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In-situ characterization of local fields in alumina using Raman microspectroscopy

Julie Chalony[1], Aurélien Doitrand[2], Sylvain Meille[3]

[1] INSA Lyon, Universite Claude Bernard Lyon 1, Ecole Centrale de Lyon, CNRS, Ampère, UMR5005, 69621 Villeurbanne, France, France. julie.chalony@insa-lyon.fr
[2] INSA Lyon, Universite Claude Bernard Lyon 1, Ecole Centrale de Lyon, CNRS, Ampère, UMR5005, 69621 Villeurbanne, France, France. aurelien.doitrand@insa-lyon.fr
[3] INSA Lyon, Universite Claude Bernard Lyon 1, Ecole Centrale de Lyon, CNRS, Ampère, UMR5005, 69621 Villeurbanne, France, France. sylvain.meille@insa-lyon.fr

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Abstract

Raman microspectroscopy allows deformation fields to be measured indirectly by tracking frequency shifts in the material's characteristic peaks. Indeed, Raman scattering is sensitive to changes in lattice vibrations due to an applied strain. A key advantage of this technique is its high spatial resolution, down to the micrometer scale, enabling precise mapping of local fields during in-situ micromechanical testing. It also appears as an alternative to Digital Image Correlation (DIC) for materials deforming at small strain levels, or presenting an initial residual stress field, such as ceramics. However, the main challenge lies in converting the measured peak shifts into meaningful stress or strain components. Raman shift–strain relationships in alumina have been studied since the late 1970s, starting with compressed samples [1] and later extending to four-point bending experiments [2]. However, the calibrated parameters reported in the literature remain inconsistent between different studies, even for simple four-point bending tests. This work aims at calibrating and using the Raman peak shift to strain relation in the case of alumina and assess the achievable resolution limits. In particular, we propose several mechanical experiments with the aim to evaluate this method's sensitivity to different components of the strain tensor. First, we perform four-point bending experiments on single crystal sapphires oriented in all three main crystal directions (a, m, c).

This experiment enables to measure most accurately how Raman peak shift is sensitive to diagonal components of the strain tensor in the crystal referential. Second, we propose new sample geometries to take the most advantage of the full-field measurement. More precisely, we aim at performing in-situ experiments with a full-field spectral mapping of some samples under loading and extracting the Raman peak shift to strain relation by setting-up an inverse identification method. The sample geometry and loading conditions will be carefully chosen in order to maximize the sensitivity of peaks shifts to some strain components, especially the shear ones. Finally, we aim to use this characterization technique during in-situ testing on alumina to determine non-homogeneous strain field. These results will feed an experiments-simulation dialogue in order to precisely determine the boundary condition of an experiment, for instance by characterizing the generalized stress intensity factors for notched specimens, and thus get a better input for further fracture mechanics simulations, or to determine mechanical and fracture material properties. References [1] Shin, S. H., Pollak, F. H., & Raccah, P. M. (1976). Effects of uniaxial stress on the Raman frequencies of Ti2O3 and Al2O3. Proceedings of the Third International Conference on Light Scattering in Solids, edited by M. Balkanski, R. C. C. Leite, and S. P. S. Porto, 401-405. [2] Pezzotti, G., & Zhu, W. (2015). Resolving stress tensor components in space from polarized Raman spectra : Polycrystalline alumina. Physical Chemistry Chemical Physics, 17(4), 2608-2627.

Keywords:

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