ PAN)



b) Microtomographic system based on a synchrotron beamline (TopoTomo, Karlsruhe)





3D visualization of the resolution phantom

Tomographic crossection of CVD diamond layer

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