TC-131: Development of a method to investigate the damage structure near a crack-tip in metals by means of SM-SAXS.

In order to study the defect gradients around the crack-tip (nucleation, growth and coalescence of microvoids) in an Al-2024 alloy without anisotropic grain-boundary interference, small regions ahead of the crack-tip were scanned using a 5µm by 5µm collimated beam.
Three scans were made, the first scan (step size 0.2mm) covered a region in y (parallel to the crack) from 0 to 2mm and from –1.5 to 2.1mm in z and was carried out to map the damage zone around the crack-tip (0,0). The second scan (step size y:18µm, z: 24µm) was more detailed to investigate the defects in a smaller region close to the crack-tip (y: 0 to 200µm; z:-60 to 60µm) using a smaller step size. A third, linear scan (from 0 to 150µm in y, step size: 7µm) was run to look inside the grains (20-25µm in diameter).
All scans revealed more or less isotropic (figure 1) and to a lesser extent diamond-shaped (figure 2) scattering images, both occasionally adorned with single streaks (figure 3). The typical anisotropic streaks with hexagonal symmetry attributed to grain-boundary scattering were no longer observed[1].
The streaks occur more frequently in closer vicinity of the crack which points to tiny cracks in the material (which do not cut the surface of the specimen). There is an indication of tiny through-cracks from SEM and TEM-images. The streaks are furthermore most often found in diamond-shaped images, which on average reveal a higher scattered intensity.

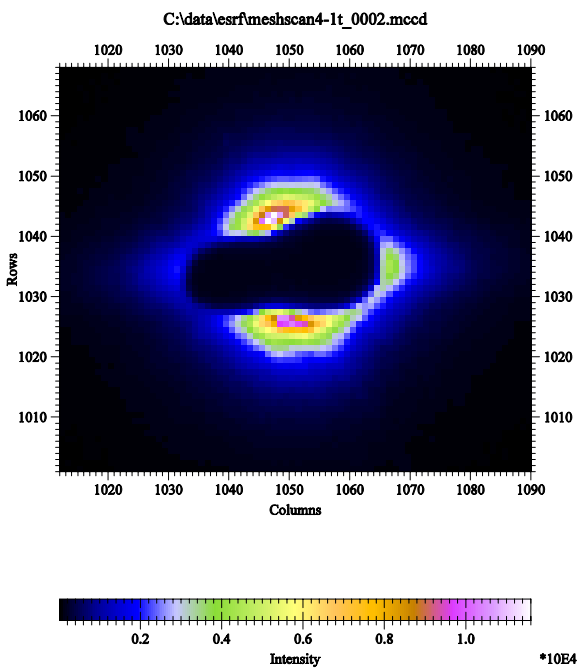

Figure 1: typical scattering image observed for many of the scanning positions.

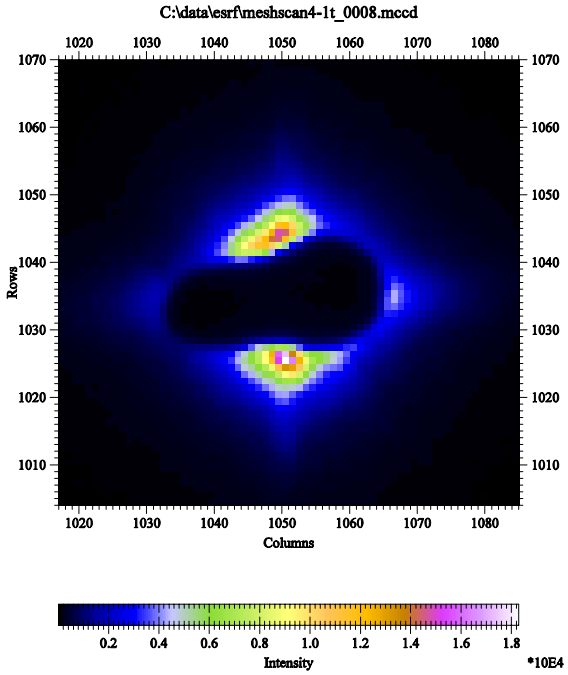

Figure 2: diamond-shaped pattern which reveals higher scattering intensities.

To determine the crack-tip accurately, photographs or light microscope data of the specimen surface with crack (480x) are required. The crack-tip could also be searched scanning the region for a difference between transmission through the crack and through the sample, but with the many microcracks present near the crack-tip, light microscope images will prove to be less time consuming.

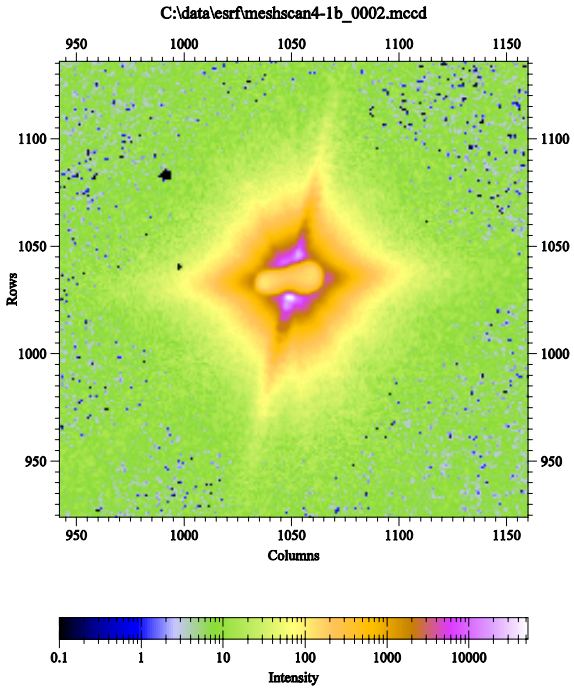

Figure 3: single streaks on a diamond-shaped scattering image (intensity displayed in log).

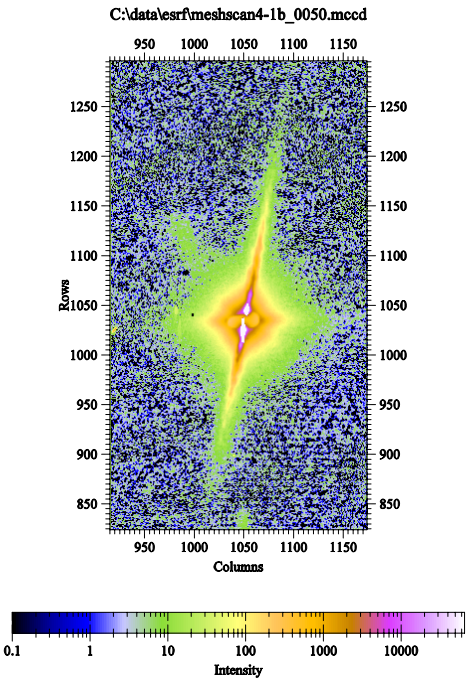

Fig. 4:The intense scattering image (log) reveals large streaks which points to scattering off the narrow crack (0.6,0.3) (very close to the crack-tip) or a tiny crack inside the material.

Figure 4 shows a scattering image which is very likely due to scanning of the crack around the crack-tip or of a micro crack, which from light microscope and SEM data are estimated to measure about 2-4µm in width, though smaller cracks inside the material which are not visible from SEM images may also be responsible.

Further analysis of the results is in progress.

[1]In an experiment by means of Electron Channeling Contrast SEM carried out very recently, a band-like region of about 220µm in width on either side of the crack over a length of about 1mm along the crack and extending beyond the crack-tip in the other direction was observed to lack grain-boundary orientation contrast by comparison with a region further from the crack-tip. From the SAXS-observations more information on this effect of deformation on the grain-boundaries (orientation, breaking up) is anticipated.