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Effects of microstructure and temperature on the plastic deformation mechanisms of synthetic halite : a micromechanical approach

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Halite is a rock forming mineral with geotechnical applications for storage in underground caverns (hydrocarbons, compressed air, wastes...). Halite is also a convenient analog polycristalline material, used to study deformation mechanisms (crystal plasticity, recrystallization, pressure solution ...). In this work we present an investigation of intragranular plastic deformation and grain boundary sliding in pure synthetic NaCl polycrystals produced by hot isostatic pressing. Uniaxial compression tests are performed in a Scanning Electron Microscope (SEM) at two temperatures, 20°C and 400 °C, on cm - sized samples. The displacement rate is kept constant at 1μm/s and the maximum axial strain is between 5 and 10 %. The surface of the samples is marked by gold micro-spheres and analyzed by 2D digital image correlation (DIC) using the CorrelManuV software, which provides full field measures of surface displacements and strains.

The dominant mechanism is intracrystalline plasticity, as revealed by the direct observation of slip lines and by DIC results showing intragranular deformation bands. Using crystal orientation mapping, the latter are related to the traces of crystallographic slip planes. However, limited grain boundary sliding (GBS) also occurs, as a secondary but necessary mechanism for accommodation of local strain incompatibilities. The relative contribution of each mechanism clearly depends on the microstructure, i.e. grain size and grain size distribution. At room temperature the strain is more heterogeneous than at high temperature, at both the aggregate scale and within individual grains, where the local activity of slip systems strongly depends on the relative crystalline and interfacial orientations. In particular, the easy glide planes ($\{110\}$ planes) are not the only active ones. In some instance, wavy slip bands clearly indicate cross slip.

The above kinematic analysis should be complemented by the knowledge of the local stress states in order to compute for each slip system of each grain a resolved shear stress and thus find which system is likely to be activated. If one assumes that the local stress state is representative of the macroscopic uniaxial compression, the analysis provides straightforwardly the appropriate Schmid factors showing which slip systems experience the largest resolved shear stresses. However, owing to local interactions between the different mechanisms and the neighboring grains, this is only a first order approximation, and one needs numerical simulations in order to compute the stress distribution at the local level. One will thus (i) characterize an observed area of a few grains in terms of geometry and initial orientation (measured by electron back-scattering diffraction, EBSD), (ii) determine the boundary conditions (including by implementing the measured displacement field) and (iii) simulate its deformation by crystal plasticity with finite element code. However, since the real 3D microstructure is unknown the actual influence of the underlying layers of grains cannot be well asserted. For this purpose, 3D reconstruction based on X-ray diffraction techniques is needed.