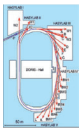
Applications of Microtomography in Materials Science at the HARWI-2 Beamline at DESY

Julia Herzen[1], Felix Beckmann[1], Tilman Donath[1], Bert Müller[3], Arne Roos[1], Jorge Dos Santos[1],
Stephan Irsen[2], Barbara Leukers[2], and Andreas Schreyer[1]

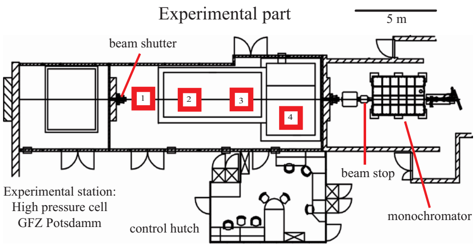
[1]*GKSS-Research Center, Geesthacht, Germany*, [2]*ceasar research center, Bonn, Germany*,
[3]*Biomaterials Science Center, University of Basel, Switzerland*

INTRODUCTION



The beamline HARWI-2 is designed for materials science experiments using hard X-rays. Recently, the fixed-exit monochromator was installed, which is optimized for diffraction and imaging applications. The monochromator [F. Beckmann et al., SPIE Proceedings 631810-1-11, 2006] combines two different sets of crystals to provide an intense and large monochromatic X-ray beam in the energy range between 15 and 200 keV. Absorption contrast microtomography was performed for different applications in materials science, including collagen-coated scaffolds for tissue engineering and hybrid friction diffusion bonding of aluminum. The large range of available energies makes sure that high absorbing materials as well as materials with a relatively weak absorption coefficient can be analyzed. The spatial resolution of 3 µm was experimentally verified.

HARWI-2 BEAMLINE



Experimantal stations run by GKSS:

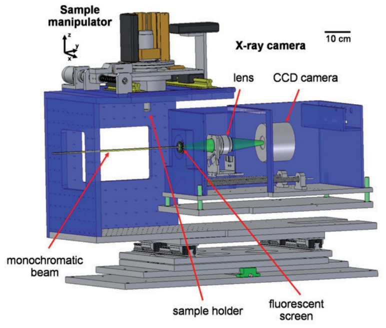
1 temporary setups
3 diffraction enhanced imaging
2 tomography
4 high energy diffractometer

Sketch of the HARWI-2 beamline showing the beamline optics, experimental stations, and control hutch.

Modernisation of HARWI:

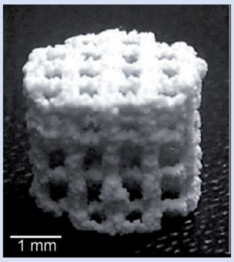
- high energy X-rays
- optimised for strain measurements, texture analysis and microtomography
- high flux
- new fixed-exit monochromator:
- double Laue/Laue-Bragg for the energy range of 20 - 100 keV and 60 – 200 keV

Absorption contrast µCT	**Old HARWI**	**New HARWI-2**
photon energy:	20 -60 keV	15 – 200 keV
sample size:		
height	4 mm	8 mm
width	15 mm	70 mm
spatial resolution:	4 µm	3 µm



Schematic of the microtomography apparatus in absorption contrast mode. The incident monochromatic X-ray beam penetrates the sample and hits the fluorescent screen, where it is converted into visible light, which then is projected onto the CCD camera.

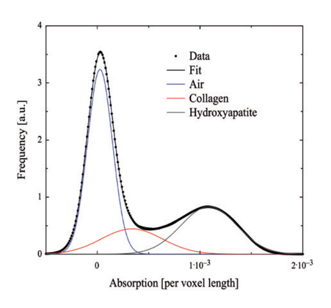
µCT OF 3D-PRINTED AND COLLAGEN-COATED SCAFFOLDS FOR BONE REPLACEMENT



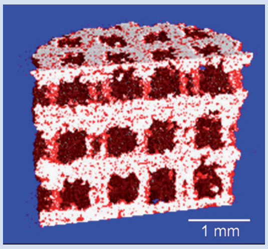
The 3D-printed and collagen-coated scaffolds are intended for use as bone replacement. The key advantage of this scaffolds is their individual computer design according to the information determined by a CT scan of the bone.

Optical image of the surface of the opaque scaffold.

Another important property of 3D-printed bone grafts is their mechanical stability, which is significantly improved by using natural coating materials such as collagen. The homogeneity of the collagen coating has been analysed by absorption contrast microtomography at the beamline HARWI-2 at a photon energy of 30 keV.



The histogram of the tomography data with a volume of (5.7 x 5.7 x 3.8) mm^3. The two peaks representing air and material can be easily separated. Using three Gaussians, the data can be perfectly fitted. The three Gaussians are associated with air (blue), coating (red), and ceramics (gray).

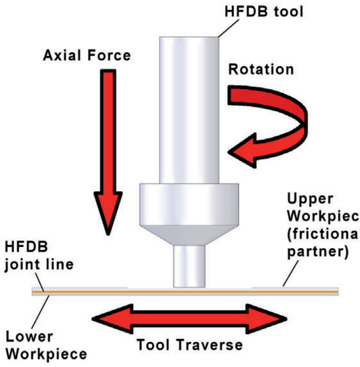


A virtual cut of the scaffold colored according to the fitted histogram using the crossing points: air – black, coating – red, and HA – white. The collagen coating is homogenously distributed on the surface of the scaffold. It also fills the open micro-pores of the HA, while the macro-pores remain open.

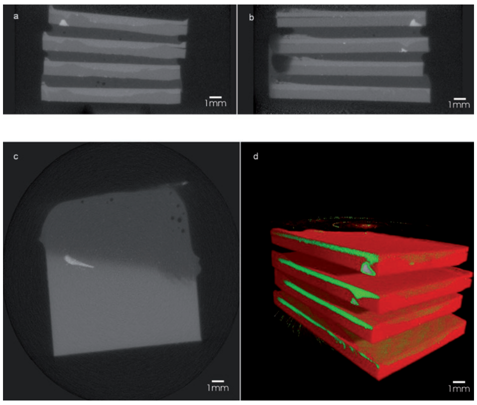
µCT OF HFDB PROCESS

Hybrid **F**riction **D**iffusion **B**onding (**HFDB**) is a friction based bonding process, which is invented and patent pending by GKSS in 2006 [A. Roos et al., GKSS Patent Application DE 102005045954.4]. It relies on three effects: 1. frictional heating, 2. axial pressure and 3. boundary diffusion of recristallised fine grain.

The Figure below shows schematicaly the HFDB process. A non consumable tool rotates over the friction partners touching the surface. Under the axial pressure the friction partners are heated and plastified. By transversing the tool especially metal foils can be either joined in overlap or butt joint configuration.



Schematic of the HFDB process



Distribution of the marker material in aluminum alloys, a) front view, b) side view, c) top view and d) 3D view.

CONCLUSIONS

For the new friction based bonding process **HFDB** (**H**ybrid **F**riction **D**iffusion **B**onding), which was invented at GKSS (patent pending), microtomography was performed to analyze the distribution of the marker material included into one of the friction partners. Tissue engineering takes also advantage of microtomography for the image-based porosity analysis of 3D-printed and collagen-coated bone grafts. These grafts are intended to replace bony tissue or to fill cavities. For the enhancement of their mechanical stability the homogeneity of the collagen coating is of importance. The application of synchrotron radiation-based micro computed tomography allows visualizing the 3D distribution of collagen coating on bone grafts without destruction.