ENE 019

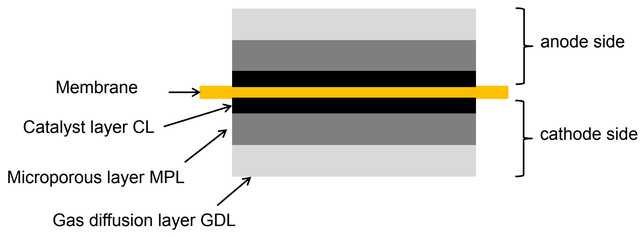
Institute of Technical Thermodynamics

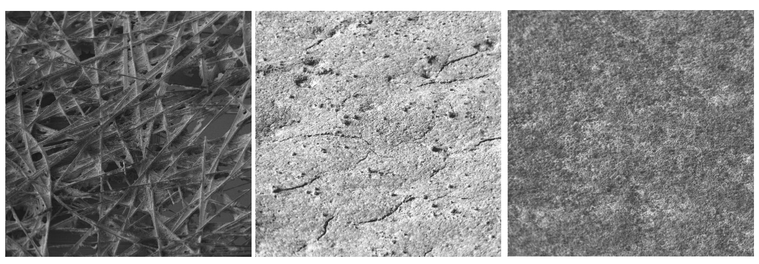
Surface Analytical Methods for the Development of Electrochemical Components of Polymer Electrolyte Fuel Cells

I. Biswas, P. Gazdzicki, M. Schulze
Deutsches Zentrum für Luft- und Raumfahrt, Pfaffenwaldring 38-40,
70569 Stuttgart, Germany

Polymer Electrolyte Fuel Cells

Environmentally friendly energy converters with high gravimetric energy density
→ Fuel cell cars
Combination with water electrolysers
→ Decentral hydrogen power plants
→ Balancing of electric grid
→ Storage of excess energy from renewable sources
→ Distributed hydrogen generation for fuel cell cars
Emission free auxiliary power units





GDL MPL CL
(3x3 mm SEM images)

Requirements to Fuel Cells

Long term stability
Cost efficiency: reduction of Pt
Highly dynamic load flexibility for fuel cell cars and hydrogen power plants

Known Problems

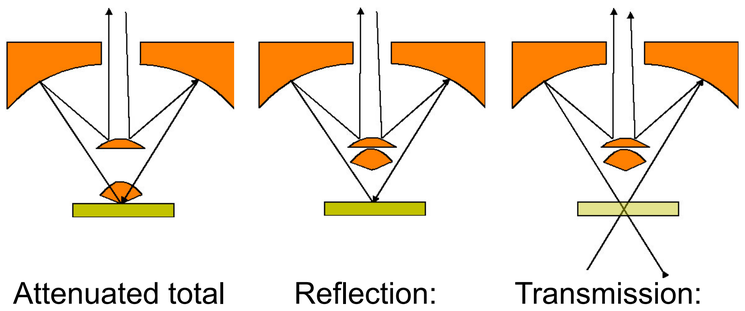
– Water management:
humid membranes ↔ dry GDLs
electrolyte conductivity↔gas transport
– Catalyst degradation:
migration, poisoning, agglomeration
– GDL degradation:
change of hydrophobicity

Requirements to Surface Analytics

– Characterisation of hydrophobicity
– Investigation of outer and inner surfaces of pore networks
– Lateral chemical mapping
– Elemental detection of trace amounts of catalysts
– Elemental distribution of catalysts in layers and in grains

FT-Infrared Absorption Spectroscopy

Molecular vibrations related to dipole moment changes

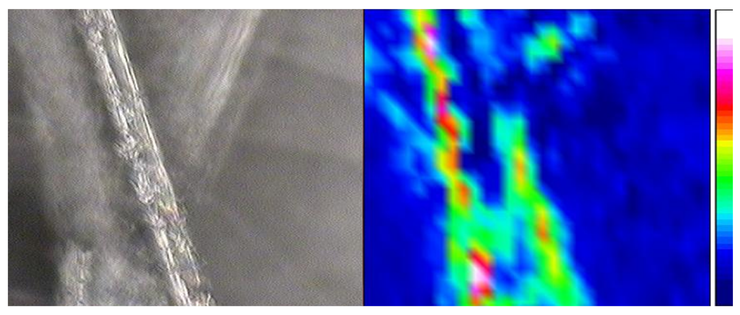


Attenuated total reflection (ATR): ~5 µm surface information, sample contact

Reflection: weak signal on dark samples

Transmission: bulk information, transparent samples, e.g. membranes

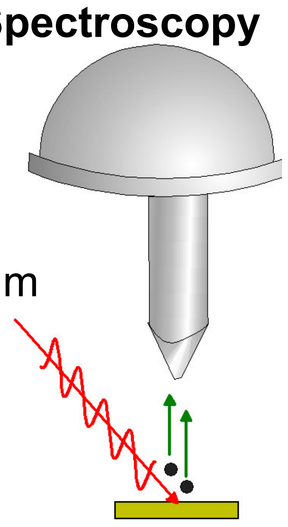
HgCdTe (MCT) detector: res. ~30 µm
+ XY stage -> large scale mapping
Imaging focal plane array (FPA) detector: res. ~1 µm
→ micro scale mapping

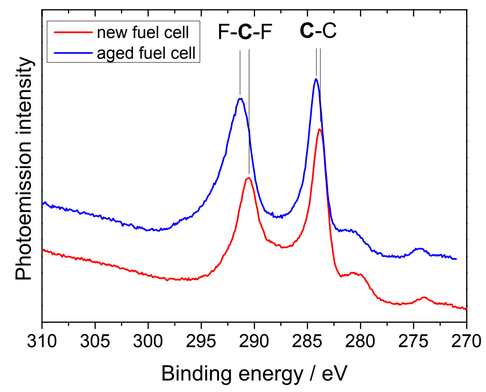


Optical and IR image of GDL focussed in carbon fibre: high PTFE content at edges and gaps (30x30 µm)

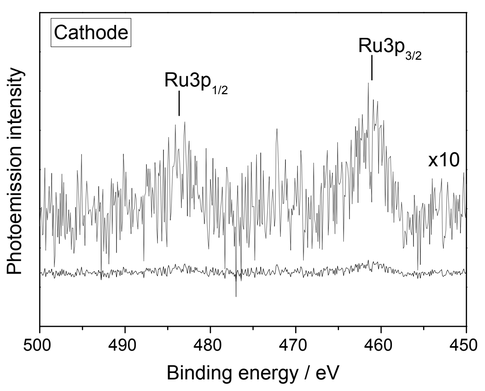
X-ray Photoemission Spectroscopy

Detection of emitted core level electrons
Elemental / chemical information
Surface sensitivity <10 nm





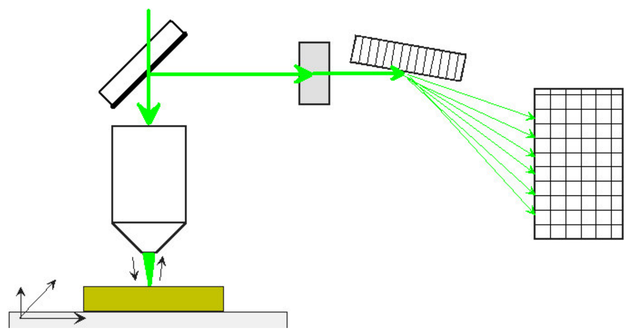
Carbon 1s level spectra of new and aged GDL: reduction of PTFE content → reduced hydrophobicity



Spectrum of Ruthenium traces (<0.5%) in a used electrode

Raman Vibrational Spectroscopy

Molecular vibrations related to polarisability changes
Variable excitation lasers → resonance enhancements, avoidance of fluorescence



XYZ stage → mapping and Z profiling

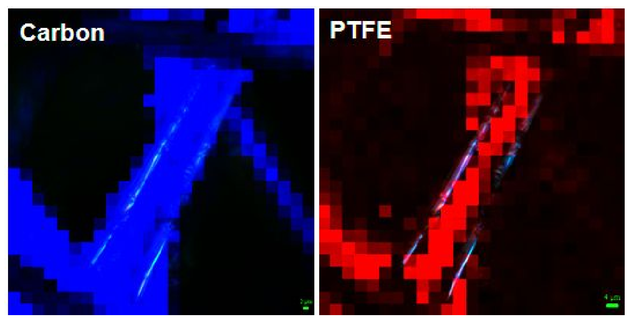
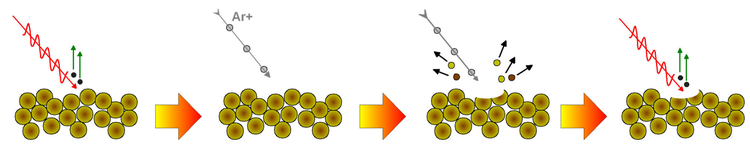
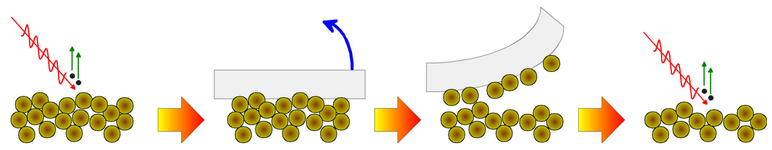


Image of GDL with Raman mapping overlay for C=C vibrations and C-F vibrations: distinction of carbon fibres and PTFE in the gaps (scale: 100x100 µm)

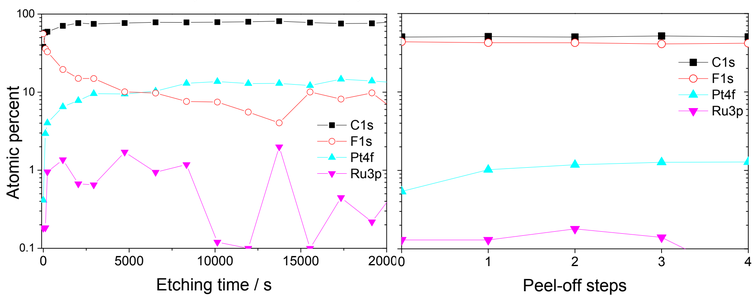
Depth Profiling of Porous Materials



Ion etching → Bulk properties
vacuum conditions necessary



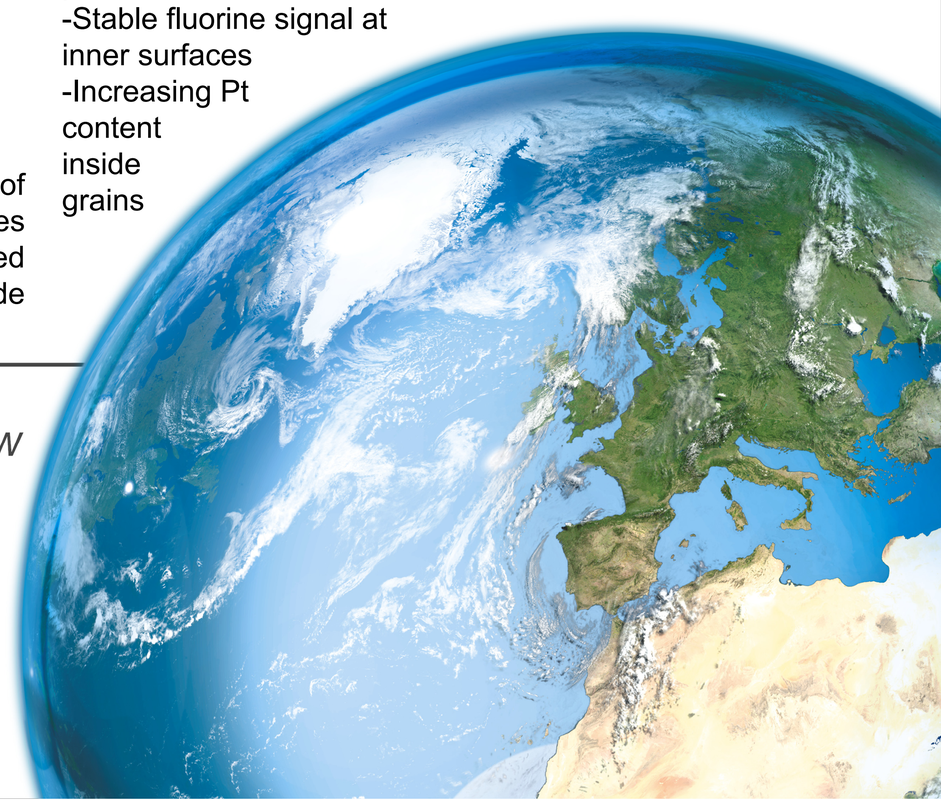
Adhesive tape delamination
→ Inner surfaces of porous materials
ambient conditions → combination with FTIR, Raman, XPS



Ion etching (left) and delamination (right) XPS depth profile of an electrode:
-Stable fluorine signal at inner surfaces
-Increasing Pt content inside grains

Knowledge for Tomorrow

Wissen für Morgen



DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center