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Digital Image Correlation and Finite Element Simulations Applied to the Analysis of the Mechanisms of Plastic Deformation of Synthetic Halite

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Synthetic halite elaborated with different microstructures (i.e. grain sizes and grain size distribution) has been deformed by uniaxial compression in a scanning electron microscope, with measure of the grain orientations, surface observation of slip lines, digital image correlation (DIC) to provide full-field estimates of displacements and surface strains (Bourcier et al. 2012). These kinematic data have indicated that the plastic deformation of halite is mostly intragranular for samples with large grains, with a few grain boundaries experiencing glide. In many cases, the slip planes can be identified, with contrasted situations: cross slip, partition of grains into several parts showing different slip lines... DIC shows that intragranular strains are organized by bands which orientation may often be explained in terms of slip plane traces and which become denser as the strain magnitudes increase. In order to complete the analysis, the knowledge of the local stresses is needed. Since they cannot be measured directly, one turns to numerical simulations based on a Crystal Plasticity Finite Element Code (CPFE).
The core of such codes is the description of the single crystal behavior. Salt and ionic crystals have been extensively studied in the past (Carter and Heard, 1970) and recently revisited (Picard et al., 2012). It has been established that the glide directions are <110> directions and that the glide planes are {110}, {100} and {111} with strongly temperature dependent initial critical shear stresses (CSS) and hardening behaviors. At room temperature, the {110}<110> systems have the lowest CSS but do not suffice to accommodate a general plastic strain, so there is an initial stress differential build up between a grain well-oriented for easy plastic glide and another “hard” grain until other systems are activated or another deformation mechanism arises.
The structure on which these computations are performed is another key element : one has to reconstruct a 3D volume and impose realistic boundary conditions.
In this work, we present first computations done on single crystals subjected to uniaxial compressions in order to compare observed or DIC estimated intragranular slip with the computed one. Then, we apply a CPFE simulation to a simple triple junction, fully documented by DIC and SEM observations. Several computational hypotheses are tested both in terms of rheology and boundary conditions. The aim is to estimate the stress distribution in the structure and understand the role that grain boundary sliding may play in relaxing local stress concentrations.

References

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