MEASUREMENT OF RESIDUAL STRAINS WITH QUANTITATIVE X-RAY TOPOGRAPHY

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Due to its excellent optical, thermal and mechanical properties synthetic single-crystalline diamond is a very well suited material for several X-ray optical elements to be used in 3^{rd} generation X-ray sources. In the case of 4^{th} generation X-ray sources like the XFEL in Hamburg it is probably the only possible material for some applications. Diamond is used for Bragg diffracting elements like monochromators, beam splitters or phase plates / polarisers. However, the beam quality should not be spoiled by those elements. Thus, a high perfection in the crystal bulk and very good surface quality are crucial.

In recent years, considerable progress has been made in the field of the HPHT synthesis methods (high-pressure high-temperature). This has allowed the growth of diamond crystals with linear dimensions of around 10 mm and with low nitrogen content (below 40 ppb instead of hundreds of ppm). The result is a material with extended areas (20 mm^2 and more) that are free of macroscopic defects like dislocations, stacking faults and inclusions. The residual strains in these areas may be on an extremely low level (smaller than 10^{-7}), fulfilling the stringent requirements on crystal quality. The sources of residual strains are long range (over millimetres!) strain fields of still existing dislocations, or local variations of the impurity concentrations. Surface scratches, which may even not be visible under an optical microscope and other imperfections at the surface, also play a role. Such low strain levels are far away from the detection limit of standard methods of X-ray diffraction. The classical measurement of the FWHM of rocking curves is far too insensitive. Even such popular X-ray topography methods like Lang topography (laboratory) or synchrotron white beam topography are not sufficiently sensitive to the levels of strain which are required to be measured, even by some orders of magnitude.

Our goal was twofold. On the one hand we wanted to push the detection limit for residual strains as far (low) as possible, and on the other hand, we wanted to obtain quantitative results with spatial resolution, based on X-ray topographs. Thus, to vary the strain sensitivity and to measure extremely low strain values, we had to use sophisticated non-dispersive double crystal diffraction topography methods ("plane" wave topography). The idea was to use a non-dispersive (n,-m)-setup with a bendable silicon monochromator, combined with high-order reflections and to also use rather high X-ray energies. In this way narrow rocking curves with extremely steep flanks could be obtained. This results in extreme strain sensitivity when using the steepest part of the flank. We were able to achieve detection limits even down to 10^{-9}. Quantitative 2D-analysis of local strain was possible with two different experimental methods. We shall demonstrate this based on results obtained from diamond plates purchased from Element Six.