Gearing X-ray microscopy towards environmental challenges

D.W. Breiby[1,2]

[1]PoreLab, Dept. of Physics, Norwegian University of Science and Technology (NTNU), 7491 Trondheim,
[2]Dept. of Microsystems, University of South-Eastern Norway (USN), 3184 Borre, Norway,
dag.breiby@ntnu.no

These are intriguing times for X-ray microscopy as converging developments within sources, optics, sample environments, and detectors, combined with advances in artificial intelligence promise new approaches to high-performance imaging [1,2]. While sub-20 nm resolution 2D/3D X-ray microscopy is becoming an established research tool for materials science, pressing challenges await within the environmental and life sciences.

Here, we shall present our recent efforts using a selection of X-ray microscopy techniques ranging from diffraction-contrast studies of fossil bones [3], via ptychographic imaging of polymer blends for solar cells [4], to silk fibre hydration [5] – all with the aim of better understanding environmentally important porous materials. *In situ* monitoring of cement exposed to supercritical CO_2 under high temperature and pressure observed with attenuation-contrast tomography [6] will be described. Coherent X-ray diffraction imaging (CXDI) offers quantitative phase-contrast imaging of microscopic particles. Becoming able to chemically and structurally scrutinize arbitrary microscopic 3D objects ranging from algae to plastics in seawater is a prerequisite for pollution monitoring and -mitigation. Similarly, airborne particulates cause severe health and climate concerns and require statistically accurate structural models. The application of CXDI to a wide range of microparticles including Li_2ZrO_3 for CO_2 capture [7], mesoporous $CaCO_3$ [8], and metal-polymer composites [9,10] will be discussed. CXDI clearly is a unique tool for understanding mesoscale structures in both natural and manmade materials. With the rapid developments of X-ray imaging techniques, once unsurmountable microscopy challenges like deep-tissue neuronal activities, metabolism in living organisms, and multi-fluid interactions in microporous media will expectedly start receiving serious attention.

References

[1] - J.M. Rodenburg, A.C. Hurst, A.G. Cullis, B.R. Dobson, F. Pfeiffer, O. Bunk, C. David, K. Jefimovs, I. Johnson, Phys. Rev. Lett. **98** (2007) 034801.
[2] - J. Deng, Y.H. Lo, M Gallagher-Jones, S. Chen, A Pryor Jr., Q. Jin, Y.P. Hong, Y.S.G. Nashed, S. Vogt, J. Jiao, C. Jacobsen. Sci. Adv. **4** (2018) eaau4548.
[3] - F.K. Mürer, S. Sanchez, M. Álvarez-Murga, M. Di Michiel, F. Pfeiffer, M. Bech, D.W. Breiby. Sci. Rep. **8** (2018) 10052.
[4] - N. Patil. T. Narayanan, L. Michels, E.T.B. Skjønsfjell, M. Guizar-Sicairos, N. Van den Brande, R. Claessens, B. Van Mele, D.W. Breiby. ACS Appl. Polym. Mater. (2019).
[5] - M. Esmaeili, J.B. Fløystad, A. Diaz, K. Høydalsvik, M. Guizar-Sicairos, J.W. Andreasen, D.W. Breiby. Macromolecules **46** (2013) 434.
[6] - E.A. Chavez Panduro, M. Torsæter, K. Gawel, R. Bjørge, A. Gibaud, Y. Yang, S. Bruns, Y. Zheng, H.O. Sørensen, D.W. Breiby. Env. Sci. Tech. **51** (2017) 9344-9351.
[7] - K. Høydalsvik, J.B. Fløystad, T. Zhao, M. Esmaeili, A. Diaz, J.W. Andreasen, R.H. Mathiesen, M. Rønning, D.W. Breiby, Appl. Phys. Lett. **104** (2014) 241909.
[8] - O. Cherkas, T. Beuvier, D.W. Breiby, Y. Chushkin, F. Zontone, A. Gibaud. Crystal Growth & Design **17** (2017) 4183-4188.
[9] - E.T.B. Skjønsfjell, Y. Chushkin, F. Zontone, N. Patil, A. Gibaud, D.W. Breiby. Optics Express **24** (2016) 10710-10722.
[10] - E.T.B. Skjønsfjell, D. Kleiven, N. Patil, Y. Chushkin, F. Zontone, A. Gibaud, D.W. Breiby. JOSA A 35 (2018) A7-A17.