Evaluation of the environmental impact on metal artifacts using electrochemistry and grazing incidence XRD

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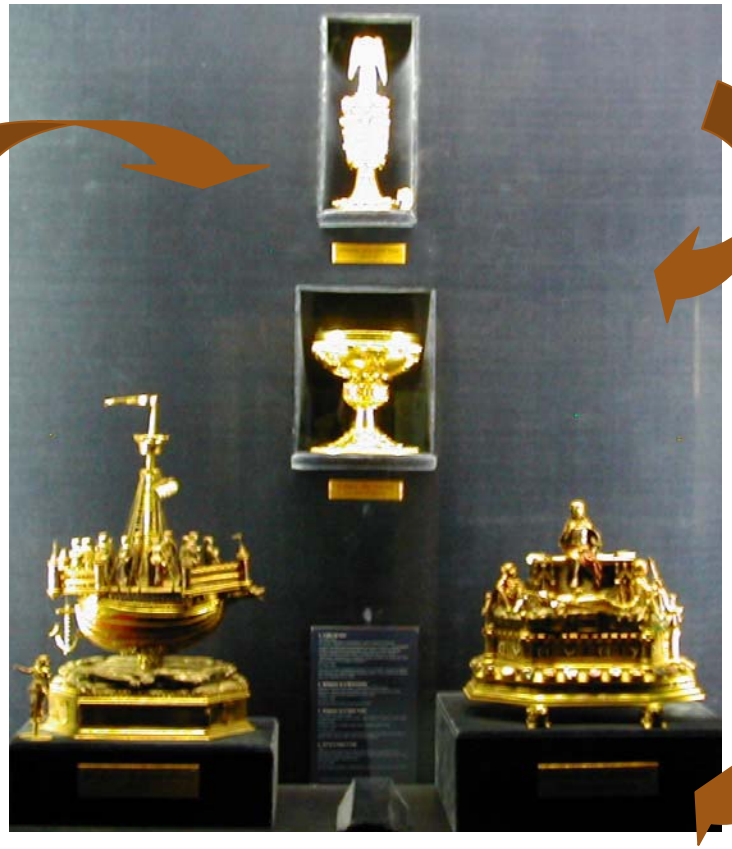
(cup Sn-Pb / wood showcase)

ancient bronze / new rubber floor

NO_x, SO_2, H_2S, COS, CH_3COOH, HCOOH



particulate matter

relative humidity

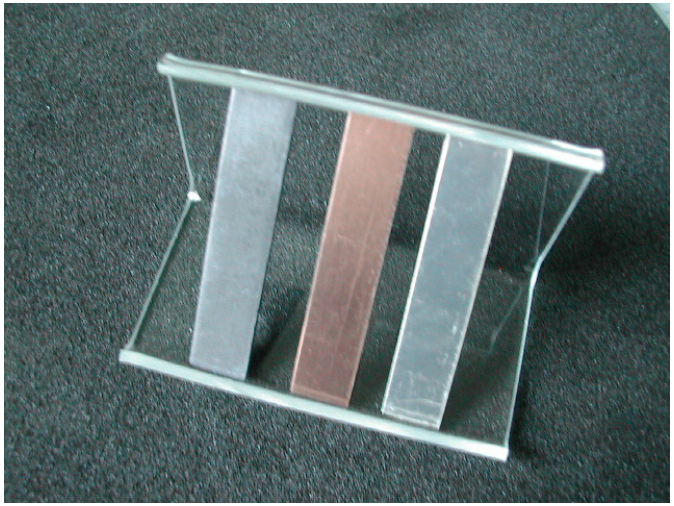
Synergy of environmental factors

limits?

damage to materials?

⇒

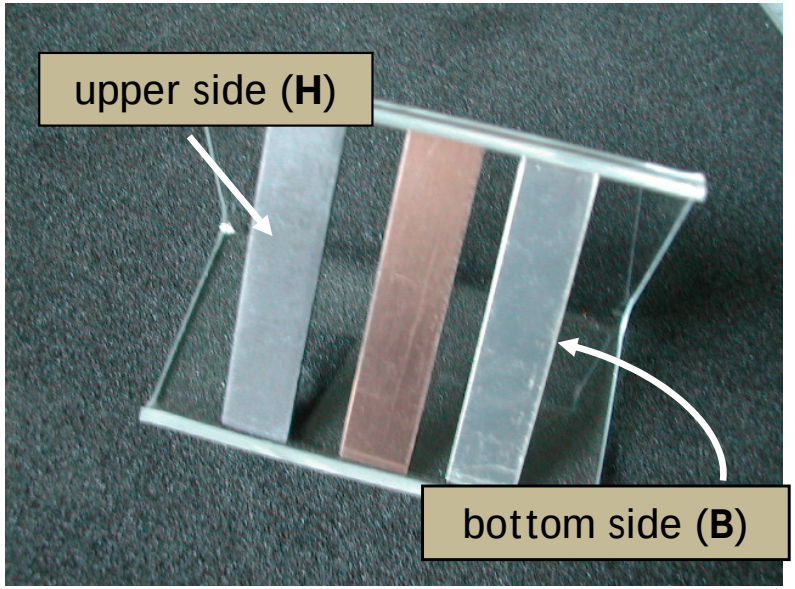
exposure of metallic coupons

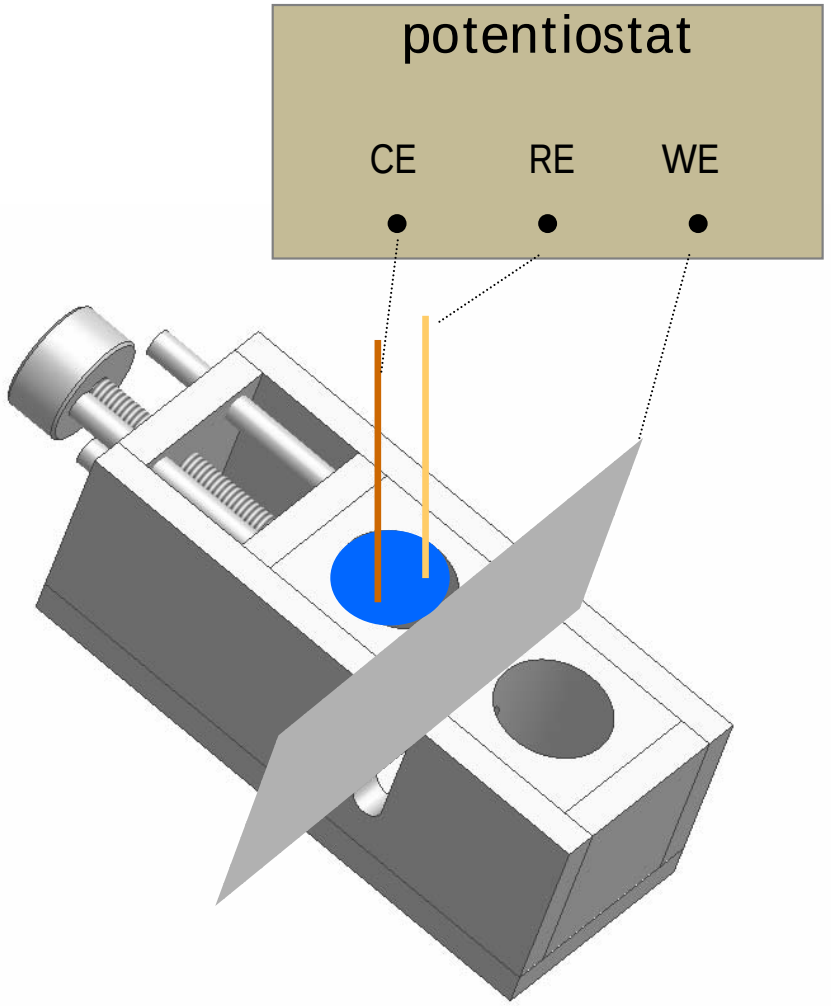



quay branly


Notre
Dame
de
Paris


Chateau
Dieppe

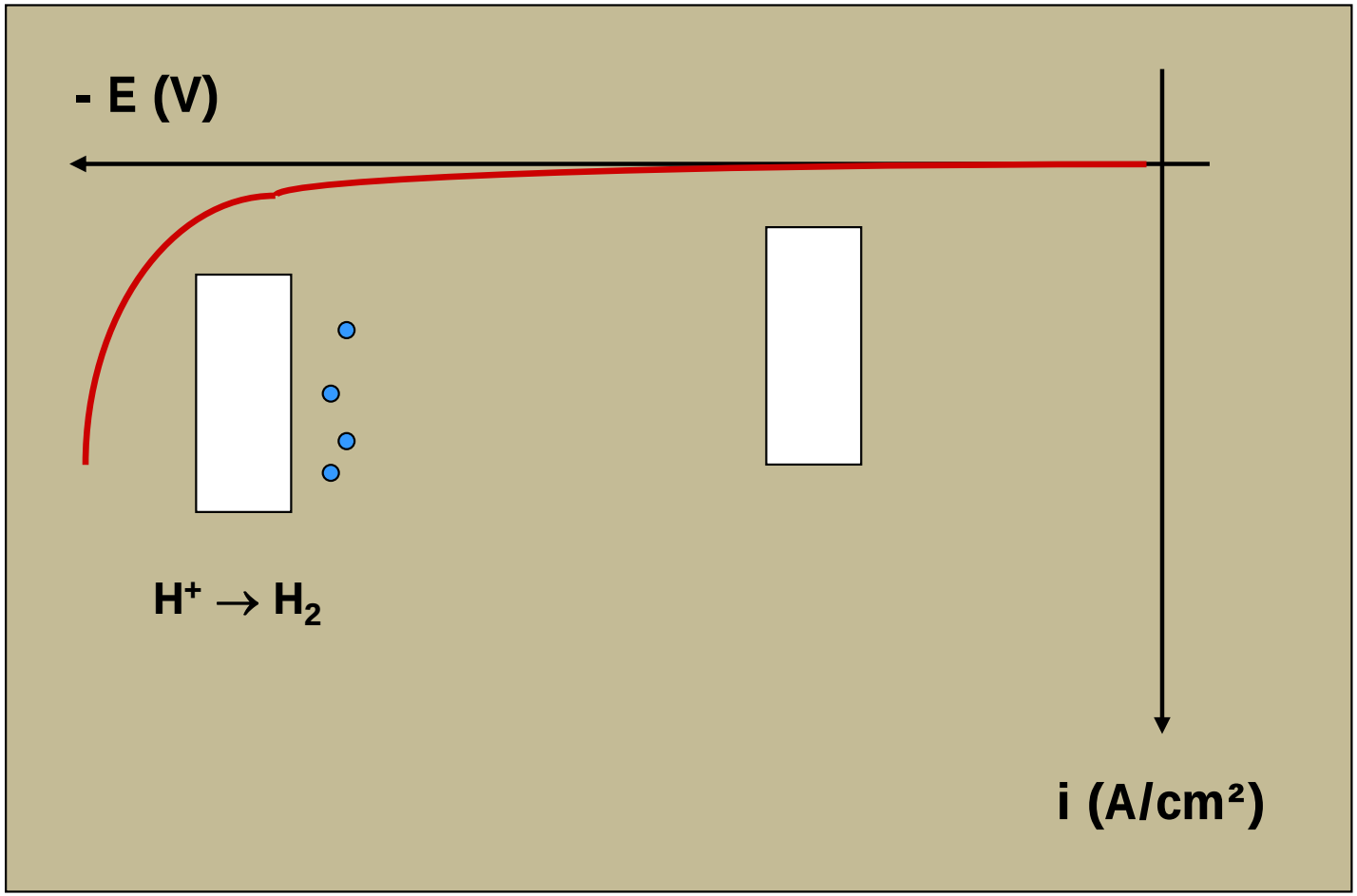


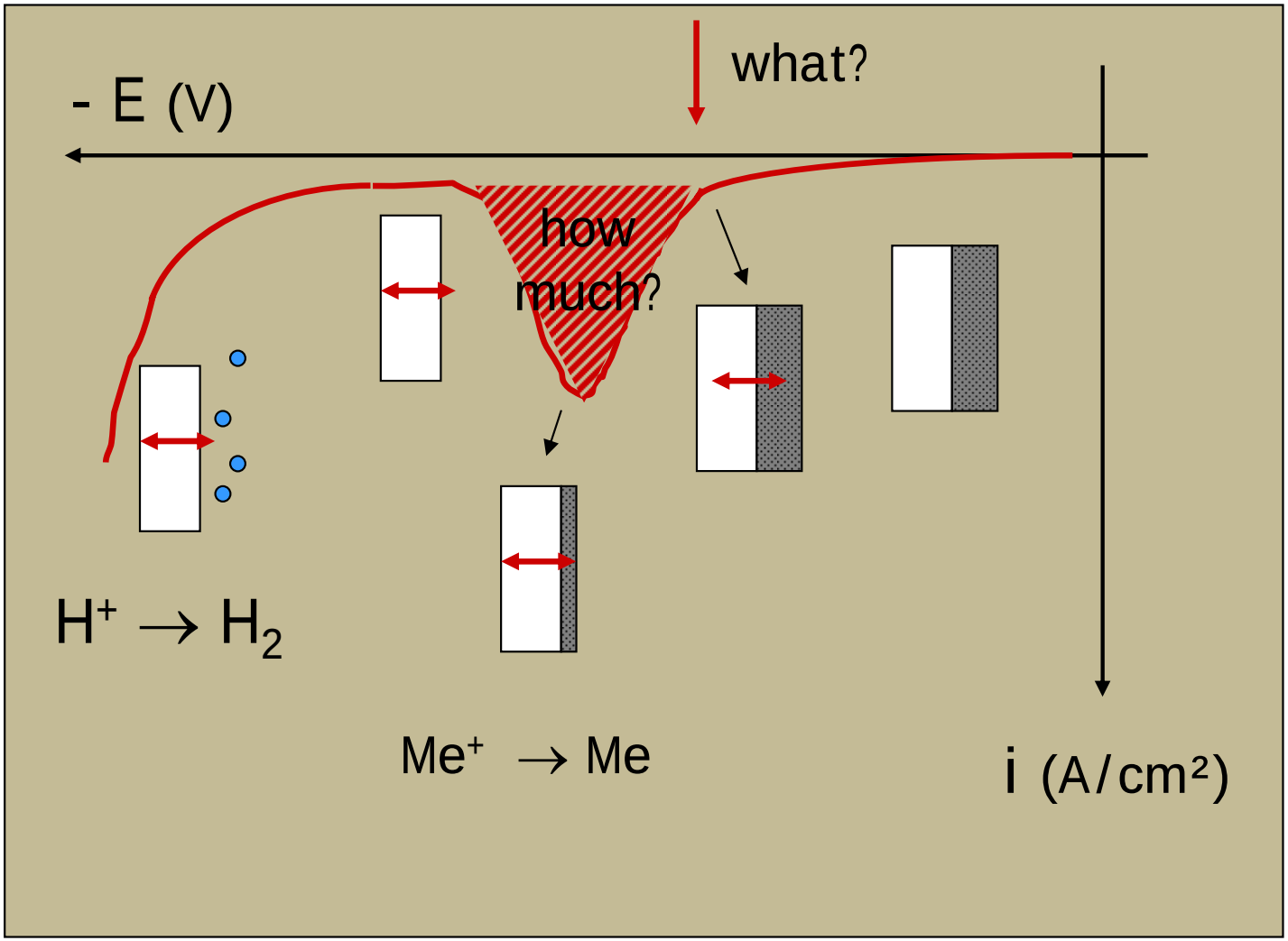


3-electrode arrangement

$i = f(E)$

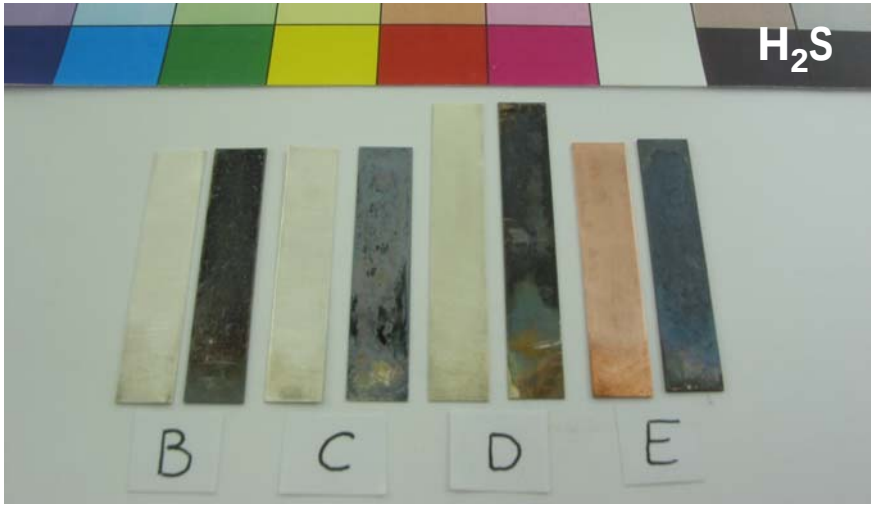
reduction of surface products: apply $-E \Rightarrow$ measure i

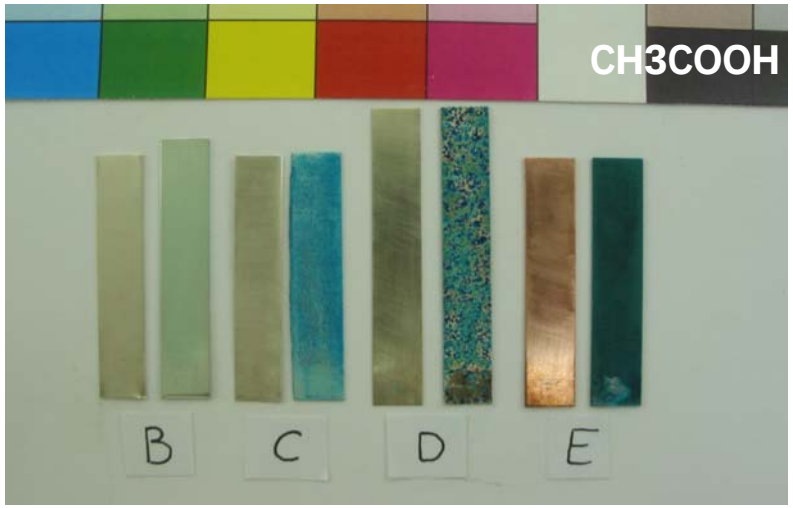

- E (V)
$H^+ \rightarrow H_2$
i (A/cm²)

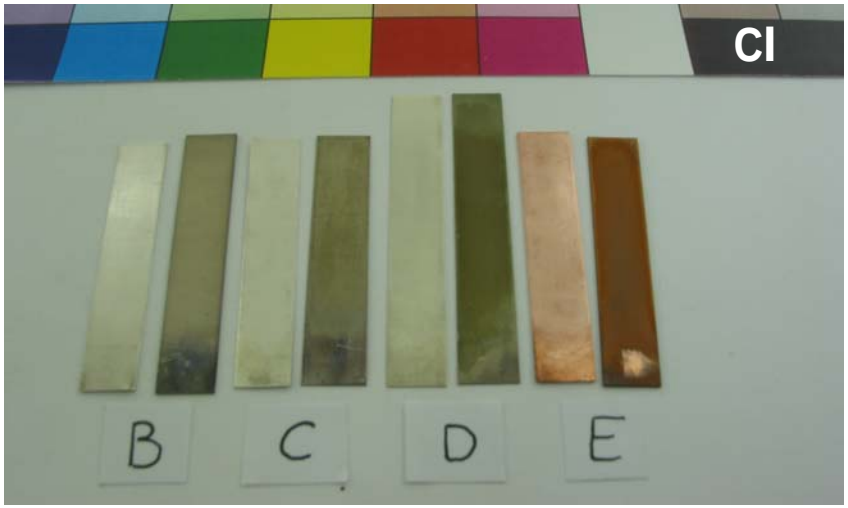


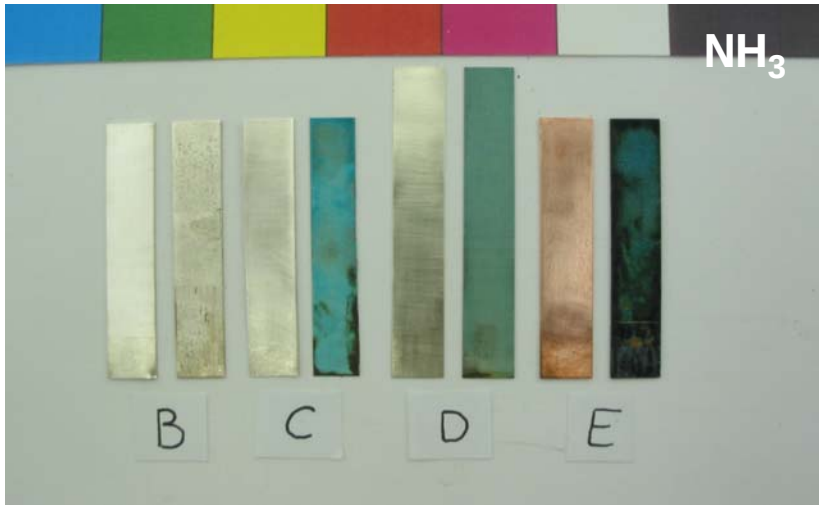
= i x t = charge (C) ⇔ mass (g) ⇔ tarnishing rate

how to assign a peak to a given compound?

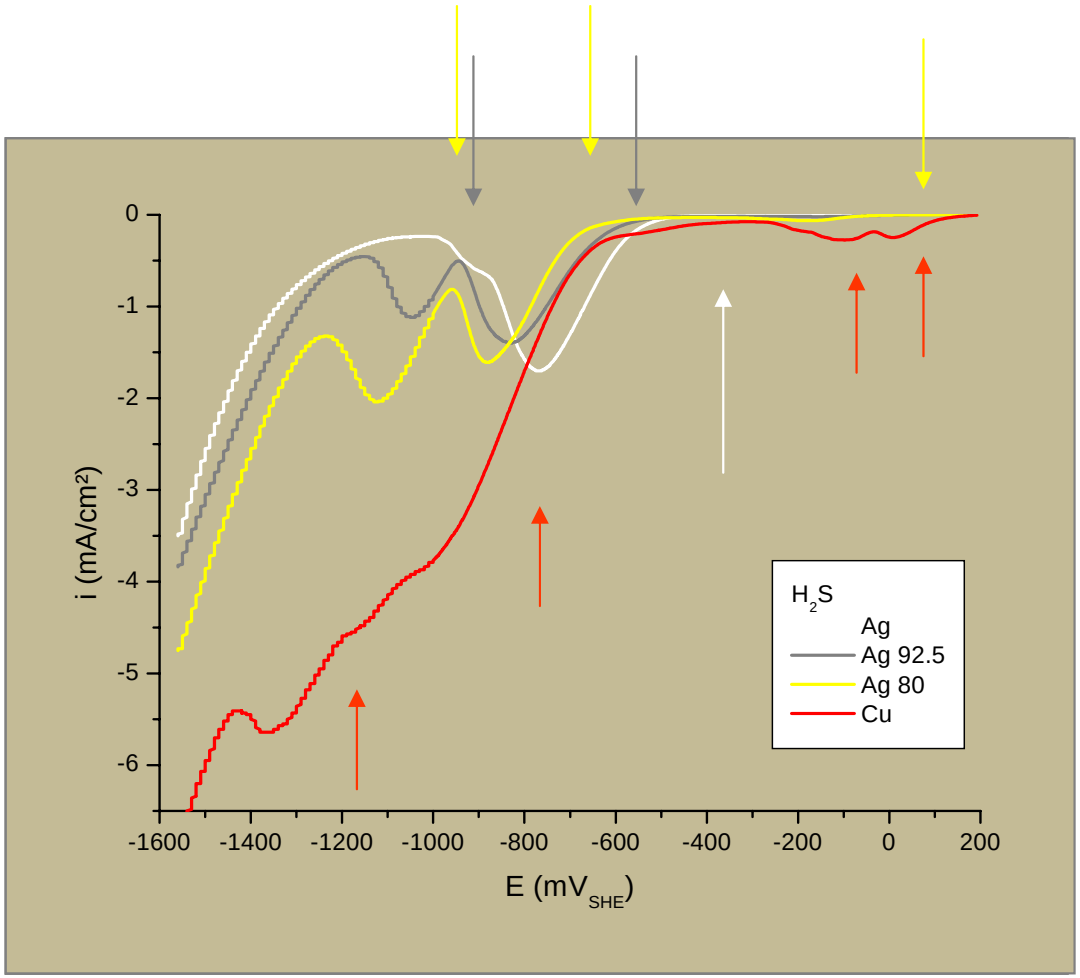








reduction curves



XRD

Ag_2S

Ag_3CuS_2 (jalpaite) 72:14:14

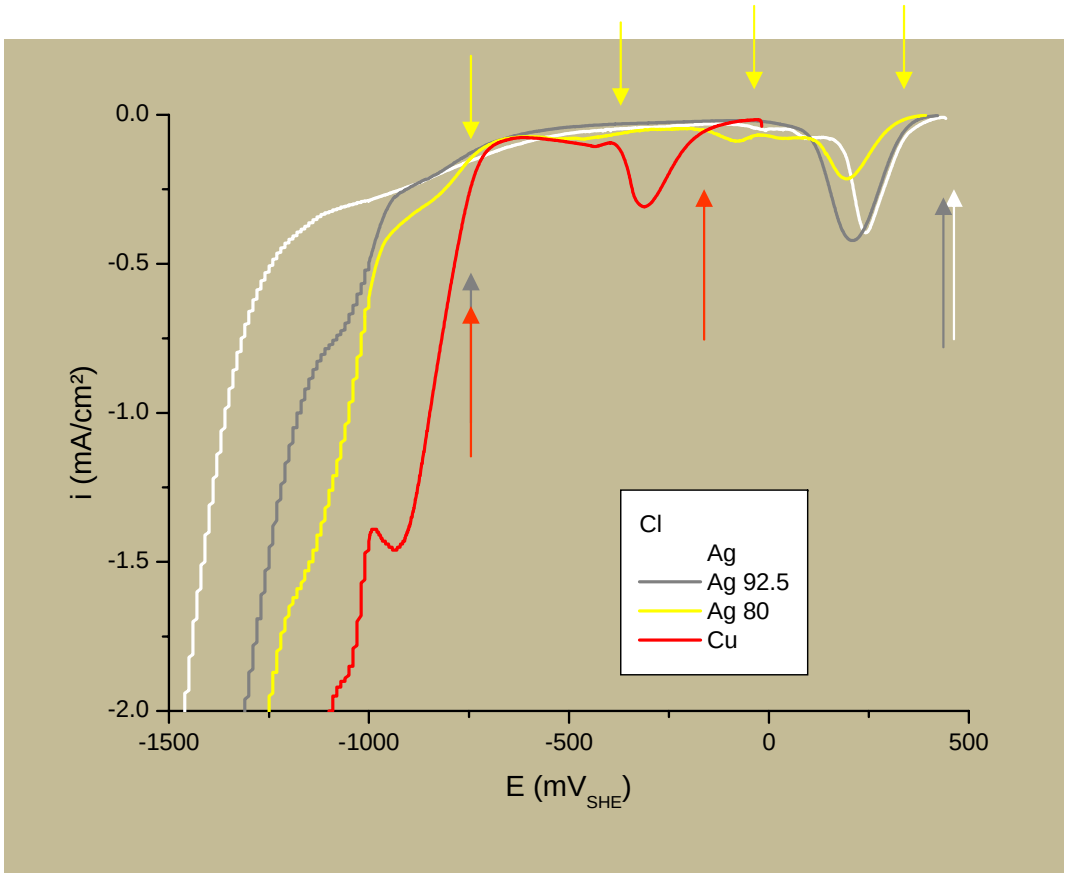
$(Ag,Cu)_2S$ (mckinstryite) 61:24:15

$(Ag,Cu)_2S$ (mckinstryite)

AgCuS (stromeyerite) 53:31:16

Cu_2O

reduction curves



XRD

AgCl

AgCl

$Cu_2(OH)_3Cl$ clinoatacamite

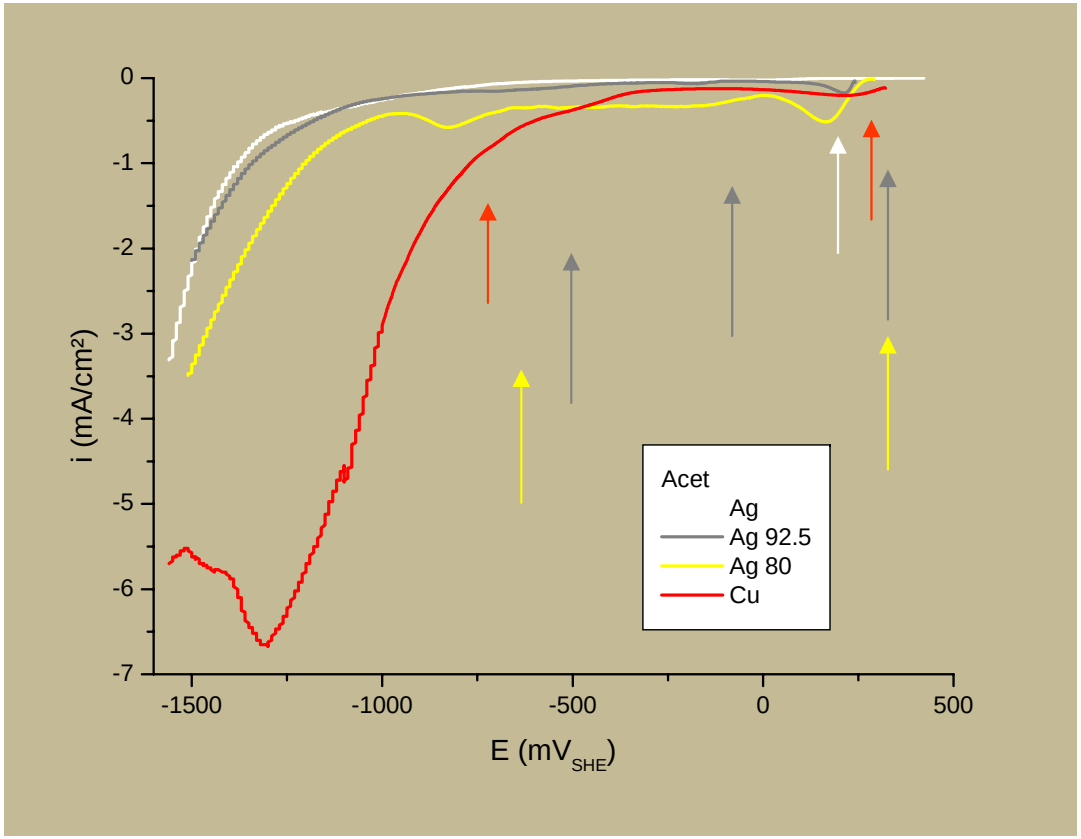
AgCl

$Cu_2(OH)_3Cl$ clinoatacamite

$Cu_2Cl(OH)_3$ atacamite

CuO

reduction curves



XRD

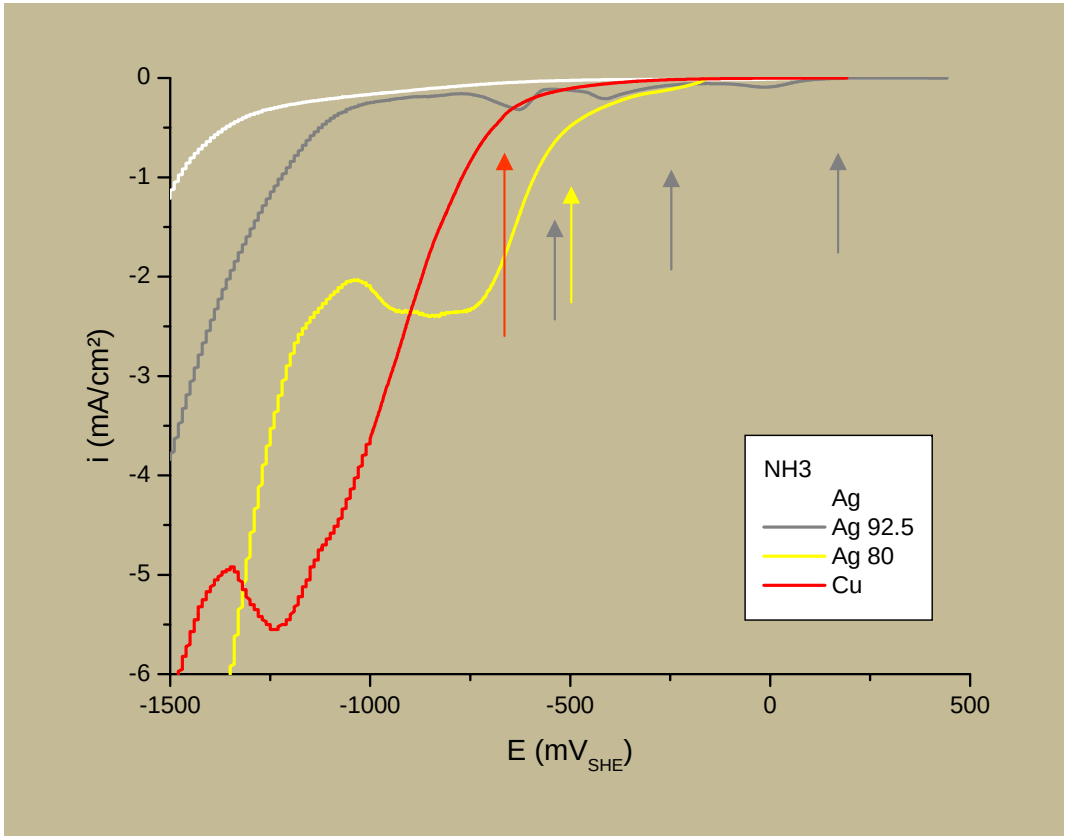
$(CH_3COO)_2Cu.H_2O$

$(CH_3COO)_2Cu.H_2O$

(CH3COO)2Cu.H2O

Cu_2O

reduction curves



XRD

$Cu(OH)_2$

$Cu(OH)_2$

$Cu(OH)_2$

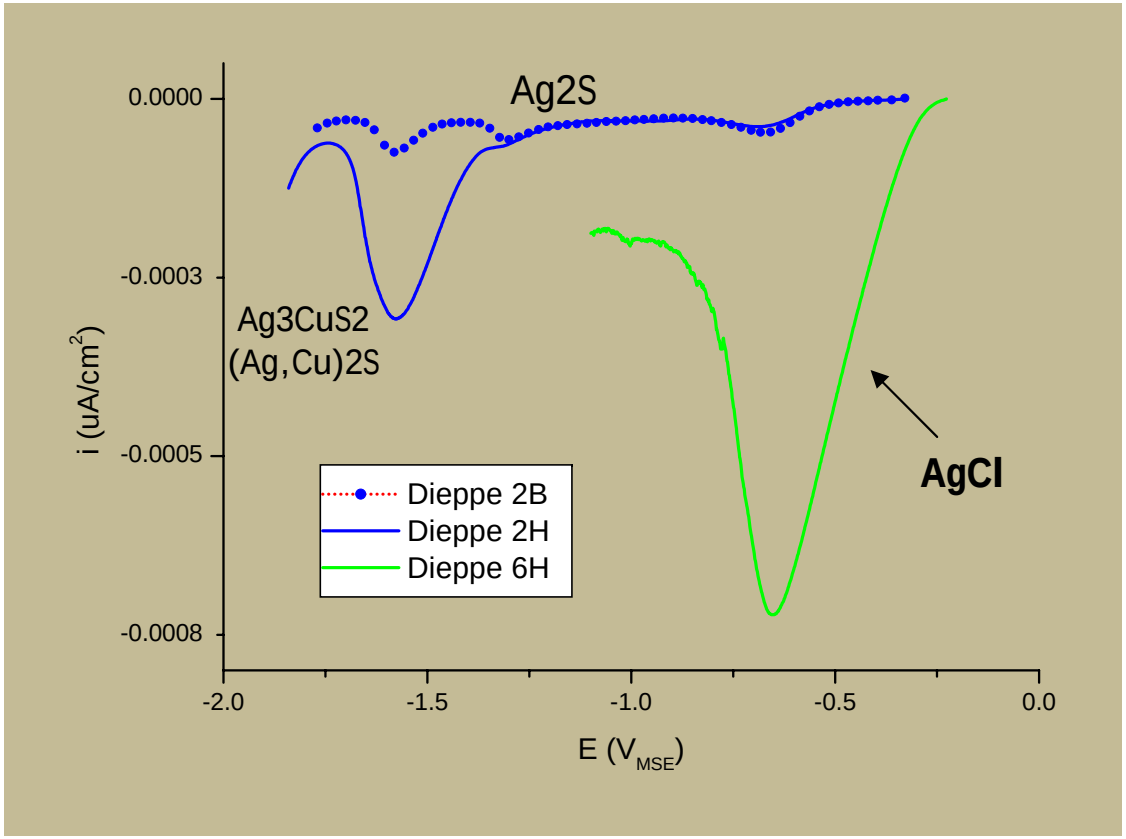
Cu_2O

room (2)

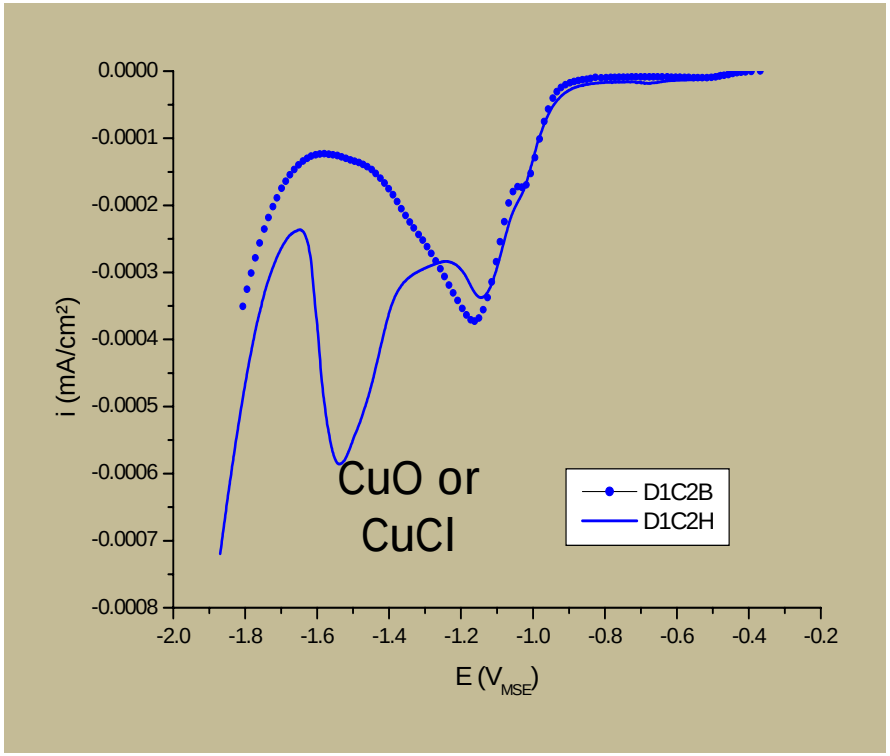
H B

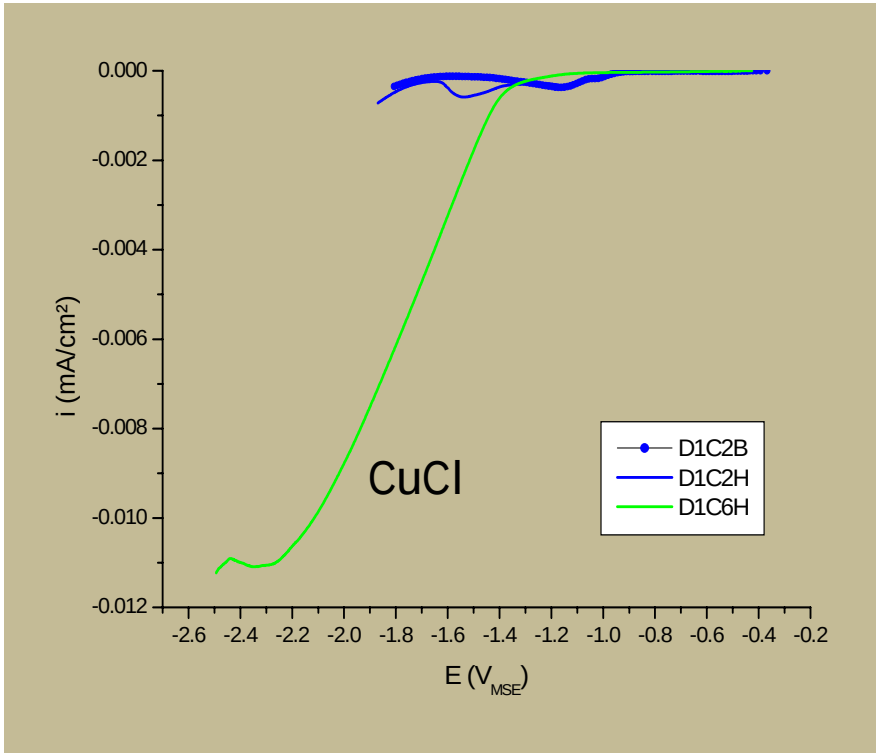
outside (6)

sterling Ag coupons

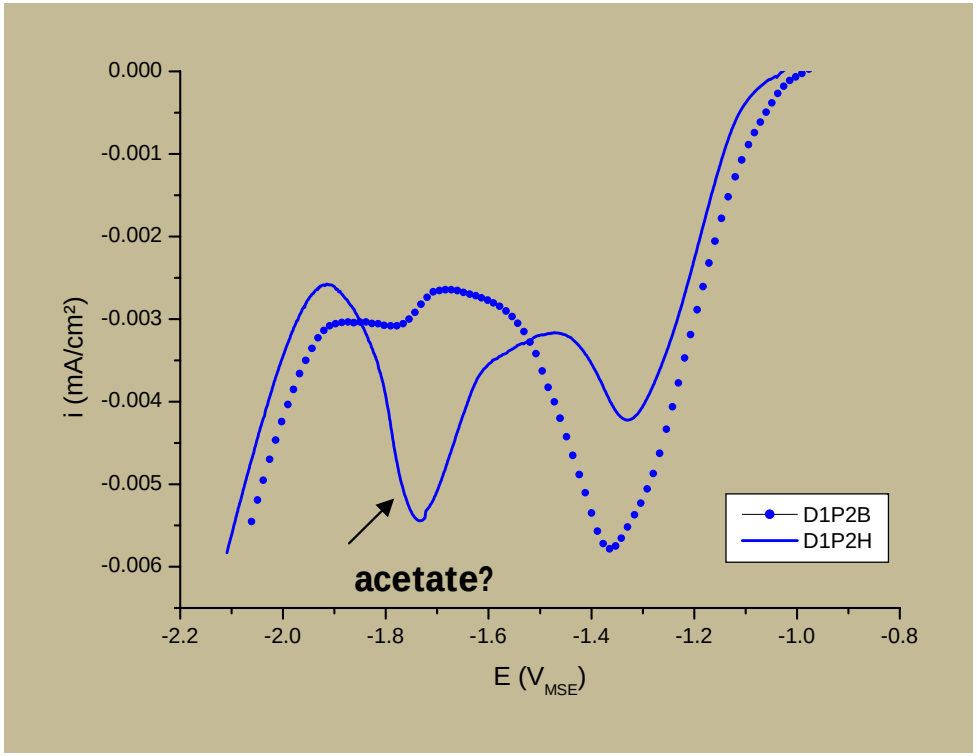


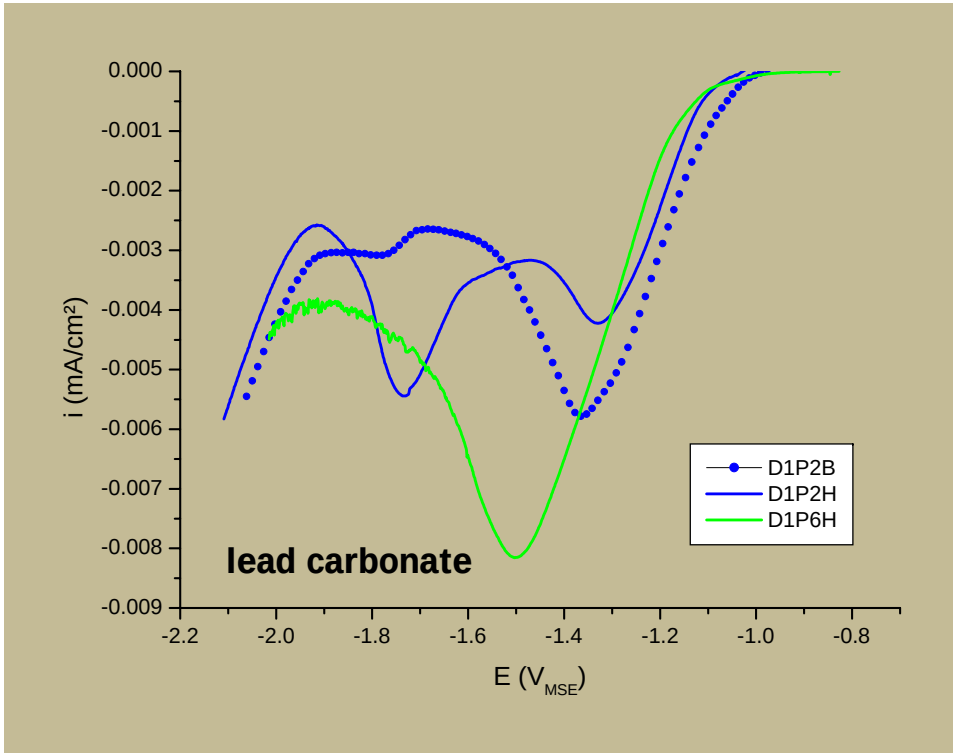
Cu coupons


0.0000
-0.0001
-0.0002
-0.0003
-0.0004
-0.0005
-0.0006
-0.0007
-0.0008
i (mA/cm²)
-2.0
-1.8
-1.6
-1.4
-1.2
-1.0
-0.8
-0.6
-0.4
-0.2
E (V_MSE)
CuO or
CuCl
D1C2B
D1C2H


0.000
-0.002
-0.004
-0.006
-0.008
-0.010
-0.012
i (mA/cm²)
-2.6
-2.4
-2.2
-2.0
-1.8
-1.6
-1.4
-1.2
-1.0
-0.8
-0.6
-0.4
-0.2
E (V_MSE)
CuCl
D1C2B
D1C2H
D1C6H

Pb coupons


0.000
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
i (mA/cm²)
-2.2
-2.0
-1.8
-1.6
-1.4
-1.2
-1.0
-0.8
E (V_MSE)
D1P2B
D1P2H
acetate?


0.000
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
-0.007
-0.008
-0.009
i (mA/cm²)
-2.2
-2.0
-1.8
-1.6
-1.4
-1.2
-1.0
-0.8
E (V_MSE)
D1P2B
D1P2H
D1P6H
lead carbonate

- electrochemical technique is quite sensitive, evidencing even tarnishing layers, ‘invisible’ to XRD

- both techniques are complementary to identify the nature of the surface compound

- results showed the importance of the situation regarding the environmental impact

- the tarnishing rate increases

room (side B) $\Rightarrow$ room (side H) $\Rightarrow$ outdoor

- particulate matter (side H) seems catalyse selective corrosion