In-situ Determination of Material Behaviour under in-situ Thermal and Mechanical Loading using High Energy Synchrotron Radiation

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High energy synchrotron radiation due to its high photon flux, parallelism and high penetration depth offers the possibilities for fast strain/stress, texture analyses as well as tomography within bulk samples. This gives access to material behaviour in-situ under thermal and mechanical loading.

Among the major challenges today is achieving a very high local resolution, which is e.g. necessary for measurements of the orientation and strains/stresses in individual grains of polycrystalline samples, e.g. stents used in coronary arteries. In these extremely small components strains/stresses can be measured by focusing the X-ray beam ex-situ now, in future experiments during stent expansion are planned. Another example where high local resolutions are needed is two-axial loading of samples by torsion, where strong strain gradients exist. In this case a high local resolution was accomplished by using a conical slit cell developed by Ris∅ National Lab /1-3/.

In multiphase functional materials, e.g. IGBTs in power electronics only the high photon flux of HESR permits high local resolution strain scanning even in phases that amount to only a few volume percent of the material /4/.

Another challenging field of experiments are those where time is an important parameter, e.g. loading experiments at elevated temperature. In order to avoid relaxation during tensile tests, the measurements need to be sufficiently fast. By decreasing data acquisition times even more, strain/stress relaxation versus temperature can be followed in stress relaxation tests /5, 6/. In future the combination of strain scanning with other techniques e.g. tomography will provide even more information about material failure e.g. during high temperature deformation and the resulting changes in the local strain/stress state in specimens.

HESR in many aspects is a complementary technique to neutron diffraction. Limits of HESR will be especially coarse grained materials as well as large components.

Future areas where HESR will enable new types of experiments are experiments combining several experimental methods such as macroscopic strain/stress analyses and profile analyses, simultaneous strain and texture analyses, strain analyses and tomography, strain analyses and small angle scattering.
Among the demands on beamlines and instruments for new kinds of experiments are e.g. the development of faster detection systems, set-ups with several detection systems, the possibilities for measurements not only in transmission but also in reflection. For better quality results also the development of customer-friendly on-line data analyses would make a strong impact.

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