Geophysical Research Abstracts
Vol. 15, EGU2013-11801, 2013
EGU General Assembly 2013

Ductile deformation mechanisms of synthetic halite: a full field measurement approach

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Halite is a commonly used analog polycristalline material. Compared to most rock forming minerals, halite exhibits extensively ductile behavior at even low temperatures and fast deformation rates. Therefore, it allows an easier study of the fundamental mechanisms of crystal plasticity, recrystallization, grain growth and texture development than any other mineral. Its high solubility also makes it an ideal candidate for investigating pressure solution creep. Most importantly, halite is very convenient to study the interactions of simultaneously occurring deformation mechanisms.

We investigated uniaxial deformation of pure synthetic NaCl polycrystals with controlled grain sizes and grain size distributions at room and moderate temperatures (400°C). The mechanical tests were combined with "in-situ" optical and scanning electron microscopy, in order to perform 2D digital image correlation (2D-DIC) and to obtain the full surface strain fields at the sample scale and at the scales of the microstructure.

We observed dominantly intracrystalline plasticity, as revealed by the occurrence of physical slip lines on the surface of individual grains and of deformation bands at the microstructure (aggregate) scale, as revealed by DIC. Crystal orientation mapping (performed by EBSD) allowed relating the latter to the traces of crystallographic slip planes and inferring the active slip systems considering the macroscopic stress state and computing Schmid factors. The strain heterogeneities are more pronounced at low temperature, at both the aggregate scale and within individual grains. The local activity of slip systems strongly depends on the relative crystallographic and interfacial orientations of the adjacent grains with respect to the loading direction. The easy glide {110} <110> systems are not the only active ones. We could identify the activity of all slip systems, especially near grain boundaries, which indicates local variations of the stress state. But, we also clearly evidenced grain boundary sliding (GBS), which occurred as a secondary but necessary mechanism for accommodation of local strain incompatibilities between neighboring grains, related to the anisotropy of crystal plasticity. The DIC technique allowed the precise quantification of the relative contribution of each mechanism. The latter clearly depends on the microstructure (i.e. grain size and its distribution): the smaller is the grain size and the stronger is the GBS contribution.

Finite element modeling of the viscoplastic polycrystalline behavior was started on the basis of our experimental microstructures with large grains (where GBS activity is limited to < 10 %), considering an extruded columnar structure in depth and single crystal flow laws from literature. The results show that the computed strain fields do not sufficiently match the experimentally measured ones. The reasons for the discrepancies are likely related to the activity of GBS, which was not accounted for, and to the influence of the real microstructure at depth (underlying grains and orientations of interfaces), which strongly condition the surface response.