SURFACE EFFECTS FOR ELECTRON CLOUD

R. Cimino LNF-INFN

Thanks to F. Ruggiero
OUTLINE

- Introduction:
  - E-cloud mitigation methods in a global scenario: compatibility with impedance, vacuum, etc.
  - The seed of e-cloud: number of photoelectrons (PY) and their effect to the surface.
  - How surface sensitive is SEY?
    - Role of Temperature, overlayer thickness, etc
- Conclusions
The global scenario: e⁻ cloud methods must be compliant with all BS features.

For LHC:

**FUNCTION**
- Reduce beam-induced cryogenic loads
- Increase development time of transverse resistive-wall instability
- Resist eddy-current forces at magnet quench
- Preserve field quality in magnet aperture
- Maintain good beam vacuum
- Limit development of electron cloud

**PROCESS**
- Limit residual heat load to cold mass
- Intercept synchrotron radiation
- Limit resistive wall impedance
- Structural material with high resistivity
- Low-permeability materials
- Provide pumping from shielded cold surface
- Limit reflectivity and SEY of beam screen surface

**DESIGN FEATURE**
- Low-conduction supports
- High-conductivity copper plating
- Cooling at low temperature
- Austenitic stainless steel structure
- Pumping slots
- Avoid temperatures favoring desorption of common gas species
- Sawtooth absorber
- Beam scrubbing

Cu layer

Pumping slots shields

Cooling tubes

“Saw teeth”

Pumping slots

V. Baglin et al. CERN-ATS-2013-006
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**Limit reflectivity and SEY of beam screen surface**

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**Alternative solution:** Laser treated materials (see: Oleg Talk)

V. Baglin et al. CERN-ATS-2013-006

ICFA 2019 - Zermatt - 25-09-2019

R. Cimino
surface morphology of LASE

Very low SEY

Is it compliant with all BS functionalities?

See Oleg Talk

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**Cooling tubes**

- Dia. 3.7/4.8 mm

**Beam screen**

- Dia. 46.4/48.5 mm

**Dipole cold bore at 1.9 K**

V. Baglin et al. CERN-ATS-2013-006
The global scenario: e cloud methods must be compliant with all BS features.

For LHC:

- Cu layer
- Pumping slots
- "Saw teeth"

\[ \text{Dipole cold bore at 1.9 K} \]
\[ \text{Beam screen} \]
\[ \text{5 - 20 K} \]
\[ \text{Dia. 46.4/48.5 mm} \]
\[ \text{Cooling tubes} \]
\[ \text{Dia. 3.7/4.8 mm} \]
\[ \text{Photons} \]
\[ \text{Hole pumping} \]
\[ \text{Wall pumping} \]
\[ \text{Desorbed molecules} \]
\[ \text{Electrons stripes} \]
\[ \text{36.8 mm} \]

The global scenario: e cloud methods must be compliant with all BS features.

\[ \text{Impedance issues?} \]

V. Baglin et al. CERN-ATS-2013-006
The global scenario: e cloud methods must be compliant with all BS features.

For LHC:

- Cu layer
- Pumping slots

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- Limit resistive wall impedance

“Saw teeth” Pumping slots

V. Baglin et al. CERN-ATS-2013-006

Impedance issues?

Oleg will answer to this!
The global scenario: e cloud methods must be compliant with all BS features.

For LHC:

- **Cu layer**
- **Pumping slots**
- **Shields**
- **Cooling tubes**

**FUNCTION**

- Reduce beam-induced cryogenic loads
- Increase development time of transverse resistive-wall instability

**PROCESS**

- Limit residual heat load to cold mass
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- Limit resistive wall

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- Cooling at low temperature

**Avoid temperatures favoring desorption of common gas species**

- Maintain good beam vacuum
- Provide pumping from shielded cold surface

**BEAM SCREEN**

- Dia. 46.4/48.5 mm

**COOLING TUBES**

- Dia. 3.7/4.8 mm

**PHOTONS**

- Hole
- Pumping
- Wall
- Pumping

**DESORBED Molecules**

**ELECTRONS**

- Stripes

**VACUUM ISSUES?**

**V. Baglin et al. CERN-ATS-2013-006**
LHC
Synchrotron Radiation Power = 0.13 W/m

FCC
Synchrotron Radiation Power = 40 W/m

Working Pressure
(<10^{-11} mbar)

Beam screen
Temperature Range

Independently on the substrate treatment, the thermal stability against small BS T fluctuation has to be guaranteed
We studied thermal stability @ LNF within EuroCirCol collaboration

Ultra high vacuum systems

- LNF-cryogenic manipulator
- Sample at 15-300 K

Secondary Electron Yield (SEY) measurements
Equipment: Electron gun, Faraday cup

Temperature Programmed Desorption (TPD) and Mass Spectrometry measurements
Equipment: QMS (Hiden HAL 101 Pic)
TPD from unbaked lase-Cu for temperature induced vacuum transients study

Comparative study of TPD from flat poly-Cu and LASE-Cu unbaked samples using different gases ($\text{Ar, CH}_4, \text{CO and H}_2$)
Single TPD peak at ~30 K corresponding to the desorption of a condensed thick Ar layer

Desorption temperature determined by the weak Ar-Ar van der Waals interaction energies

L. Spallino, M. Angelucci, R. Larciprete, R. Cimino,
TPD from unbaked lase-Cu for temperature induced vacuum transients study: Ar

- Single TPD peak at ~30 K corresponding to the desorption of a condensed thick Ar layer
- Desorption temperature determined by the weak Ar-Ar van der Waals interaction energies


TPD peak at ~30 K corresponding to the desorption of a condensed thick Ar layer together with a broad TPD profiles, whose peak temperatures and widths depend on the Ar dose

Ar on poly-Cu

Ar on LASE-Cu
TPD from unbaked lase-Cu for temperature induced vacuum transients study: Ar

TPD characteristics determined by the sponge-like structural features of LASE-Cu
Conceptually identical results have been obtained with CH$_4$
Conceptually identical results have been obtained with CO TPD from unbaked lase-Cu for temperature induced vacuum transients study: CO
TPD of 100 L H$_2$ dosed on poly-Cu and LASE-Cu samples held at $T \sim$15-18 K

No TPD signal should be observed by considering the H$_2$ vapor suture pressure curve!!!

The wide distribution of high energy adsorption sites within the inner pore is responsible for the H$_2$ TPD signal from LASE-Cu sample
Further studies and electron/photon stimulated desorption are necessary to validate/optimize LASE-Cu at low T.

Low SEY AND Low impedance AND Vacuum compatibility, etc. must be granted!
Introduction:

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- How surface sensitive is SEY?
  - Role of Temperature, overlayer thickness, etc

Conclusions
Experimental Parameters

- Phot. Energy range 35 ÷ 1800 eV
- Beam height h=0.3 mm
- Incident Beam measurement
- GaAsP Photodiodes (4x4mm) (0.1*4mm)
- Incident angle 0.25, 0.5, 1°

We can measure PY and R in operational conditions

The Beamline


The Reflectometer

The sample studied:
Cu (different Roughness)
LHC - Saw Tooth
LASE
Cu+ amorphous Carbon Thin Film
And: NEG, Stainless Steel, ...
In all cases, PY is higher at higher photon energies.

- The PY dependence on $\theta_i$ is consistently dimmed and finally washed out when surface Ra is increasing.

- In all cases, the Cu-L2-3 absorption edge at 930-950 eV is visible and cause an increase in the measured PY.

- In all spectra we measure a significant effect due to the C K-edge at 280 eV and O K-edge at 530 eV (surf. Contaminants)

- Roughness does influence the PY. The lower is Ra, the highest is the measured PY.

E. La Francesca et al: submitted to PR ST
Preliminary results on PSD from small samples @ DAΦNE

Photo Stimulated Desorption

Pressure Evolution

Surface Chemistry Changes (Conditioning)

Photon / Electron Scrubbing comparison

Photon interaction studies (RT) @ DAΦNE-L

Dynamic Pressure (mbar/current)

Photon Dose (photons/mm²)

- Total Pressure
- H₂
- H₂O
- CO
- O₂
- CO₂
Photon interaction studies (RT) @ DAΦNE-L

Preliminary results from small samples

Studied on the same surface

Photon Scrubbing

Surface Modifications

Photo Yield

SEY

Strong variation of surface conditions at “low dose”

Slow variations at “high doses”

Finale State SEY=1.3
Surface Modifications

Modification of Carbon C-1s
From sp\(^3\) to sp\(^2\)

Same chemical process of Electron Scrubbing

But SEY\(_{\text{Max}}\) Decreases to 1.3
as for low energy electrons

Still in progress!
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SEY behavior is strongly influenced by the chemical state of the surface


Contaminants from atmosphere ~ 5 - 20 nm
SEY at LT (20 K) ~ SEY at RT but...

- SEY is highly sensitive to the presence of adsorbates, even at sub-monolayer coverages.

- SEY of cold surfaces influenced by gas physisorption.
SEY Surface sensitivity: gases on LT Cu

CO thick layer coverage

Ar thick layer coverage

H$_2$O thick layer coverage


L. Spallino, M. Angelucci and R. Cimino, to be published

V. Baglin, et al Proceedings of EPAC 2000, Vienna, Austria

SEY is an intrinsic material property strongly sensitive to the surface composition and chemical state

Element and coverage specific
HOW A COATING MODIFY SEY?
(the case of a-C on Cu)

We followed the growth of thin a-C layers on Cu with XPS to measure its thickness.

A. Novelli et al., in preparation
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In XPS:

\[ I_{Cu}^{C} = (I_{Cu, bulk}^{C})*\exp\left(-d/\lambda_{Cu,C}\right) \]

\[ I_{C} = I_{C, bulk}^{C}*(1-\exp\left(-d/\lambda_{C,C}\right)) \]

where \( d \) is the unknown thickness and \( \lambda \) is the inelastic mean free path.

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where \( d \) is the unknown thickness and \( \lambda \) is the inelastic mean free path.

We also calibrate the 1ML Carbon signal with the one emitted from Gr/Cu (1 ML)
HOW A COATING MODIFY SEY? (the case of a-C on Cu)

-Preliminary-

By simultaneously follow SEY changes with a-C thickness we can measure SEY dependence on actual a-C coverage.

Increasing C

$\delta_{\text{max}}, E_{\text{max}}$ sets to their (a-C) final values quite soon, while minor changes still occurs at higher doses in the very low ($< \sim 20$ eV) and quite high primary energy ($> \sim 400$ eV) part.

A. Novelli et al., in preparation
How a Coating Modify SEY? (the case of a-C on Cu)

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Increasing C

A. Novelli et al., in preparation
HOW A COATING MODIFY SEY? (the case of C on Cu)

Could follow $d_{\text{max}}$ vs C coverages

In Graphite:
1 ML $\sim$ 3.4 Å

$\Rightarrow$ 15-20 ML ($\sim$ 5-6 nm) of a-C determines SEY properties.

A. Novelli et al., in preparation
DO WE LEARN SOMETHING ON SCRUBBING?

- To have a fully scrubbed Surface, we need more than 5-6 nm of (low SEY) a- C covering our surface.
- Original Contaminant thickness depends on the material and material cleaning. (can be between 4 to 20 nm)
- During irradiation (ph and e-) both desorption and substrate chemical modifications occurs.
- Are we always sure that we are left with the minimum C coverage to reduce SEY below 1.1?
- Why photons and low energy electrons (below 50 eV) behaves differently than high energy electrons (above 50 eV up to 3keV)?
CONCLUSIONS

- All new materials should be validated in all aspects in a global approach.
- Laboratory experiments have been and must be refined.
- Material studies in conditions as close as possible to operating ones (preparation, Low Temperature & geometry) is mandatory.
- There are still open aspects in the scrubbing process.
- Very thin coatings (about 6 nm for a-Carbon) are enough to completely reduce clean poly - Cu SEY to the one of a-C.
Thank you for your attention

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