Micro-Tomography for structural analysis of metallic foams

Computed tomography has been available for medical diagnostics since the early seventies of the last century. In 1979 the inventors G. Hounsfield and A. Cormack received the Nobel Prize for their invention. J. Radon (1917) and P. Funk (1916) contributed the mathematical foundations.

We introduced the synchrotron micro-tomography in the department SF3 (materials research) of the Hahn-Meitner-Institut in order to perform high-resolution, non-destructive, three-dimensional structural investigations and material characterizations on metallic foams. The term µ-tomography, used to describe this method, refers to a spatial resolution in the micrometer region. In Figure 1 the set-up used for the tomographic measurement is sketched schematically.

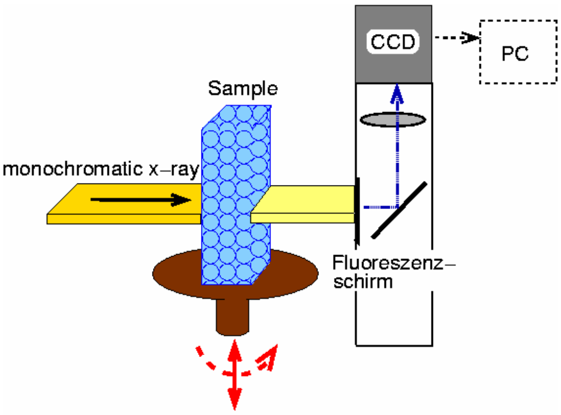

Fig. 1: Sketch of the measurement set-up for computed tomography

This tomography is based on the attenuation of monochromatic radiation by an object, e.g. by a metallic foam, for many different angular positions. Due to the different absorption coefficients of the different regions, the X-ray radiation is attenuated differently. This results in a set of about 700-900 single radiographic projections which are used for reconstructing the complete 3D-picture.

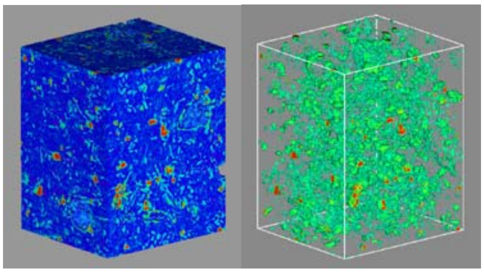

Fig. 2: Left: Tomographic image of the foam precursor containing AlSi10 Mg (blue), 10 % SiC (cyan), and 0.5 % blowing agent TiH_2 (red). Right: Distribution of the SiC-particles and the blowing agent separated from the aluminium matrix.

The measurement was carried out at BAMline, a beamline operated by the Federal Institute for Materials Research and Testing (BAM) at BESSY. The extremely parallel, highly intensive synchrotron radiation allows for a high spatial resolution and a very good signal-to-noise ratio. Moreover, by monochromizing the beam we are able to distinguish between different phases in the samples. The X-ray energy range is tuneable from 6 to 60 keV.

Figure 2 shows two tomographic images of a metallic foam precursor. The cast solid precursor consists of the aluminium alloy Al Si10 Mg (blue) and some particles of the blowing agent titanium hydride (TiH_2, red). After heating up the precursor to above the decomposition temperature of the blowing agent, the hydrogen is released and a porous structure is generated. To achieve a better stability of the metallic foam during the foaming process, 10 % (vol.) of insoluble, partially wetted, micrometer-sized silicon carbide particles (cyan) were added to the alloy. Thus, the viscosity of the melt is increased during the foaming process, and the surface tension decreases. Drainage along the walls then occurs less rapidly, and therefore the bubble collapse is slowed down. This leads to an evenly distributed pore structure. On the right hand side of Figure 2 the homogeneous distribution of the SiC-particles and the TiH_2-particles is visualized. Because silicon carbide and aluminium have nearly the same absorption coefficient, we need the monochromatic synchrotron radiation (E=25 keV, $\Delta E/E=10^{-2}$) to distinguish between them.

Fig. 3 shows a photograph and a tomographic view of the material after the foaming process.

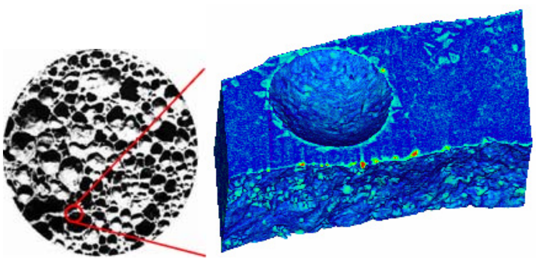

Fig. 3 Photograph of the aluminium foam (left). tomographic clip of a pore wall of the fully foamed, solid aluminium foam with a smaller pore in it (right)

Now the silicon carbide particles (cyan) are mostly arranged on the wall's surface in front and around the smaller pore. The red areas in the right picture are remnants of the blowing agent titanium hydride. Thanks to the tomographic measurements, the rearrangement mechanism can be observed three-dimensionally and the distribution of the SiC-particles can be visualized and evaluated quantitatively.

A. Haibel, A. Rack