SURFACE PROPERTIES OF TECHNOLOGICAL MATERIALS AND THEIR INFLUENCE ON THE OPERATION AND CONDITIONING OF R.F. COUPLER

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CERN - LHC/VAC

THE MEASUREMENTS PRESENTED HERE WERE OBTAINED WITH THE HELP OF:

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TOPICS:

* PURE METALS ⇔ TECHNICAL MATERIALS : THE INFLUENCE OF THE SURFACE

* MATERIALS IN COUPLERS: INSULATORS, CONDENSED GASES

* CHANGING THE S.E.Y. :

  → Surface composition

  → Surface roughness

  → Irradiation by energetic particles: Conditioning

* CONCLUSIONS
THE SECONDARY ELECTRON EMISSION

MECHANISMS

\[ \delta \]

\[ E_{\text{max}} \]

PRIMARY ELECTRON

SECONDARY ELECTRONS

SECONDARY ESCAPE DEPTH

Metals <-> insulators
THE SECONDARY ELECTRON EMISSION

OLD SUBJECT : AUSTIN –STARK (1902)
MOST OF PURE METALS MEASURED
BEFORE LAST WAR

Table I. Values of \( \delta_m \) and \( E_{\text{em}} \) for Metals, Arranged According
ATOMIC NUMBER (Z)

<table>
<thead>
<tr>
<th>Z</th>
<th>Metal</th>
<th>( \delta_m )</th>
<th>( E_{\text{em}} )</th>
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<tr>
<td>3</td>
<td>Li</td>
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<td>300</td>
<td>a,d</td>
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<td>(500)</td>
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<td>&gt;250</td>
<td>d</td>
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<td>82</td>
<td>Pb</td>
<td>1.1</td>
<td>500</td>
<td>m,t</td>
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ORIGIN OF THE DISCREPANCY => OXIDES + CONTAMINANTS
INFLUENCE OF OXIDE

SECONDARY ELECTRON YIELD VERSUS ARGON ION DOSE
ALUMINIUM SAMPLE

INITIAL TREATMENT

2nd TREATMENT AFTER AIR EXPOSURE

PURE ALUMINIUM
SECONDARY ELECTRON YIELD
As received

- Aluminium 99.5%
- Beryllium
- Copper OFHC
- Stainless steel
- Titanium

SECONDARY ELECTRON YIELD
Copper as received

- Copper baked to 300°C
- Copper + A.G.D.
PURE METALS AND TECHNICAL MATERIALS

INFLUENCE OF WATER

SECONDARY ELECTRON YIELD OF CONDENSED WATER

VARIATION OF THE S.E.Y. WITH THE CONDENSED WATER THICKNESS

- Clean sample
- 45 monolayers of water
- 85 monolayers of water
- 200 monolayers of water
SECONDARY ELECTRON YIELD OF CONDENSED HYDROGEN

- 0.01 H2 MONOLAYERS
- 0.8 H2 MONOLAYERS
- 10 H2 MONOLAYERS
- 33 H2 MONOLAYERS
- 42 H2 MONOLAYERS
- 54 H2 MONOLAYERS
- 75 H2 MONOLAYERS

Maximum SEY from Condensed Gases on Copper

- Ar/Cu(4K)
- CO2/Cu(77K)
- H2/Cu(3K)
SECONDARY ELECTRON YIELD OF INSULATORS AFTER A 250 °C BAKE OUT

ENERGY OF THE MAXIMUM YIELD

Sapphire
Alumina 97.6%
Alumina 94%
Zyranox
Quartz
REDUCING SECONDARY ELECTRON YIELD

4 MAIN WAYS

MODIFY THE SURFACE COMPOSITION

BAKE-OUT REACTIVE SPUTTERING $N_2$, $A+O_2$

VERY SENSITIVE TO AIR EXPOSURE

IN SITU BAKE NEEDED

CHANGE THE MATERIAL: COATINGS

CHANGE SURFACE TOPOGRAPHY

‘BLACK LAYERS’: AQUADAG, GOLD-BLACK, SOOT...

DENDRITIC LAYERS

MUCH MORE IMMUNE TO AIR EXPOSURE
REDUCING SECONDARY ELECTRON YIELD
SURFACE COMPOSITION

VARIATION OF THE SECONDARY ELECTRON YIELD OF NIOBIUM WITH THE SURFACE TREATMENTS
EFFECT OF A NITROGEN GLOW DISCHARGE ON COPPER

ENERGY (eV)

SECONDARY ELECTRON YIELD
REDUCING SECONDARY ELECTRON YIELD

COATINGS

SECONDARY ELECTRON YIELD OF VARIOUS TiN LAYERS
after 80°C bake out

SECONDARY ELECTRON YIELD

As received

SECONDARY ELECTRON YIELD

TiN (A.R.)
TiN (150°C)
TiN (300°C)
REDUCING SECONDARY ELECTRON YIELD

COATINGS

GETTER LAYERS: ACTIVATION AND DECREASE OF SEY

SECONDARY ELECTRON YIELD OF A GETTER LAYER Ti Zr V

- As received
- 2 hours 120°C
- 2 hours 160°C
- 2 hours 200°C
- 2 hours 250°C
REDUCING SECONDARY ELECTRON YIELD

COATINGS

INSULATORS: COUPLER WINDOWS!

INFLUENCE OF COATINGS

![Graph showing the influence of coatings on secondary electron yield.](image-url)
REDUCING SECONDARY ELECTRON YIELD

COATINGS

SECONDARY ELECTRON YIELD OF COATED ALUMINA

SECONDARY ELECTRON YIELD OF TITANIUM COATED ALUMINA

SECONDARY ELECTRON YIELD OF TITANIUM COATED ALUMINA (BAKED 350°C)
REDUCING SECONDARY ELECTRON YIELD

TOPOGRAPHY CHANGES

Copper as received, Mag = 15 000

Cu after oxidation in air at 20°C and 350°C bakeout

Cu after oxidation in air at 350°C and 350°C bakeout

Copper after 5 min air exposure at 350°C and 350°C bakeout under vacuum Mag = 15 000
REDUCING SECONDARY ELECTRON YIELD

TOPOGRAPHY CHANGES

CODEPOSITION Ti

UNDER ION BOMBARDMENT
REDUCING SECONDARY ELECTRON YIELD

CONDITIONING

![Graph showing the relationship between dose and secondary electron yield.]
CONDITIONING

DESORPTION AND SECONDARY ELECTRON EMISSION

DESORPTION ELECTRON EMISSION

INCIDENT PARTICLE

STIMULATION OF DIFFUSION, CREATION OF DEFECTS......

ENERGY TRANSMISSION

PRIMARY PARTICLE ENERGY LOSS
CONDITIONING

DESORPTION AND SECONDARY ELECTRON EMISSION

VARIATION OF THE ELECTRON INDUCED DESORPTION WITH THE ELECTRON DOSE (AS RECEIVED COPPER)

DESORPTION YIELD RATIO

ELECTRON DOSE (cm$^{-2}$)

H$_2$, CO, CO$_2$, CH$_4$, C$_2$H$_6$
VARIATION OF THE ELECTRON INDUCED DESORPTION WITH THE BEAM DOSE (AS RECEIVED COPPER)

N. Hilleret – HPC /02
CONDITIONING

DESORPTION AND SECONDARY ELECTRON EMISSION

VARIATION OF THE SECONDARY ELECTRON YIELD WITH THE DESORPTION YIELD

\[
\delta = 10.4 \times \eta + 1.09
\]

\[
\delta = 0.822 \times \eta + 1.836
\]

DOSE: \( \sim 10^{16} \) e\(^-\) / cm\(^2\)
VARIATION OF THE DESORBED GAS QUANTITY AS A FUNCTION OF THE SECONDARY ELECTRON YIELD

- H2-23/03
- CO-23/03
- CO2-23/03
- CH4-23/03
- C2H6-23/03
- H2O-23/03
- TOT-23/03
- TOT-31/01
SPS run 2002 in situ SEY measurements on copper
CERN LHC/VAC B. HENRIST 9/3/2002

DATE (10/7 days)
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4
ENERGY OF MAXIMUM YIELD (eV)
0 50 100 150 200 250 300 350 400 450

SECONDARY ELECTRON YIELD

SEY Ap6
SEY Ap4
Emax Ap6
Emax Ap4

AIR EXPOSURE
3692 C
3519 C
5515 C
DECONDITIONING

EFFECT OF VACUUM / AIR EXPOSURE

IS CONDITIONING LOST??

VARIATION OF THE SECONDARY ELECTRON YIELD WITH THE ELECTRON DOSE BEFORE AND AFTER AIR EXPOSURE

SECONDARY ELECTRON YIELD

ELECTRON DOSE ( C/mm² )

INITIAL BOMBARDMENT

AFTER 10 DAYS AIR EXPOSURE
DECONDITIONING

UNDER VACUUM DECONDITIONING VISIBLE WHEN $e^-$ ACTIVITY IS INTERRUPTED

AFTER AIR EXPOSURE: BACK TO UNTREATED VALUE (10 DAYS)

BUT RECONDITIONING MUCH SHORTER (FACTOR 10 IN DOSE)
CONDITIONING

ORIGIN

VARIATION OF THE SECONDARY ELECTRON DOSE WITH THE ELECTRON / ION DOSE

- **e- IMPACT ON A.R. COPPER**
- **e- IMPACT ON A.G.D. COPPER**
- **ARGON ION BOMBARDMENT ON CONDITIONNED COPPER**
CONDITIONING

ORIGIN??

PROCEDURE FOR ION BOMBARDMENT

1/ ELECTRON BOMBARDMENT 1 C/mm²

2/ ARGON ION BOMBARDMENT

3/ S.E.Y. MEASUREMENT
VARIATION OF THE S.E.Y. OF A CONDITIONNED COPPER SAMPLE DURING ARGON ION BOMBARDMENT

MAXIMUM S.E.Y. AFTER ARGON GLOW DISCHARGE $3 \times 10^{18}$ IONS/cm$^2$

ENERGY OF THE MAXIMUM S.E.Y. AFTER ARGON GLOW DISCHARGE $3 \times 10^{18}$ IONS/cm$^2$

ARGON ION DOSE (IONS/CM$^2$)

MAXIMUM S.E.Y.

ENERGY OF THE MAXIMUM S.E.Y. (eV)
CONDITIONING

ORIGIN??

INFLUENCE OF CLEANLINESS: IN SITU A.G.D. CLEANED SAMPLES

VERY LOW DESORPTION YIELD PRODUCED:

S.E.Y. DECREASES WHEN AN A.G.D COPPER SURFACE IS EL. BOMBARDED

S.E.Y. INCREASES WHEN CONDITIONED CU IS A.G.D

THE CLEANEST SURFACE HAS NOT THE LOWEST SECONDARY ELECTRON YIELD
SURFACE MODIFICATIONS DURING CONDITIONING

SHIFT IN THE POSITION OF C-KLL PEAK =>

MODIFICATION OF THE CARBON CHEMICAL BOND NO SHIFT FOR OXYGEN

![Graph showing N(E) vs kinetic energy (eV)]
SURFACE MODIFICATIONS DURING CONDITIONING

ORIGIN OF THE CARBON?

VARIATION OF $\delta$ WITH THE DOSE

NORMALISED SECONDARY ELECTRON YIELD

- $P = 4 \times 10^{-7}$ Torr CH$_4$
- $P = 4 \times 10^{-7}$ Torr CO
- Total $P = 5 \times 10^{-10}$ Torr
SURFACE MODIFICATIONS DURING CONDITIONING

INITIAL DECREASE OF OXYGEN AND CARBON ON THE SURFACE \((10^{17} \text{ e}^-/\text{cm}^2)\)

SMALLER DECREASE FOR OXYGEN:

DESORPTION COMPENSATED BY MORE SIGNAL FROM OXIDE

MAXIMUM COPPER PEAK FOR A DOSE \(~ 10^{17} \text{ e}^-/\text{cm}^2\)

DESORPTION MEASUREMENTS => \(6 \times 10^{15} \text{ mol/cm}^2\) RELEASED FOR THIS DOSE

FOR HIGHER DOSES CARBON PEAK INCREASES

EXPERIMENTS AT VARIABLE PARTIAL PRESSURES OF CO, CH\(_4\)

=> NO INFLUENCE ON THE DOSE DEPENDENCE

ORIGIN OF THE CARBON??? STILL A QUESTION

CONDITIONING: => INITIAL CLEANING FOLLOWED BY CARBON LAYER BUILD UP
CONCLUSIONS

S.E.E is strongly surface dependent:

Determined more by the surface preparation than by the base material itself

Wonder layers need to be produced in-situ or baked out to be fully efficient

Conditioning: old recipe based on the decrease of S.E.Y. with $e^-$ dose

Usual condensed gases have little effect on the secondary electron yield exception: noble gases at thick coverages. Conditioning??

Desorption and conditioning: parallel phenomena:

Gas flux variation is a good indicator of the conditioning process

Subtle changes in the surface composition parallel (at the origin of) conditioning