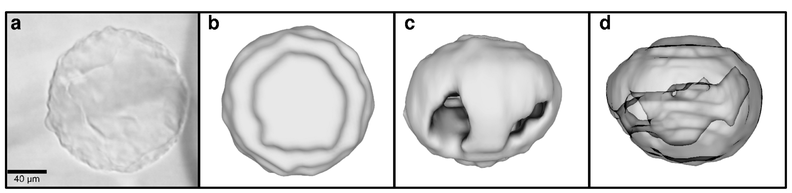
ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Christian Weikusat, Sepp Kipfstuhl, Ilka Weikusat

Raman tomography of natural air hydrates

Ice cores are the only climate archives incorporating paleo-atmosphere as individual gas inclusions, enabling the extraction and analysis of the contained gasses. A firm understanding of the processes involved is mandatory for a reliable interpretation of the gas records. One prominent process is the transition from air bubbles to crystalline air hydrates, which is known to influence, at least temporarily, the gas mixing ratios by diffusion and fractionation. This transition is still not understood completely and the existing theories do not explain the large diversity of observed hydrate morphologies.

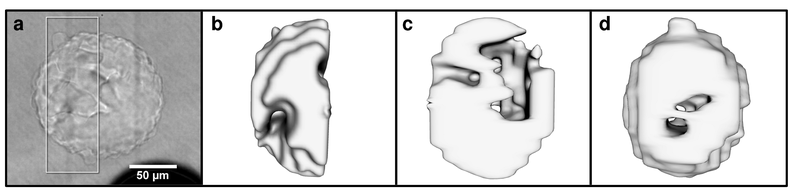
Raman tomographic measurements using the AWI cryo-Raman system provide 3D reconstructions of air hydrate morphologies. The results show complex growth structures that emphasize the importance of crystallography, microstructure and ice rheology for the hydrate formation process. Accurate hydrate volumes can be calculated from the 3D objects, improving the estimates of total gas contents.



„cloudy“ air hydrate from EDML, depth 1005 m

a Microscopic image
b 3D reconstruction viewed in the same orientation
c Side view, large holes in the shell are evident
d Semi-transparent side view with ice intrusion

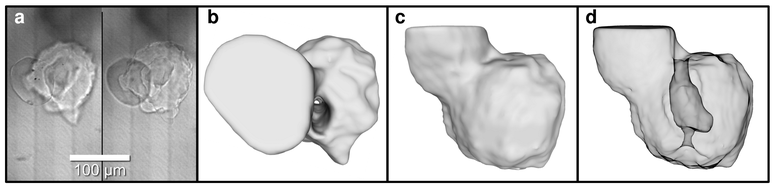
stepwidth x:	3 µm	acq. time:	0.2 s	hydrate volume:	9.89 x 10^5 µm^3
stepwidth y:	3 µm	full spectra:	48355	intrusion volume:	2.12 x 10^5 µm^3
stepwidth z:	10 µm	total time:	3 h	ratio V_i/V_h:	0.2



„cloudy“ air hydrate from EDML, depth 1048 m

a Microscopic image with highlighted scan area
b 3D reconstruction viewed in the same orientation
c Side view of the section with ice intrusion
d Side view from the opposite side

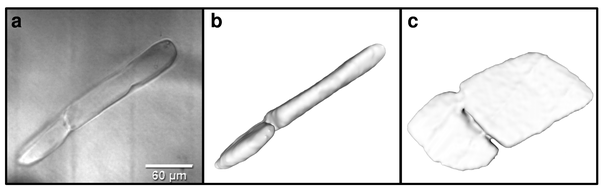
stepwidth x:	2 µm	acq. time:	0.2 s	hydrate volume:	3.45 x 10^5 µm^3
stepwidth y:	2 µm	full spectra:	34031	intrusion volume:	1.07 x 10^5 µm^3
stepwidth z:	10 µm	total time:	2 h	ratio V_i/V_h:	0.31



connected hydrates from EDML, depth 1084 m

a Microscopic images
b 3D reconstruction viewed in the same orientation
c Side view reveals a connection between the AHs
d Semi-transparent side view with ice intrusion

stepwidth x:	3 µm	acq. time:	0.3 s	hydrate volume:	1.59 x 10^6 µm^3
stepwidth y:	3 µm	full spectra:	212333	intrusion volume:	9.17 x 10^4 µm^3
stepwidth z:	3 µm	total time:	18 h	ratio V_i/V_h:	n/a



„plate-like“ air hydrate from EDML, depth 1083 m

a Microscopic image
b 3D reconstruction viewed in the same orientation
c View perpendicular to ***b***

stepwidth x:	3 µm	acq. time:	0.3 s	hydrate volume:	6.5 x 10^5 µm^3
stepwidth y:	3 µm	full spectra:	341185	intrusion volume:	n/a
stepwidth z:	3 µm	total time:	28 h	ratio V_i/V_h:	n/a

Outlook

refine AH selection and measurement techniques | measure and map N_2/O_2 ratios corrected for crystal orientation | model relevant diffusion processes

References

Weikusat, C., Kipfstuhl S., Weikusat, I., Raman tomography of natural air hydrates, Journal of Glaciology, in press.

SPP1158
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ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG
HELMHOLTZ GEMEINSCHAFT

BREMERHAVEN

Am Handelshafen 12
27570 Bremerhaven
Telefon 0471 4831-0
www.awi.de