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Characterization of Porous Snow with SEM and Micro CT

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Firn is a porous material, which can be thought of as an intermediate stage between ice and snow. It is formed by the slow densification of snow due to temperature gradients and overburden pressure. The resulting microstructure is an interconnected network of tortuous pore space segmented by ice particles. With increasing depth pores become segregated and the material ceases to be firn but is characterized as ice. Firn microstructure is of the utmost importance in polar research due to its role in ice-air interactions, texture formation, and its ability to trap chemical impurities.

Traditionally, porous snow has been characterized using quantitative optical microscopy or stereology paired with thin-sectioning techniques utilizing infiltration with a polymer [1, 3]. In practice these methods are low resolution, time consuming and involve complex and destructive specimen preparation. By using scanning electron microscopy (SEM) and micro X-ray computed tomography (micro CT) high resolution data of the 2-D and 3-D microstructure can be obtained.

For this project, an FEI XL30 field emission gun (FEG) environmental scanning electron microscope (SEM) equipped with a Gatan cooling system has been used to examine porous snow. The cooling system consists of a cold stage, an airlock and an electronic temperature controller. The stage can be cooled to liquid nitrogen temperature quickly by circulating chilled nitrogen gas through the tubing located within the stage. Specimens are loaded through the airlock system, which can be vented or pumped independently to prevent frosting in the main chamber. This cooling system greatly increases the, longevity of the sample and thus the duration of experiments. By coupling energy dispersive spectroscopy (EDS) and electron back scattered patterns (EBSP) with the SEM it is possible to document the microstructural location of impurities and crystallographic orientation of grains in ice [2, 4]. These methods together can be used to fully describe the 2-D microstructure. For the purpose of this project the SEM is run at -120^{o}C and 15kV for imaging firn and -180^{o}C and 2kV for more delicate snow samples.

A Skyscan 1172 micro CT is used for non-destructive characterization of the internal structure of firn. The system is operated in a -10^{o}C cold room at a 40 kV accelerating voltage and 250 μA current. In micro CT, the specimen is mounted between an X-ray source and a 2-D detector. A series of projection images are acquired at a step size of 0.9^{o} as the sample makes an 180^{o} rotation. Post processing of the projection images consists of gray-scale cross-section image reconstruction, binary image conversion and 3-D data and model acquisition. Usually, high resolution 2-D image of the specimen is used to accurately post process the images. 3-D properties of importance are, pore anisotropy, porosity, surface area to volume ratio and the number of voids present.

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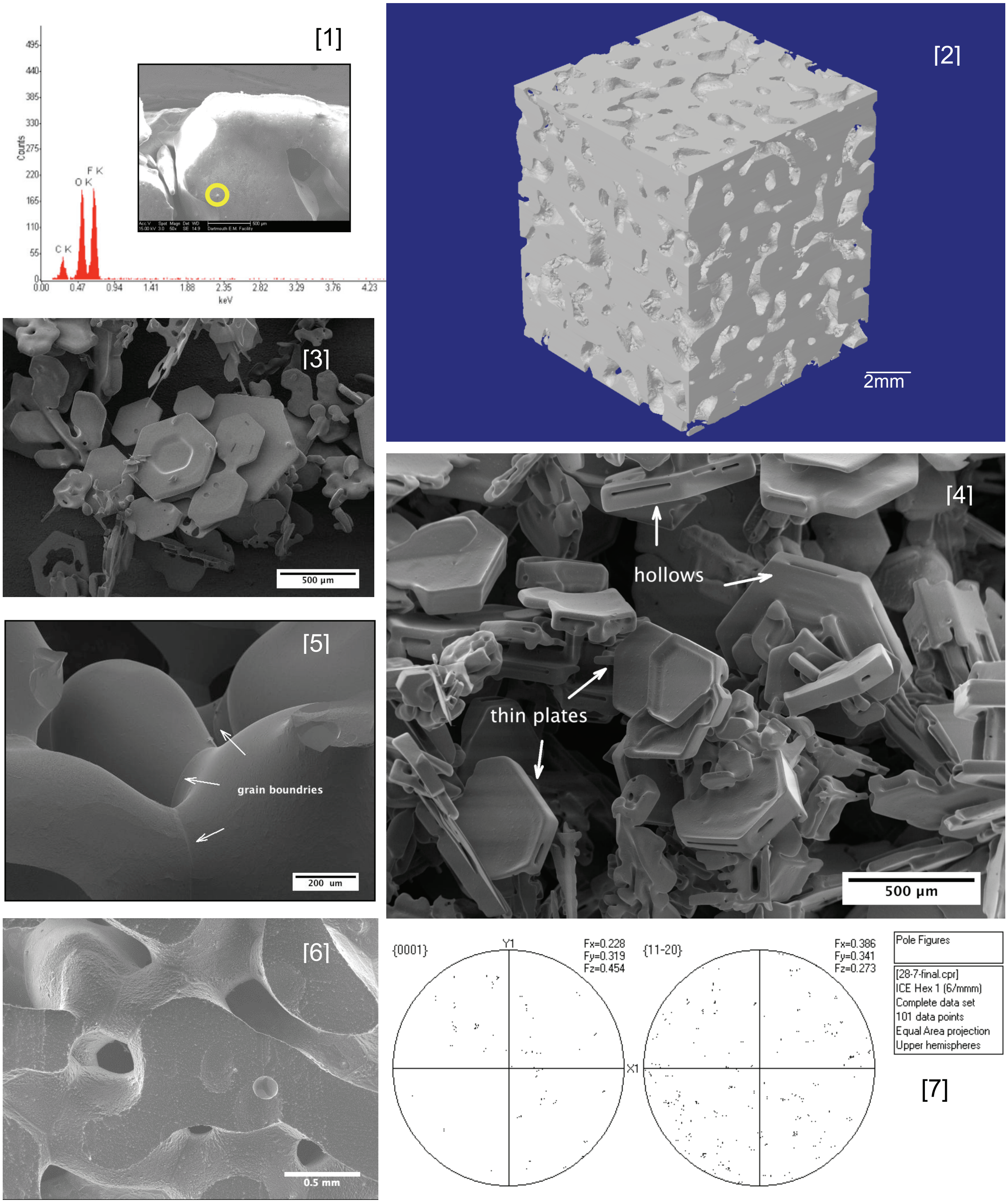

[1] An EDS spectrum for a circled firn impurity. [2] A micro CT 3-D reconstruction of firn from Summit, Greenland (28m depth). [3] SEM image (2kV) of snowflakes showing plate-like crystals. [4] SEM image (2kV) of fresh snow. [5] SEM image (2kV) of sintered snow showing connected rounded ice particles. [6] SEM image (15kV) of a firn specimen, shaved flat with a sterilized razor. [7] Pole figure of firn from Summit, Greenland (28m depth).

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