X-ray micro-imaging using different contrast modes and partially coherent synchrotron light

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Synchrotron-based micro-imaging is a valuable tool in materials research, life science, non-destructive evaluation, and palaeontology. The high brilliance at synchrotron light sources can be used to record images with an extremely low noise level and high spatial resolution within short acquisition times. Additionally, monochromatic radiation can be used to reduce artefacts while increasing the material contrast. The spatial coherence of the light source gives access to improved interfaces- and/or material-contrast by adding interferometric techniques to the available imaging modes. Novel contrast mechanisms which were applied to micro-tomography (μCT) are: X-ray fluorescence tomography (sensitive to the local chemical species distribution), refraction enhanced tomography (sensitive to inner surfaces and interfaces), diffraction tomography (contrasting the local texture of polycrystalline material grains) and holotomography (imaging the real decrement of the materials' refractive index) [1-3].
Over the past few years, the Helmholtz-Zentrum Berlin für Materialien und Energie (HZB), together with the Bundesanstalt für Materialforschung und –prüfung (BAM), has developed a micro-imaging station at Berliner Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung (BESSY). Absorption contrast, refraction enhanced imaging as well as inline phase contrast μCT are the standard imaging modes [2]. The available contrast mechanisms were recently extended to holotomography [3].
The principle of holotomography is illustrated in Figure 1. Tomographic datasets are recorded at different sample-detector distances. Here, the phase contrast imaging mode yields to the formation of high-contrast interference fringes at materials interfaces and micrometre-sized inhomogeneities. This effect gains in strength the more the images are defocused, i.e. for larger sample-detector distances. Whilst the inline phase contrast mode is often used directly for imaging, numerical phase retrieval can be applied to one or several such images, yielding a projection map of the real decrement of the materials' refractive index (absorption images represent the imaginary part, usually 2-3 orders of magnitude smaller than the real decrement which is approximately the local electron density). These so-called phase-maps are used for reconstructing volume images. Figure 2 illustrates the differences between (a) absorption,

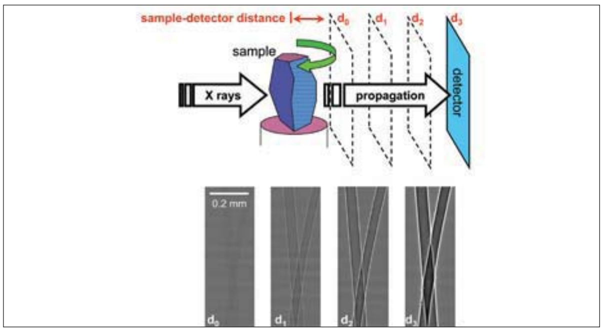

Fig. 1 Fresnel-propagated X-ray imaging illustrated for radiographs of two hairs recorded with increasing sample-detector distance [2,4].

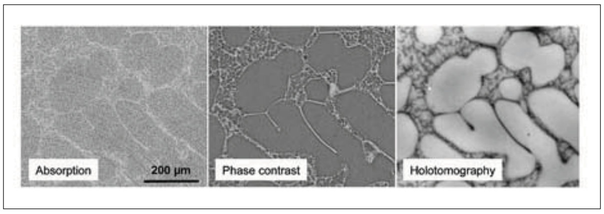

Fig. 2: Slices taken from three different tomograms of an AZ91 alloy: a) absorption contrast tomography, b) phase contrast tomography and c) holotomography [2].

(b) inline phase contrast and (c) holotomography for a tomographical slice showing the microstructure of a metallic specimen made from AZ91 alloy (Mg-particles in Mg-Al matrix). Holotomography features a highly improved density contrast which is important for imaging specimens of weak absorption (biological samples) and specimens with two or more material phases of similar density.

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