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Residual Stress Analysis with Multiple HKL Rings Collected by Area Detectors

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Future Directions and Challenges in Residual Stress Analysis (E. Üstündag & M. Prime)

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I intend to publish this paper in the ICRS-8 conference proceedings.

RESIDUAL STRESS ANALYSIS WITH MULTIPLE HKL RINGS COLLECTED BY AREA DETECTORS

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Measurement of residual stresses in thin films or textured materials by X-ray diffraction is always a challenge task. The limited diffraction volume in thin films or the directions with low pole density in sharply textured materials results in a weak diffraction signals. The sharp stress gradient, anisotropic grain shape and inhomogeneous phase and microstructure distribution also add difficulties in stress analysis with the conventional X-ray diffraction method. The nonlinear $\varepsilon_{\psi\phi}$ - $\sin^2\psi$ behavior commonly associated with thin films and textured materials produces poor results. This paper introduces a method using diffraction rings from multiple (hkl) crystalline planes collected with area detectors to analyze residual stresses.

The stress measurement with an area detector is based on a direct relationship between the stress tensor and the diffraction cone distortion. The fundamental equation for stress measurement is developed with the matrix transformation defined for the two-dimensional diffraction. The diffraction vectors cover more directions at each measurement and the diffraction vectors do not have to be distributed along a longitudinal direction as the conventional $\sin^2\psi$ method. Since the diffraction frames collected with area detectors typically contains more than one diffraction ring, the stress analysis can be calculated from diffraction rings from multiple (hkl) crystalline planes. First, this will increase the available data points for stress calculation and so to improve the sampling statistics. Secondly, due to the different orientation distributions from different (hkl) planes, the weak diffraction signal from one plane at certain diffraction vector direction is most likely to be compensated by a strong diffraction signal from another plane at a nearby diffraction vector direction. By using multiple diffraction rings, it is also possible to reduce the number of sample tilt angles without reduce the angular coverage. An example is given by stress measurement on a 1 μm textured Cu film on a proprietary substrate using 1.4Å synchrotron beam and CCD detector. The stress calculations with single (331) or (420) peak and combined analysis with both peaks are compared.