The Impact of Electric Fields on Surfactant-Molecules- A Small Angle X-ray Scattering Study

J. Akbarzadeh*; S. Flaig†; N. Hüsing†; H. Peterlik*

*University of Vienna, Faculty of Physics, Dynamics of Condensed Systems, Austria

†Paris-Lodron University Salzburg, Materials Chemistry, Austria

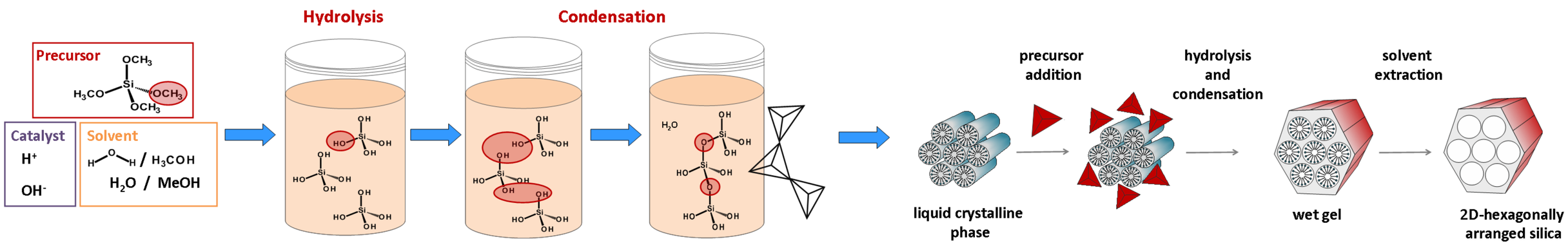
Abstract

The combination of different synthetic strategies such as sol-gel processing together with templating approaches has been proven to be an effective method in the preparation of long range ordered mesoporous materials. However, for many applications (e.g. microelectronic devices, membranes...) not only highly ordered mesopores but also a precisely defined pore orientation would be desirable. One way to achieve such highly oriented mesopores is to expose the sample to an electric field during the sol-gel process.

Electric field induced orientation of mesopores has already been reported in literature, for example Ku et al. have shown that the application of an low-strength electric field in the preparation of surfactant - templated nanoscopic silica fibers leads to oriented nanochannels with both micrometer and nanometer levels of hierarchy [1]. Trau et al. have demonstrated that the use of high-strength electric fields in the production of nanoscopic patterned thin films leads to nanochannels oriented parallel to the applied electric field [2].

In this work we investigate the behaviour of cetyltrimethylammonium bromide (CTAB) surfactant molecules in an external electric field ranging from some kV/m up to 1 MV/m. These molecules will further serve as a template phase in the sol - gel process to produce long range ordered and highly oriented mesoporous materials. The structural change on the nanometer level is followed by small-angle X-ray scattering (SAXS).

The Sol-Gel Process



Experimental Set-Up

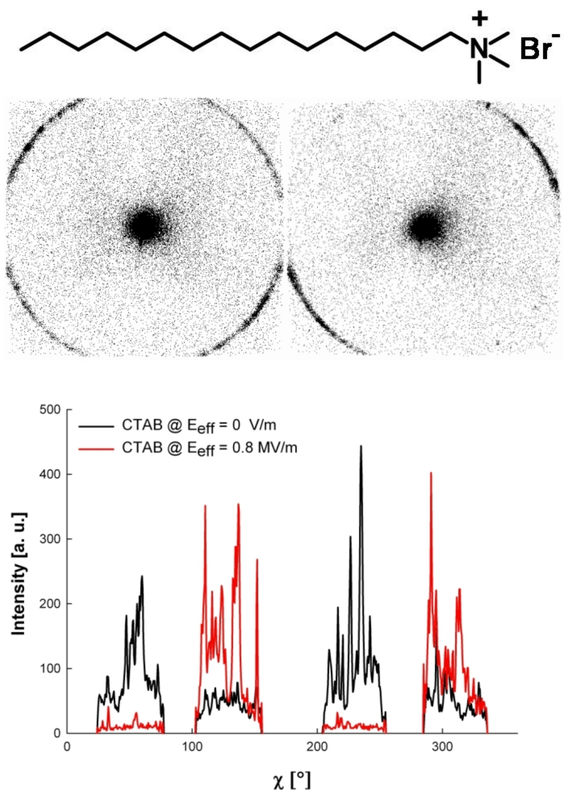
Implementation

A suspension of 0.135 g cetyltrimethylammonium bromide (CTAB) in 5 ml toluene was formed. The suspension was investigated at room temperature with and without the presence of an electric field. For this purpose the suspension was filled into a quartz-glass capillary and placed between two electrodes. The left figure shows the used home-made X-ray transparent device which allows the application of high voltage electric fields up to a few MV/m. In order to overcome discharging effects the measurements were carried out at ambient conditions.

The right figure shows first successful results: After exposing the suspension to an effective electric field of 0.8 MV/m for one hour, a significant change in the scattering intensity occurs, confirming an orientational change due to the applied electric field.

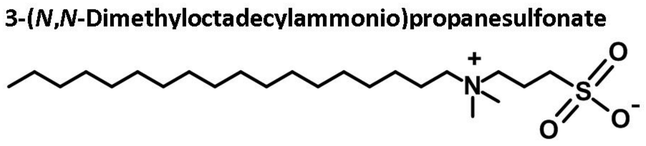
The scattering pattern are azimuthally averaged for better visualisation of the directional changes of the micelle orientation.

Orientation of CTAB Micelles in an Electric Field

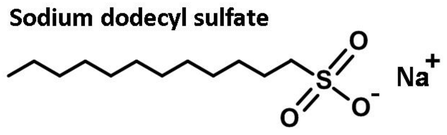


Outlook

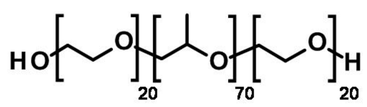
3-(*N*,*N*-Dimethyloctadecylammonio)propanesulfonate



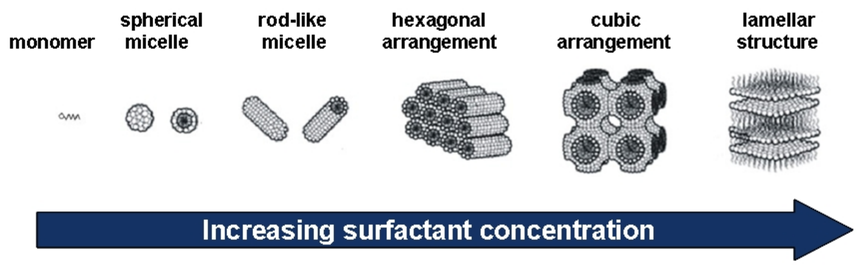
Sodium dodecyl sulfate



Pluronic® P123



- Investigation of other (anionic, zwitterionic, block copolymer) surfactant molecules (left figure).
- Studying the impact of temperature and electric fields on orientation of the micelles.
- Analysis of surfactant concentration effects (right figure)
- Application of other solvents (ethylene glycol, isopropanol, water, ...)



Literature

[1] A. Y. Ku, D. A. Saville, I. A. Aksay; Langmuir 2007, 23, 8156-8162

[2] M. Trau, N. Yao, E. Kim, Y. Xia, G. M. Whitesides, I. A. Aksay; Nature 1997, 390, 674-676

Acknowledgements

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