Synchrotron-based X-ray Micro-Tomography of Seawater Ice Grown in a Tank

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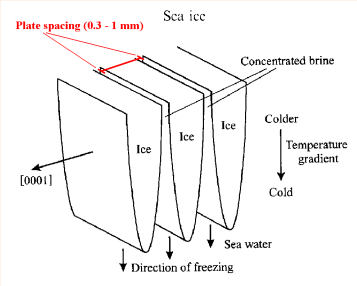
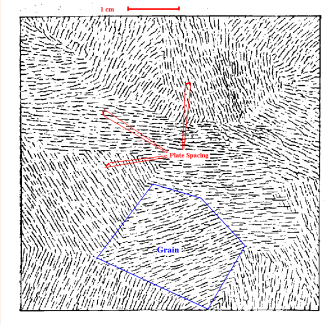
1 Sea Ice Microstructure



Principal sub-grain sea ice structure near the freezing interface; modified from Petrenko and Whitworth (Ice physics, 1999)

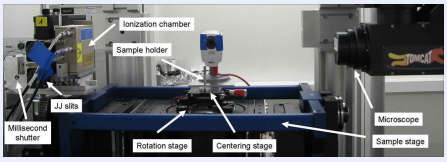


Tinfoil replica from the sea ice bottom (1897 by E.v. Drygalski)

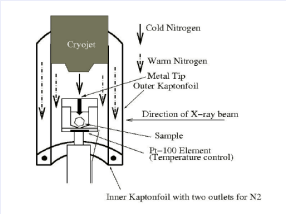
Columnar sea ice grows with a lamellar interface of vertically oriented plates, parallel within each grain. This plate spacing, typically 0.3-1 mm, is fundamental for the evolution of its physical properties.

2 Synchrotron: X-ray tomography

Swiss Light Source Synchrotron



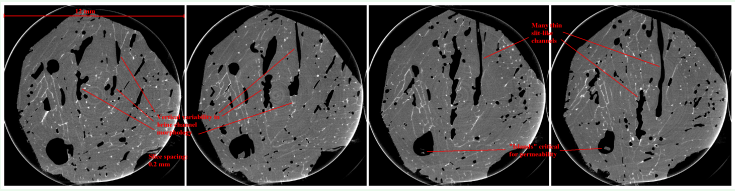
Setup at TOMCAT tomography beamline



- voxel sizes 0.35 to 11.84 μm
- up to 2 x 2 cm field of view
- short aquisition times (15 minutes)
- cryojet cooling below -40 °C, warm outer jet prevents condensation

⇒ Non-destructive 3-dim images with micrometer resolution

5 Brine Channel Architecture



Horizontal, centrifuged, voxel size 5.6μm.

- complex architecture over short (0.1 mm) vertical distance
- permeability modelling challenging

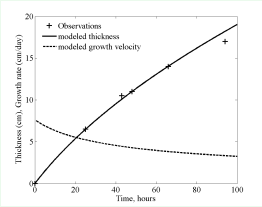
7 Conclusion and Outlook

Synchrotron-based X-ray tomography provides

- 3-dim and non-destructive microstructure images
- 1-2 orders of magnitude higher resolution than earlier work
- new perspectives of sea ice physical property studies

Ref.: Maus (2007), in "Physics and Chemistry of Ice", ed. W. Kuhs, Royal Society of Chemistry, pp. 371382.

3 Growth Velocity and Plate Spacing



Ice growth in laboratory

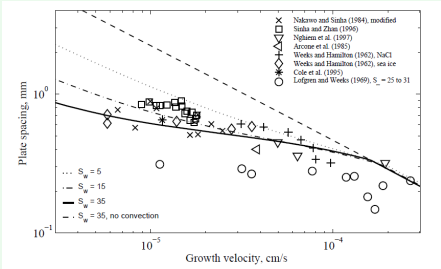


Plate spacing from morphological stability theory (Maus, 2007) versus compiled field observations

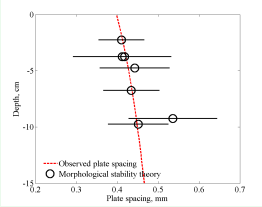


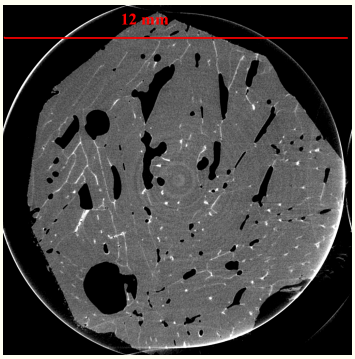
Plate spacing from present laboratory study versus theory

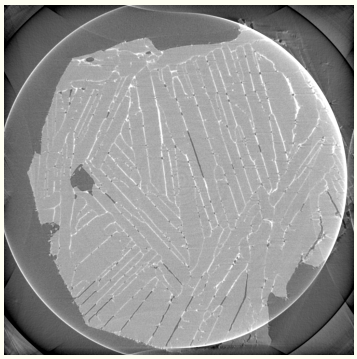
Controled ice growth in the laboratory

- easier structure preservation by centrifugation
- known growth conditions ⇒ validation of morphology models

Challenge in laboratory: mimic more complex field conditions (e.g., turbulence, waves, crystal orientation, temperature cycling). Limitations: old ice, aging and metamorphosis.

4 Imaging the Salt and Pore Space





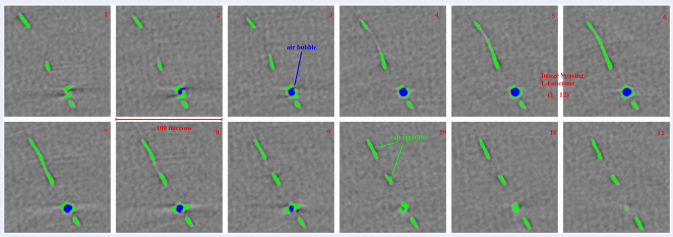
Centrifuged, 5 cm depth, voxel size 5.6 μm Not centrifuged, close to freezing interface

Imaging of centrifuged samples at ≈ -35 °Cdistinguishes air (dark), solid salts (bright) and pure ice (grey).

- Air (Centrifuged) ⇒ interconnected pore space
- Salt (not centrifugable) ⇒ likely disconnected pore space

Without centrifuging ⇒ estimate brine loss during sampling

6 Very High Resolution Imaging



At our highest resolution (0.7 μm, binned two times) we retrieve the most tiny inclusions. Meanwhile TOMCAT allows for resolution of 0.35 μm, appropriate to resolve single salt crystals.