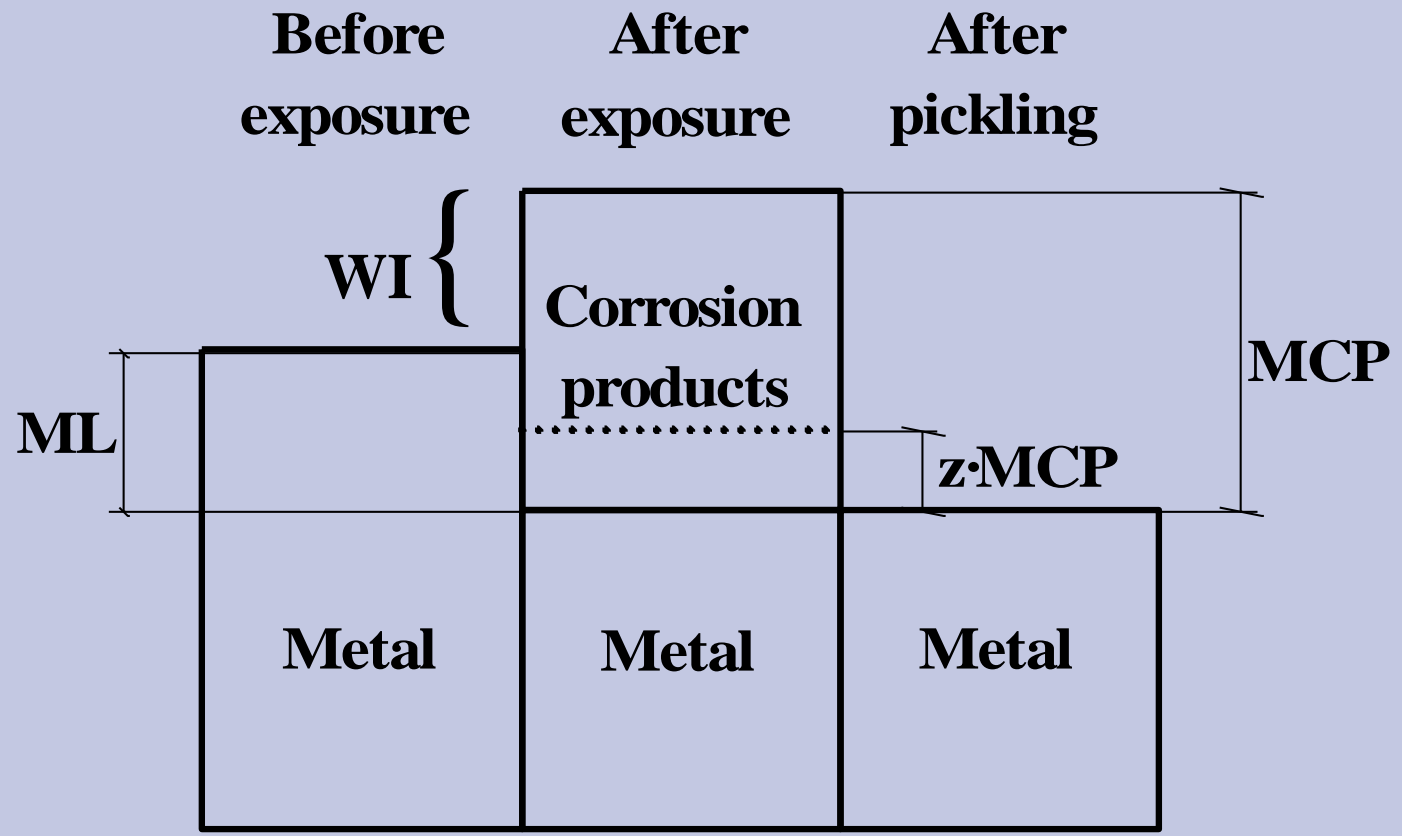


Evaluation of corrosion attack for metals

Basic and more advanced techniques

Two principal ways to quantitatively assess corrosion attack gravimetrically



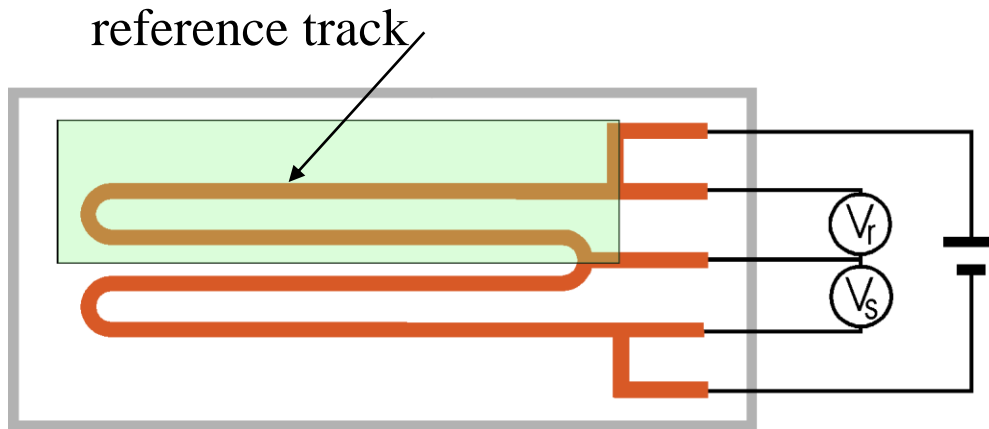
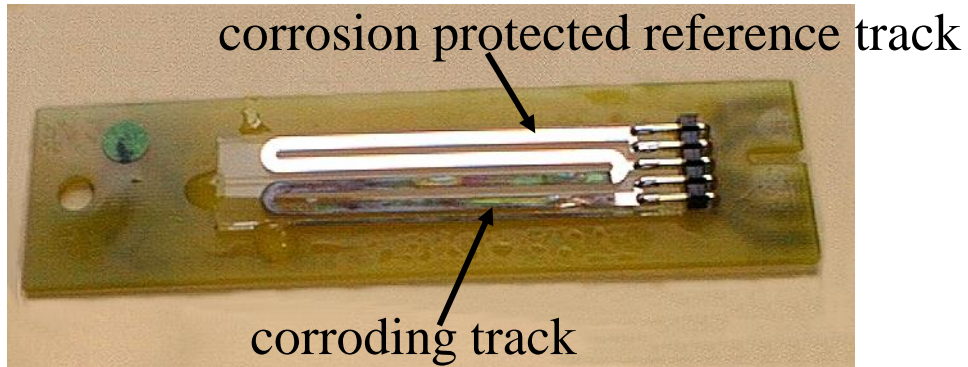
WI – weight increase

ML – mass loss = corrosion attack = standard method

Quantitative techniques

- Mass Loss (ML)
 - Normal balance, standard 10 x 15 cm samples (outdoor)
 - Microbalance, small 1 x 5 cm samples (indoor)
 - Resistance sensors
 - Cathodic reduction (only copper and silver)
- Weight Increase (WI)
 - Normal balance, standard 10 x 15 cm samples (outdoor)
 - Microbalance, small 1 x 5 cm samples (indoor)
 - Quartz Crystal Microbalance (QCM)

Resistance sensors



Corrosion =

$$= t_i \cdot \left(1 - \frac{R_{ref}}{R_s} \cdot \frac{R_{i,s}}{R_{i,ref}} \right)$$

Quartz crystal sensors



$$\Delta f = - \left(\frac{f_0^2}{N \cdot \rho_q} \right) \cdot \Delta m$$

Δf = change in frequency, f_0 = resonance frequency

N = frequency constant (1670 kHz mm for a transversal wave in AT-cut quartz)

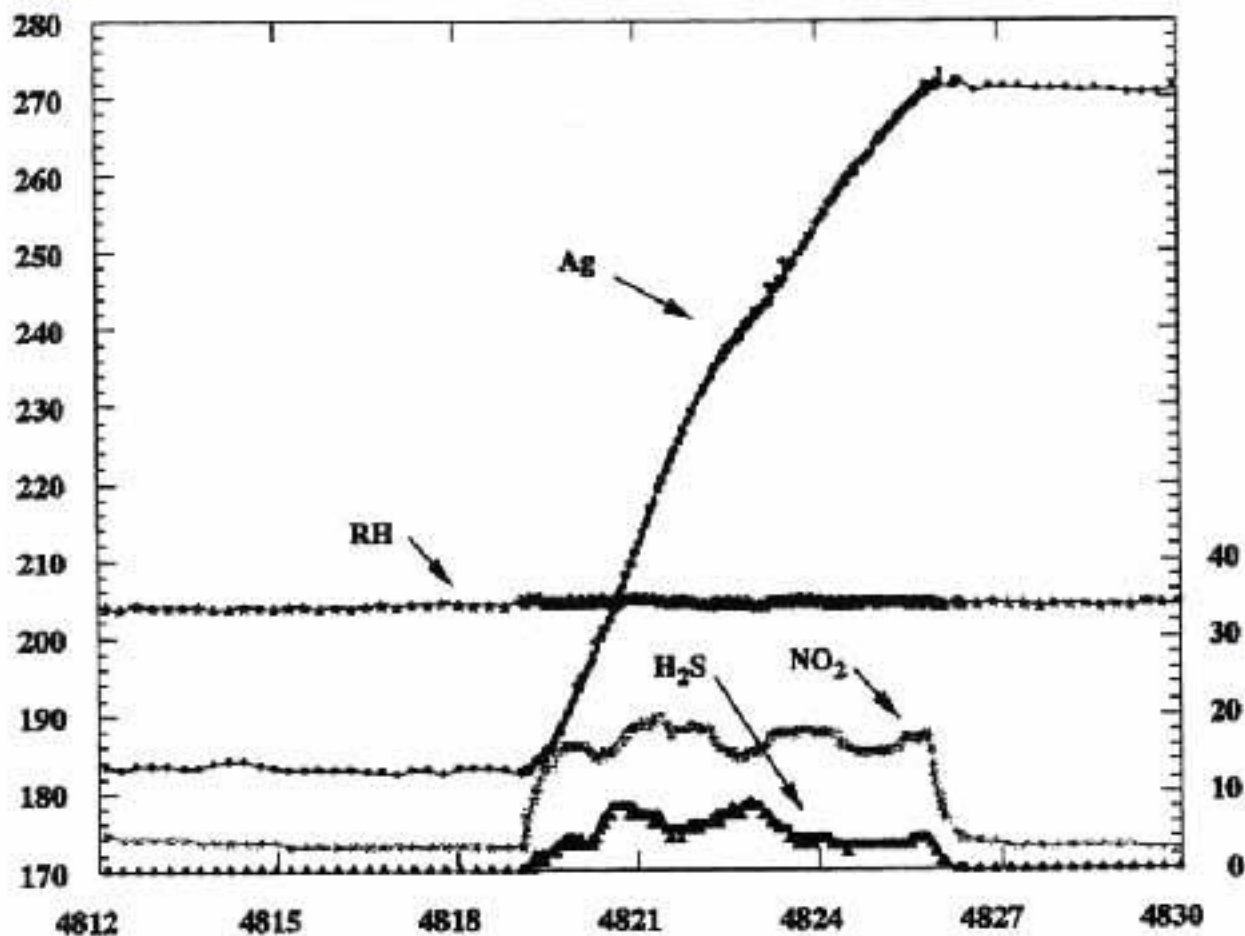
ρ_q = density (2,648 g/cm³ for quartz)

Δm = mass change/area, assuming film growth on one side of the crystal

*Mass respons
of Ag vs. time
during a
simulated
malfunction
of the air
filter system
in an electrical
control room.*

Δm (ng/cm²)

Conc. (ppb), RH (%)



Time (h)

On-line corrosion monitoring of indoor atmospheres

Quartz crystal microbalance

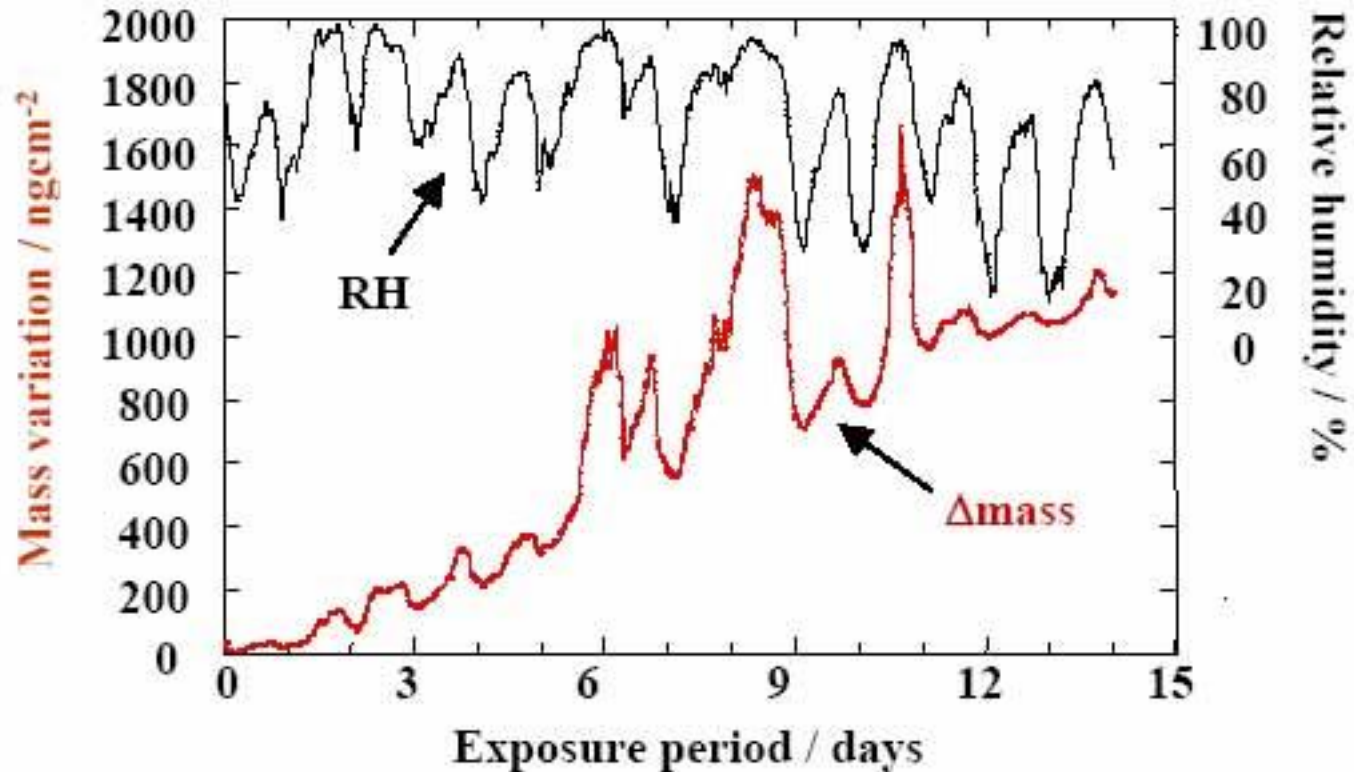
- used in practice
 - metals subject to even corrosion only
 - sufficiently sensitive for indicating changes
- mechanically vulnerable
 - affected by temperature
- affected by humidity
- affected by dust etc.
- signal disturbances

Electrical resistance sensors

- not as common under atmospheric conditions
- slightly vulnerable
- unaffected by humidity
- unaffected by dust etc.
- large spread in results

Electrical resistance sensors considered most promising,
improvement necessary for corrosivity classification use

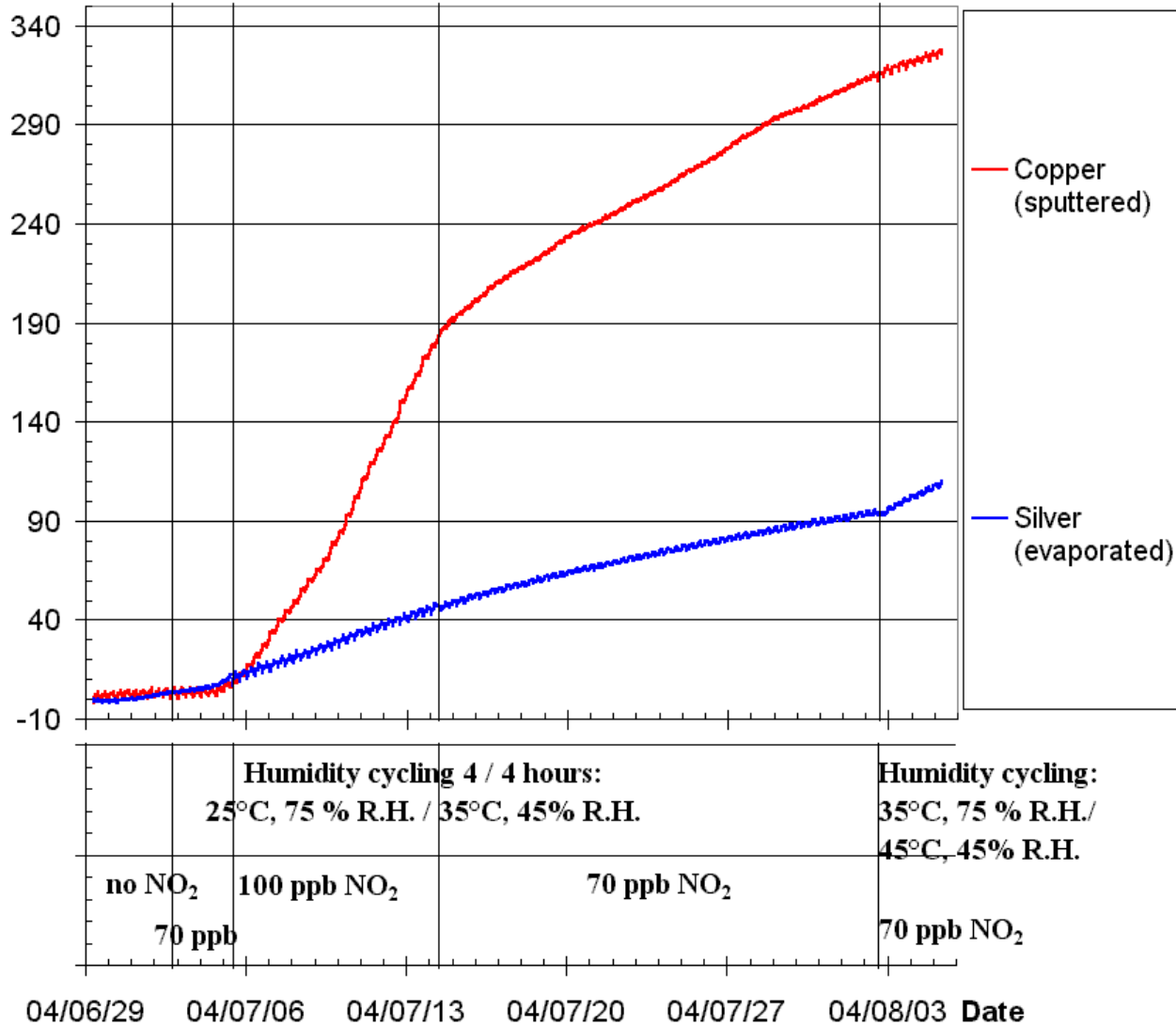
The water adlayer.



Mass and relative humidity variations during outdoor exposure of gold, based on the quartz crystal microbalance.

- Corrosion sensors

Corrosion (Å) Corrosion logger results, copper and silver sensors



More advanced techniques



Experimental techniques for analysis of indoor corrosion effects.

Technique

Microgravimetry
Cathodic reduction
Quartz crystal microbalance
Atomic force microscopy
X-ray photoelectron
spectroscopy
Infrared reflection
absorption spectroscopy
Kelvin probe

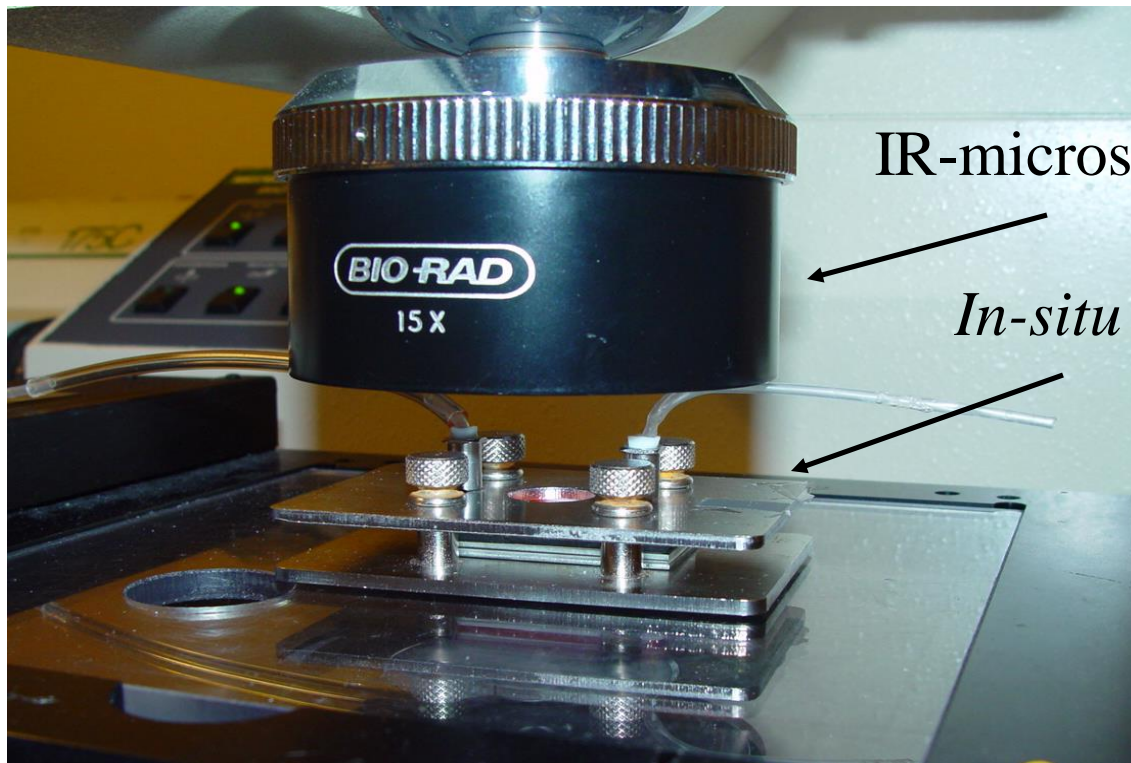
Information measured

Mass change, sensitivity 10 mg/m^2
Mass of corrosion products, 5 mg/m^2
Mass change, 0.2 mg/m^2
Surface morphology
Surface chemical composition

Surface chemical composition

Volta potential

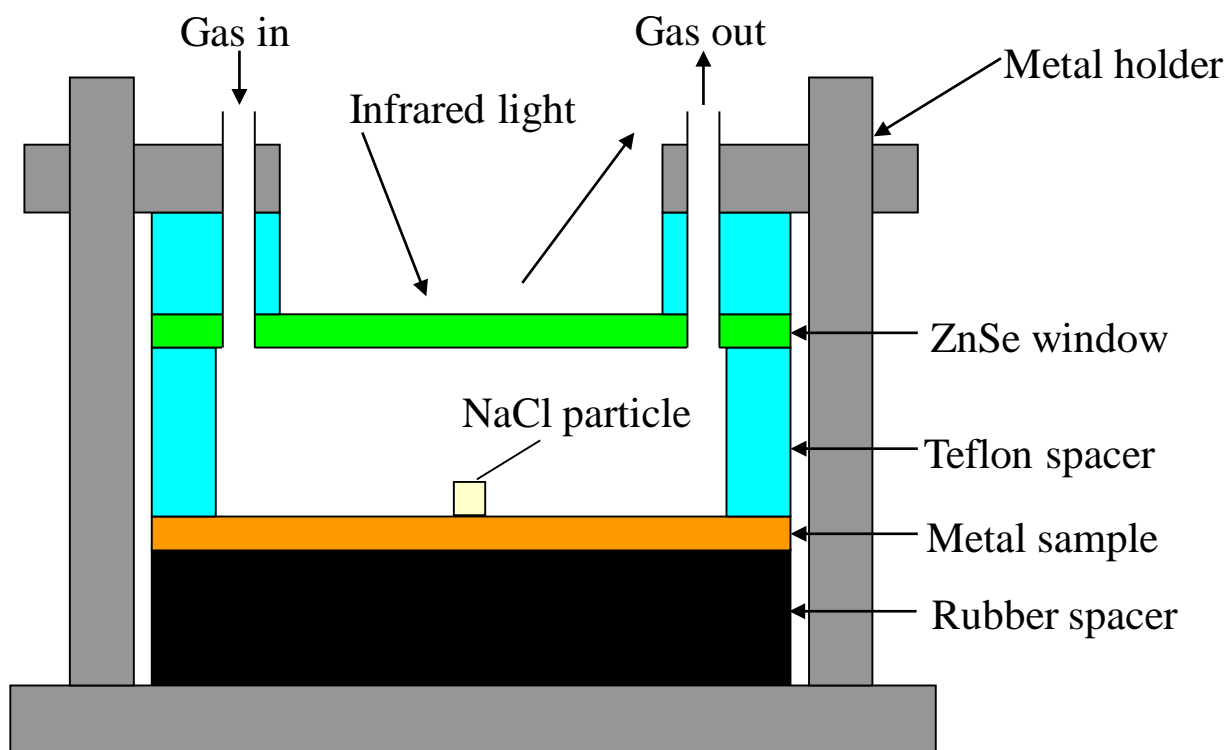
In-situ FTIR-microspectroscopy



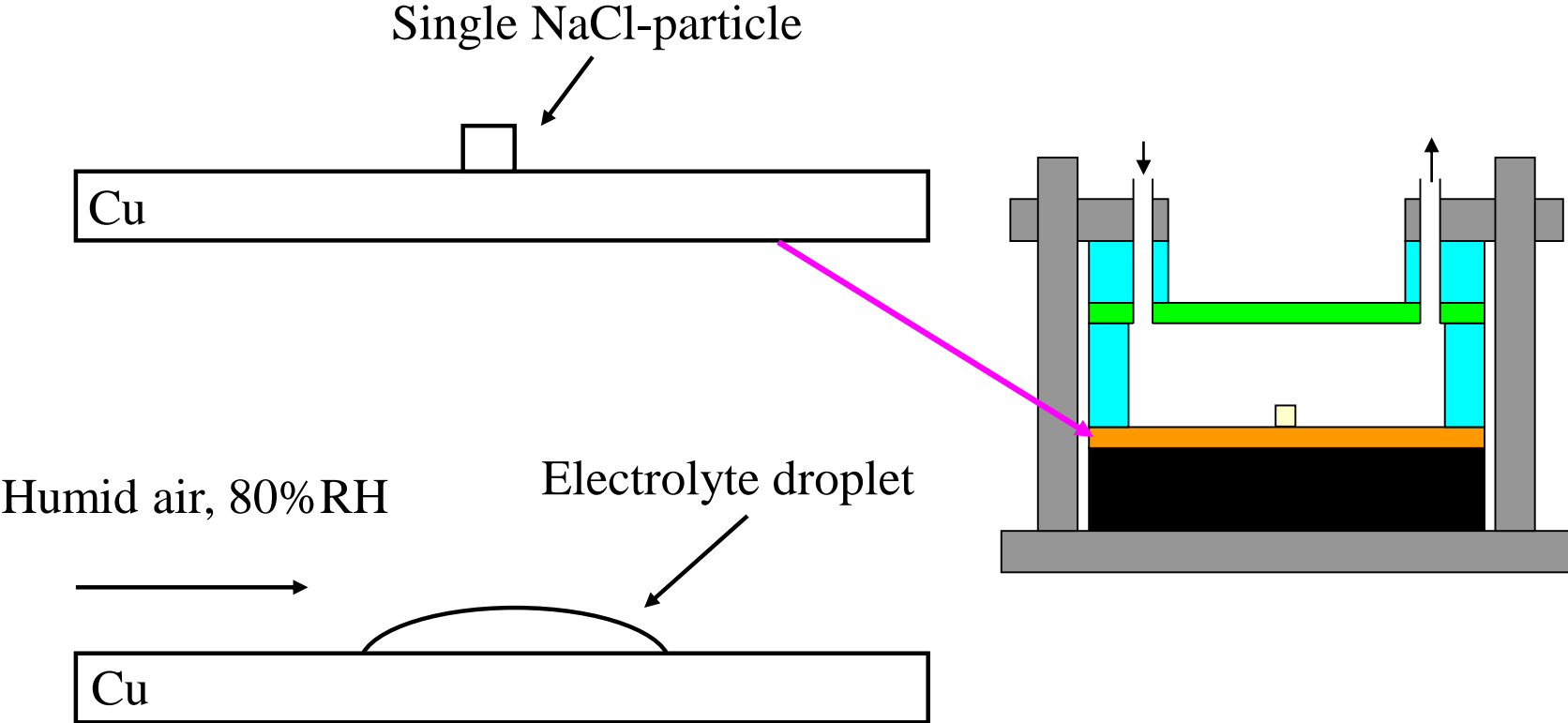
IR-microscope objective

In-situ experimental set-up

Schematic drawing of the newly developed experimental set-up for *in situ* FT-IR microspectroscopy



Schematic illustration of the model experiment

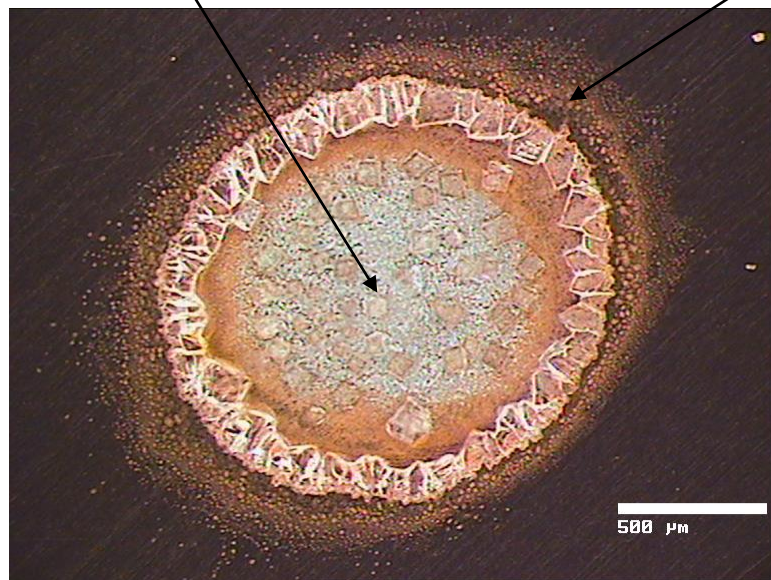


RH: $80 \pm 2\%$; Exposure time: 6 hours.

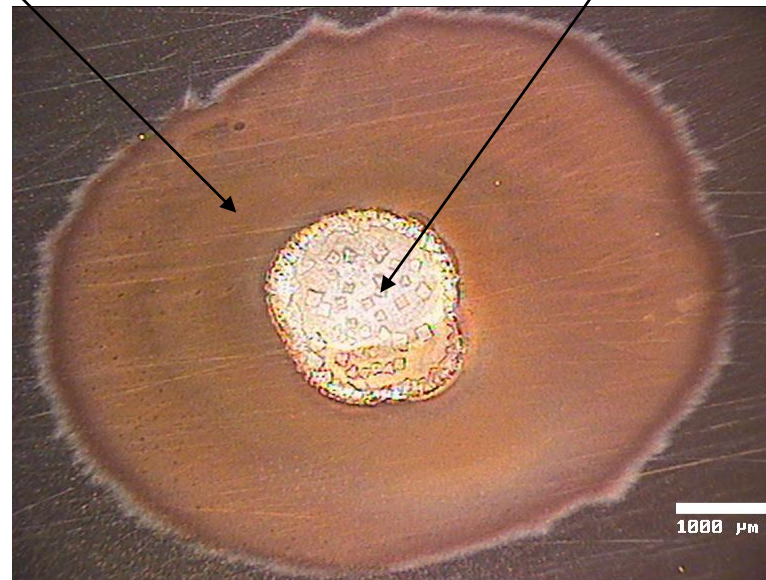
Original water droplet

Secondary spreading area

Original water droplet



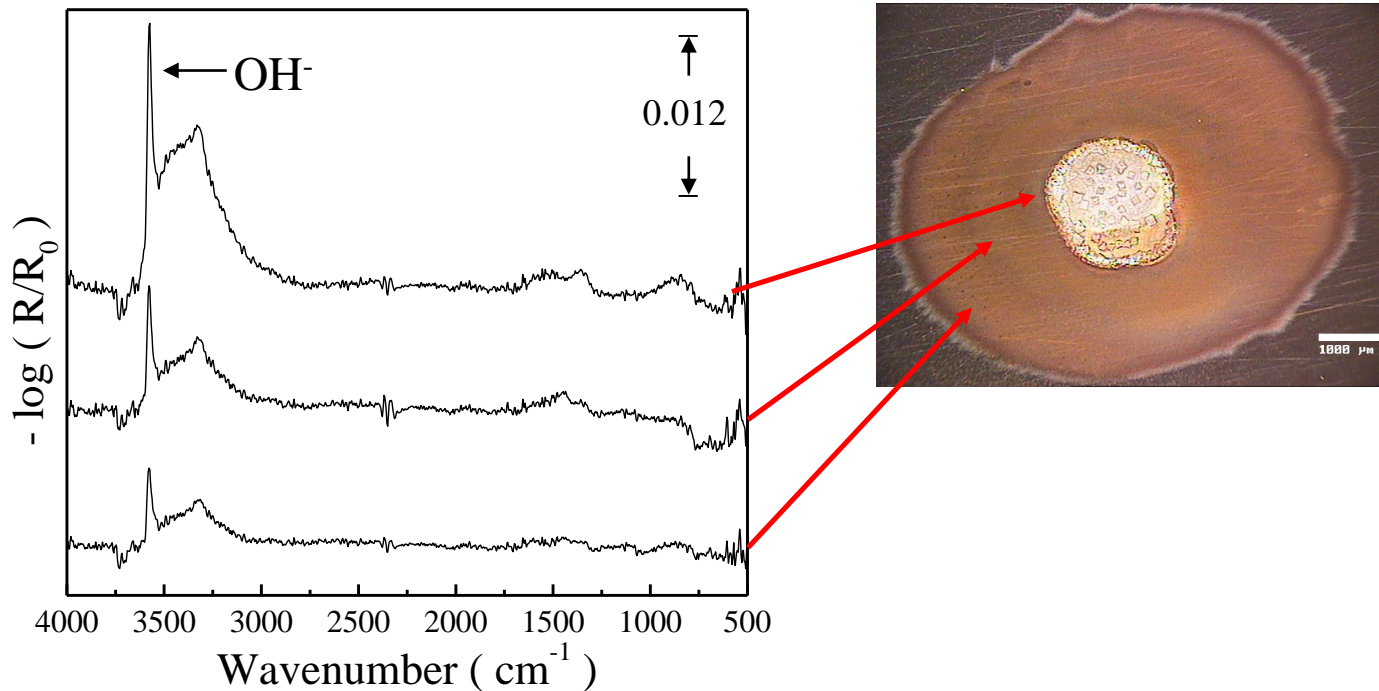
350 ppm CO₂



< 5 ppm CO₂

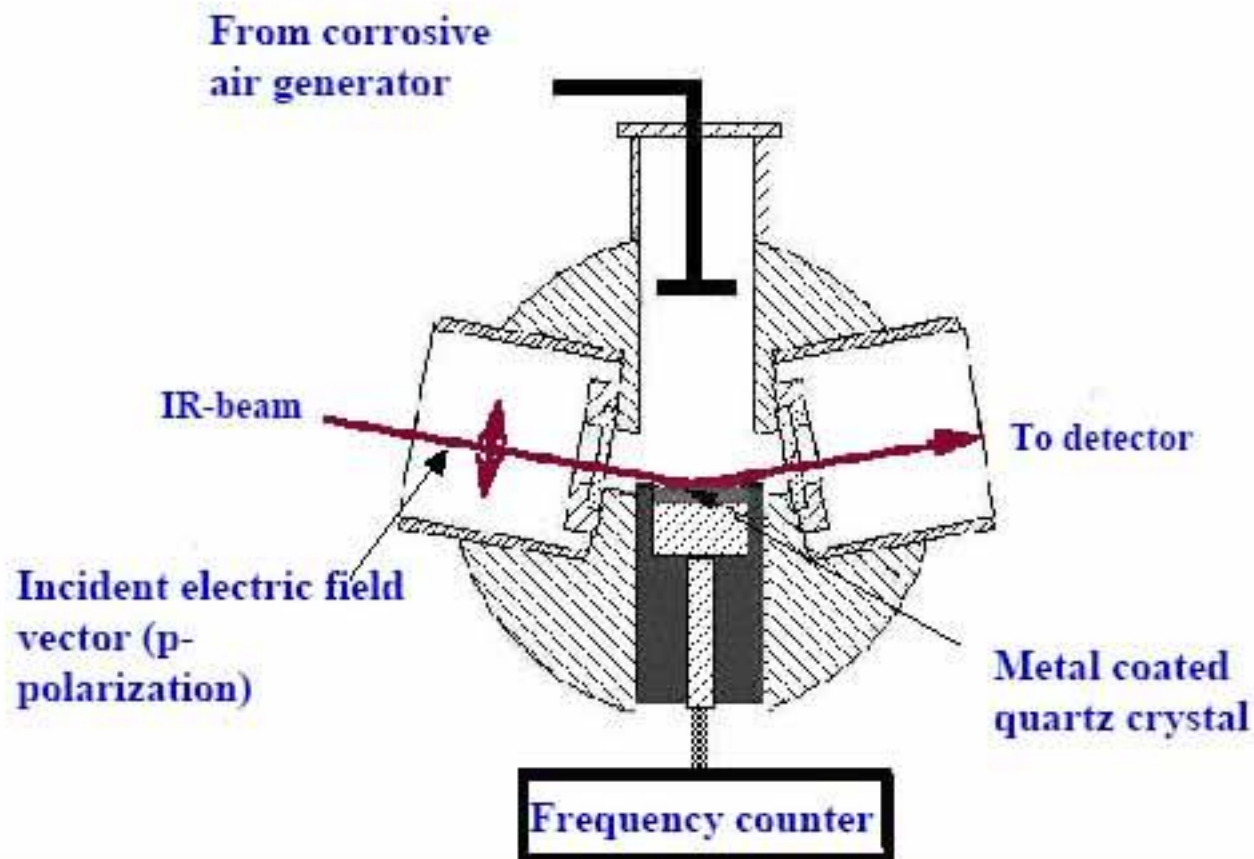
- A secondary spreading effect was observed outside the original water droplet, which was much larger at <5 ppm CO₂ than at 350 ppm CO₂.

Ex situ FT-IR microspectra obtained at the secondary spreading area.
(RH: $80 \pm 2\%$; $< 5 \text{ ppm CO}_2$; Exposure time: 6 hours.)

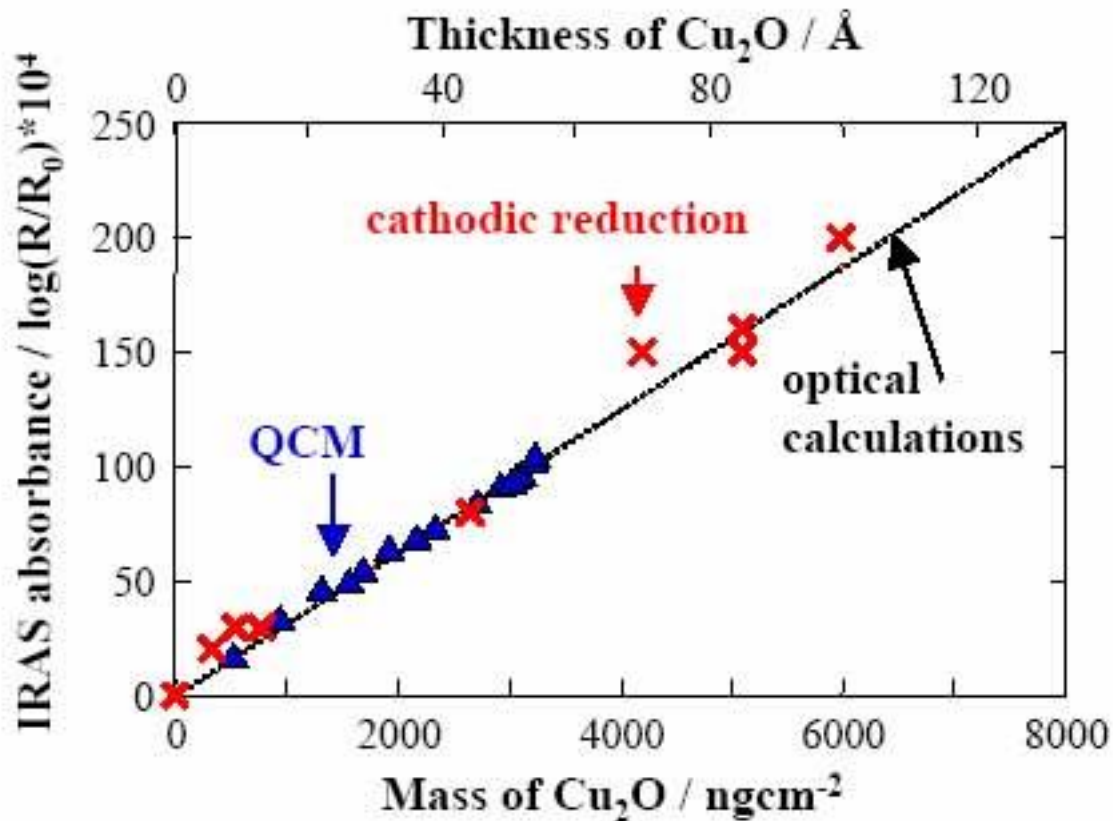


- Hydroxyl ions (OH^-) were formed in the secondary spreading area due to the cathodic reaction.

Combined IRAS and QCM.



Correlation between IRAS absorbance and mass of Cu_2O , based on three techniques.



Mass change and surface species on Cu in humid air, SO_2 and O_3 - based on IRAS/QCM.

