UPPSALA
UNIVERSITET

Study of Copper Corrosion in Pure Water

Co-workers:
Prof. R. Berger
Prof. M. Boman
Prof. T. Gustavsson
Prof. L. Nyholm
Prof. G. Westin
Dr. M. Ottosson
Dr. C. Olsson
Dr. M. Klintenberg
Dr. I. L. Soroka

Prof. Yvonne Andersson

Department of Materials Chemistry

Uppsala University

SKB:s referensgrupp möte för kopparkorrosion i syrefri miljö.
Möte 2. Stockholm, Sweden, 7 June 2010

UPPSALA
UNIVERSITET

The Ångström Laboratory

Materials Chemistry

Other Departments at the Ångström Laboratory:
Technology, Physics, Physical Chemistry,
Photochemistry & Molecular Science, Mathematics,

UPPSALA UNIVERSITET

Materials Chemistry

Syntheses of new compounds and materials

Thin films

Nano-sized particles

Bulk

Characterization

X-ray diffraction

electron microscopy

Electrochemical methods

ESCA

Raman spectroscopy

UPPSALA UNIVERSITET

Copper corrosion in water

- The process of metal corrosion in pure water accompanies by hydrogen gas evolution: $Me+H_2O \leftrightarrow Me^{+}+H_2\uparrow$
- In the experimental study (*Hultquist, Corr.Sci.1986*) it was assumed that copper corroded to Cu_2O according to: $2Cu+H_2O \rightarrow Cu_2O+H_2\uparrow$
- The reaction was further modified (*Szakalos et.al. Electrochem Solid State Lett. 2007*) to:

$$Cu+yH_2O \rightarrow H_xCuO_y+(2y-x)H_{ads}$$

UPPSALA UNIVERSITET

Calculation of Cu corrosion rate from hydrogen evolution

- *Hultquist, Corrosion Science **26**, 173–176 (1986).*

  0.98 μm/year or **9.8 cm**/100 000 years

- *Szakálos et.al, Electrochemical and Solid-State Letters **10**, C63–C67 (2007)*

  10^{-5}cm/year or **1 cm**/100 000years

- *Hultquist, Catal. Lett. **132**, 311-316 (2009).*

  3.7 nm/year or **0.037 cm**/100 000 years

UPPSALA UNIVERSITET

Experimental

Sample preparation: Cu 99.95% purity

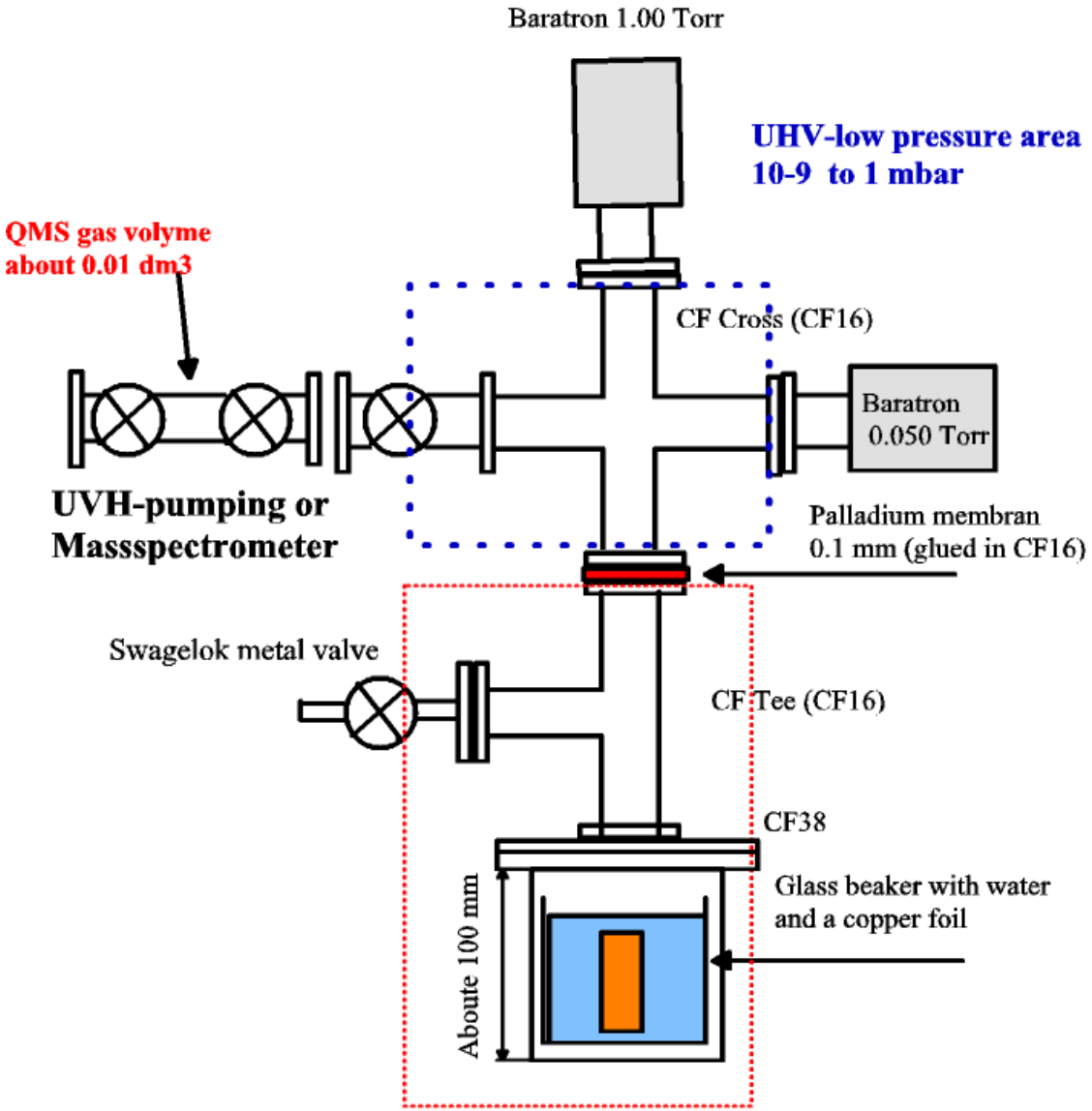
1. Mechanically polished
2. Electrochemically polished

Three experimental set-ups:

1. Milli-Q water
2. Cu in water
3. Cu in diluted acid

UPPSALA
UNIVERSITET

Vacuum system for measurements of hydrogen production during Copper corrosion.



UPPSALA UNIVERSITET

Factors, which may influence the detection limit of H_2

- UHV system leaks (external and interior)
- Outgassing rate of UHV components (chambers, glue)
- Palladium membrane
- Cu metal surface can catalyze hydrogen development

UPPSALA UNIVERSITET

Experimental methods to study Cu corrosion products

- The thickness of the surface layer as well as its composition can be studied by **XPS (ESCA)** analysis.
- **ICP-MS** to measure trace amounts of elements in the water. The detection limit for Cu in solution is 2×10^{-11} g/mL.
- **GD-OES** (Glow discharge optical emission spectrometry) to study hydrogen concentration gradients in Cu.
- **FTIR** (Fourier Transform Infrared Spectroscopy) and **SERS** (Surface Enhanced Raman spectroscopy) to detect the O-H, Cu (I)-O, Cu(II)-O etc. vibrations.
- **GI-XRD** (X-ray diffraction and grazing incidence X-ray studies)
- **pH** of the water solution will be controlled after immersing the Cu foil into the water
- Soft X-ray analysis (**XAS** and **XES**).