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Impurities throughout the EGRIP ice core – a microstructural perspective

Content

Impurities in polar ice cores are analyzed for various reasons, ranging from the reconstruction of the climate of the past to the absolute positioning of age markers. In particular, microstructural impurity research provides insights into the internal deformation of ice and post-depositional stratigraphy changes. However, most studies offer limited snapshots of impurity characteristics at a few specific depth regimes, highlighting the need to determine the localization and chemistry of impurities throughout one ice core with complementary methods. We report a detailed investigation of solid and dissolved impurities throughout the 2120 m long East Greenland Ice Core Project (EGRIP) ice core. Using microstructure mapping and confocal Cryo-Raman spectroscopy, we analyzed solid micro-inclusions inside 25 solid ice samples covering the last 50 ka. Micro-inclusions are heterogeneously distributed inside the ice matrix and in Holocene ice, as an upper limit assumption, between 22.3 and 42.4% are located in the vicinity of grain boundaries. We identified the mineralogy of more than 1600 solid inclusions. Most are terrestrial dust minerals, such as quartz, feldspar, mica, carbonaceous particles, and sulfate minerals, such as gypsum. Less common minerals are e.g., dolomite, hematite, nitrates, rutile, and anatase. However, the upper 900 m are characterized by various sulfate minerals, while gypsum is the dominant sulfate species below. In the deepest 400 m of the core, we expose the mineralogy inside and surrounding distinct cloudy bands. Aiming at a holistic picture of soluble and insoluble impurities, we combined two methods for the first time: We further analyzed most samples with laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). Due to recent adaptions, LA-ICP-MS now enables us to image the 2D distribution of elements, such as Na, Mg, Al, and Fe, with a resolution of up to 10 microns showing element-depended differences in localization. For example, Na is primarily located at grain boundaries, and Al indicates dispersed particle clusters. Mg, and to some extent also Fe, are found in both regimes. Our results illustrate the merit of combining cryo-Raman spectroscopy and LA-ICP-MS to obtain new insights into small-scale deformation, chemical stratigraphy, and processes in deep ice and the future potential to enhance our understanding of impurities by exploiting such a multi-method approach.

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