# Exploring the capabilities of NAP-XPS: Application to biofilms, nanoparticles and metal-organic frameworks

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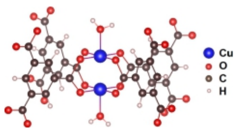
## Investigation of HKUST-1 exposed to methanol

- HKUST-1 consist of Cu(II)-dimers with 1,3,5-benzenetricarboxylic acid (BTC) as organic linker




- Sample exposed to maximum 20 mbar methanol (fig 1f)
- Increasing contribution of Cu(I) during dosing (fig. 2)
- Radiation induced damage, influence of gas-peaks and quantitative analysis must be carefully considered

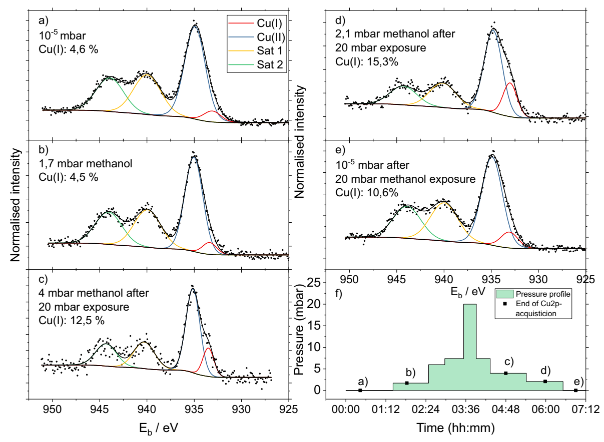



Fig. 1: Core level spectra of Cu $2p_{3/2}$ before, during and after dosing with methanol as indicated in f). Acquisition time per spectra was limited to 14 min to minimise radiation damage.

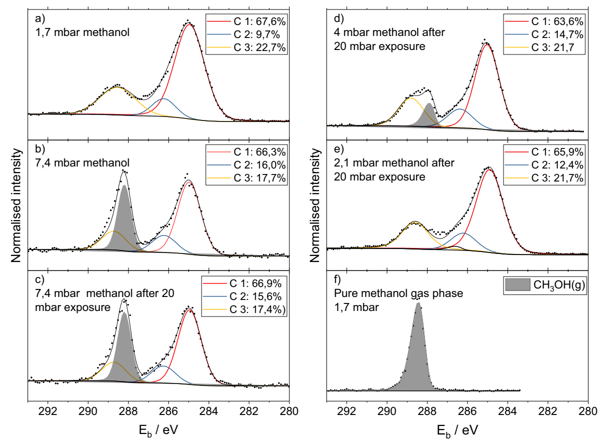



Fig. 2: Core level spectra of C 1s during methanol dosing. Component C1 originates from the aromatic ring in BTC and adventitious carbon, C2 from C-O bindings and C3 from carboxylic carbon in BTC

## Detection of suspended nanoparticles

- $SrF_2/CaF_2$ core -hell nano-particles in ethylene glycol (fig. 3) and silver nano-particles in aqueous solution (fig. 4) detected by NAP-XPS [1]
- Quality of spectra comparable to UHV-measurements for nanoparticles in ethylene glycol due to low vapor pressure (0.08 mbar at 20°C)
- $E_b$ is shifted 0.7 eV for Ag 3d in aqueous solution - change of surface potential
- NAP-XPS measurements with EnviroESCA, UHV-measurements with Kratos Axis Ultra

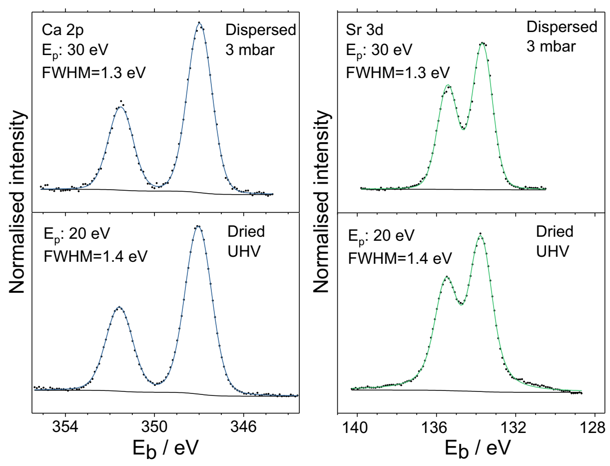



Fig. 3: Core level spectra of Ca 2p and Sr 3d from $SrF_2/CaF_2$ core-shell nanoparticles dispersed in ethylene glycol and dried on a Si-wafer

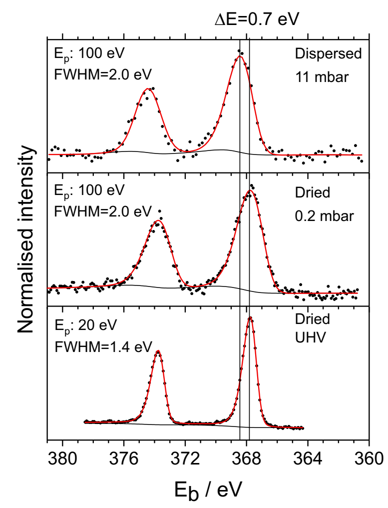



Fig. 4: Ag 3d core level spectra of silver nanoparticles in aqueous solution and dried on a Si-wafer.

## Surface characterisation of biofilms in humid conditions

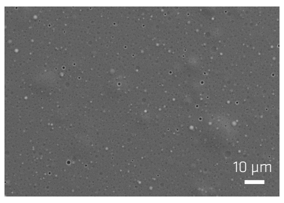


Fig. 5: Agarose as model for EPS-matrix. Fig. 5-7 are SEM-micrographs.

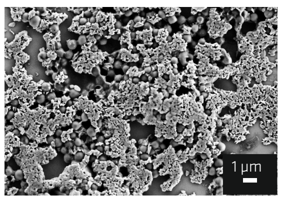


Fig. 6: Biofilms *(S. Aureus)*

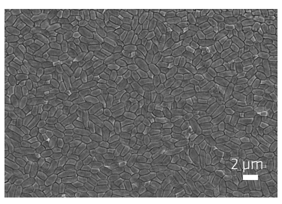
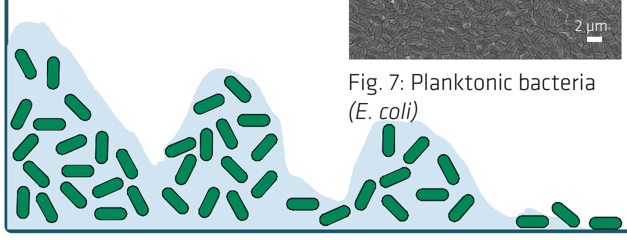


Fig. 7: Planktonic bacteria *(E. coli)*



- Biofilms are bacteria embedded in a self-produced polysaccharide matrix
- Inherently humid: NAP > UHV
- Various model systems (fig 5-7) to assess homogeneity and reproducibility

| | C1: C-C, C-H | C2: C-O, C-N | C3: (N, C)-C=O, O-C-O | C4: COOH |
|---|---|---|---|---|
| Sample a | 39.9±1.4 | 39.4±0.7 | 17.3±0.6 | 3.5±0.0 |
| Sample b | 40.3±0.4 | 37.6±0.6 | 3.75±0.1 | 3.8±0.2 |
| Sample c | 41.8 | 38.3 | 15.3 | 4.6 |

Tab 1: C 1s component area distribution (%) for samples of P. Fluorescens. Average and standard deviation based on three spots for sample a and two spots for sample b.

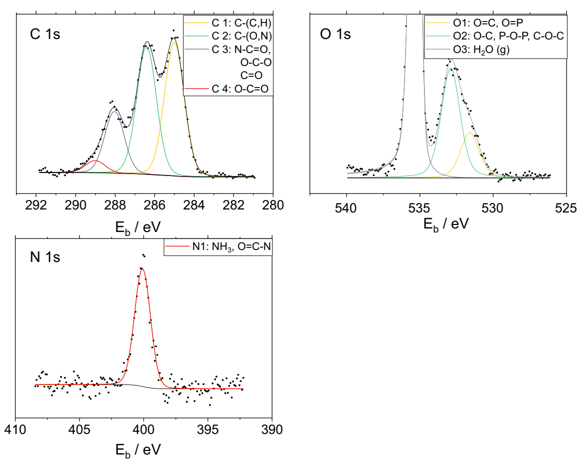



Fig. 8: Representative core level spectra of C 1s, O 1s and N 1s of planktonic *P. Fluorescens* acquired in 15 mbar water vapor

[1] M. Kjærvik et al., J. Phys. Condens. Matter, vol. 29, no. 47, p. 474002, 2017.

[2] M. Kjærvik, K. Schwibbert, P. Dietrich, A. Thissen, and W. E. S. Unger, Surf. Interface Anal., 2018.

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