Istituto Nazionale di Fisica Nucleare
LNF
Divisione Ricerca: DAFNEL

Terzo Meeting DAΦNE-Light
16 Maggio 2019

Proprietà dei materiali e loro potenziale impatto sulle prestazioni degli acceleratori in vuoto criogenico

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Istituto Nazionale di Fisica Nucleare

Research funded by EuroCirCol project (Grant No. 654305)

Work Package 4: Cryogenic beam vacuum system

Task 4.4: Study vacuum stability at cryogenic temperature

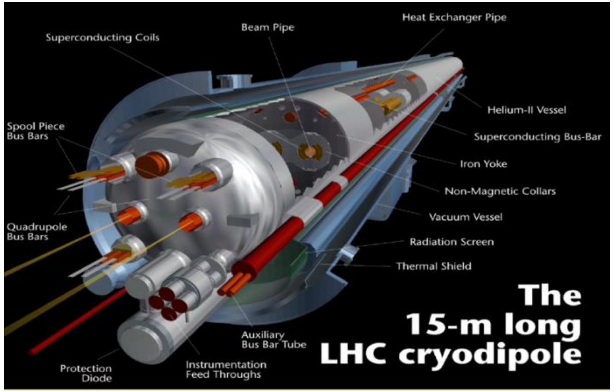
From 06/2015 up to 12/2019 M. Angelucci and L. Spallino

Outline

- Introduction
- Strategy and experimental set-up
- Results
  - TPD from LASE-Cu for temperature induced vacuum transients study
  - SEY to probe surface coverage
  - Electron desorption studies: preliminary results

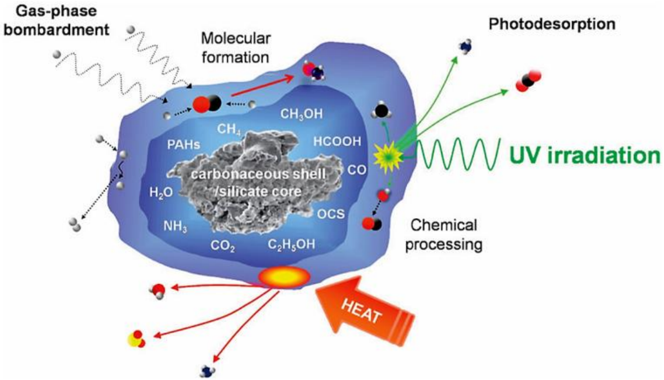
Introduction

Why deal with cryogenic vacuum?

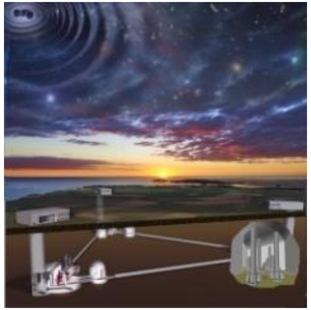


L. Rossi, IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY,13 (2003)

In accelerators (superconducting magnets)



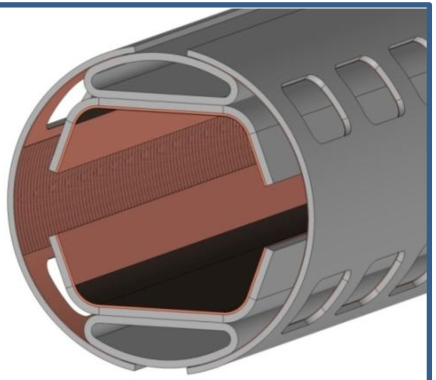
In astrochemestry (interstellar medium)

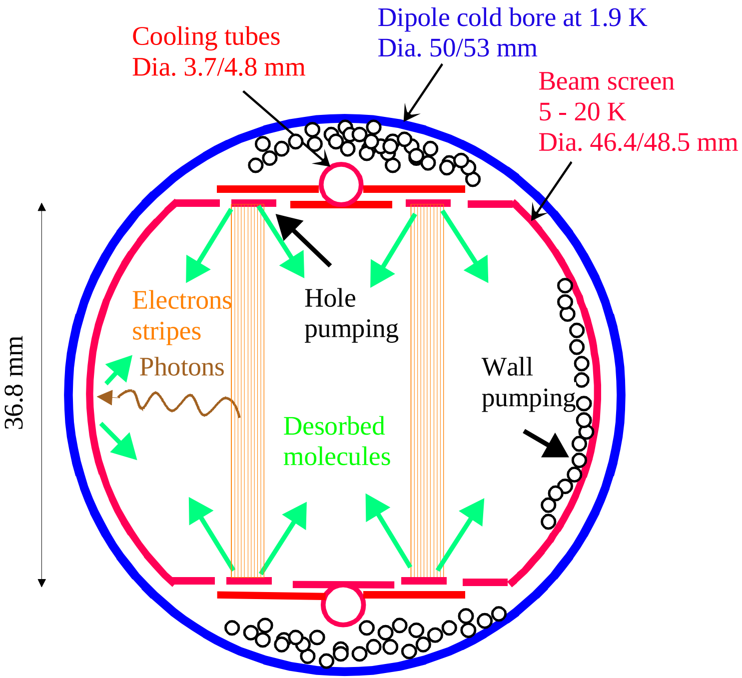


In every detection system with cold components (as for example in the Einstein Telescope)

Einstein gravitational wave Telescope conceptual design study, ET-0106C-10 (2011)

Introduction





Not only intrinsic properties of surface but also the effects of:

- **Temperature transients**
- **Photons-surface interaction**
- **Electrons-surface interaction**

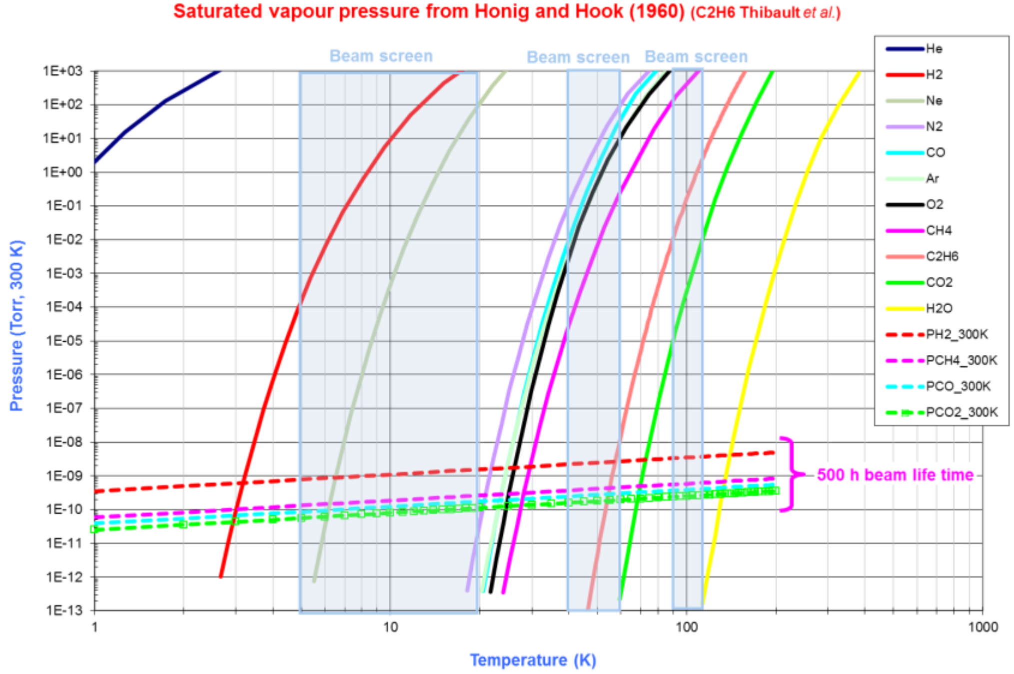
Temperature transients

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 vacuum stability due to the desorption of residual contaminant gases has to be guaranteed

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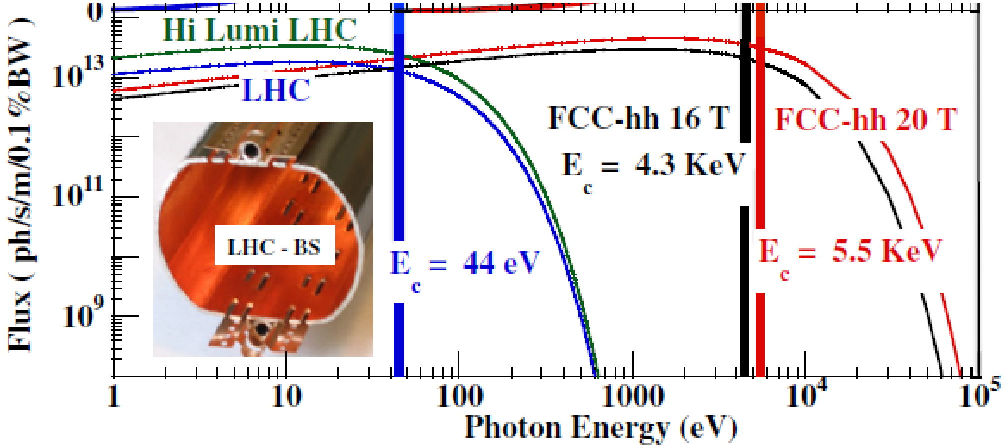
Photons-surface interaction



R. Cimino et al., PRL 115, 264804 (2015)

Photons induce:

- **Heat load**
- **Photoelectrons and related instabilities**
- **Photo induced desorption**

See next:
"Importanza della Luce di Sincrotrone sulle prestazioni degli acceleratori: riflettività e Photo-Yield" by A. Liedl

"Desorbimento indotto da Luce di Sincrotrone: impatto sulle prestazioni degli acceleratori e sua importanza nello studio dello spazio interstellare" by M. Angelucci

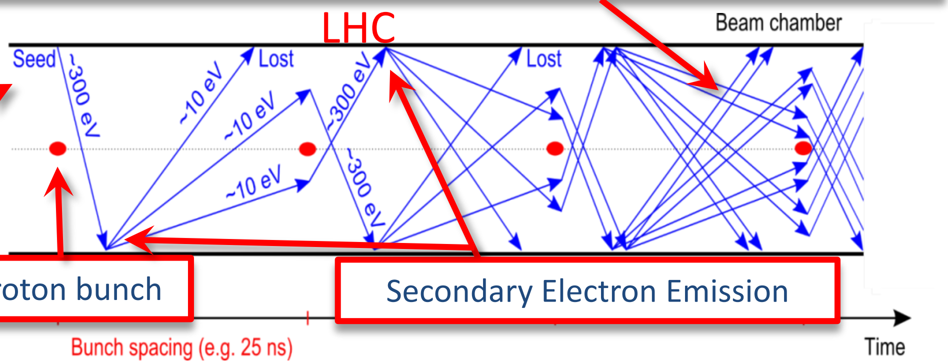
To be studied:

- **Reflectivity (where photons interact with BS)**
- **Photo Yield (Number of photo-el produced)**
- **Photon Stimulated Desorption (PSD)**

Electrons-surface interaction

Secondary Electron Emission can drive an **avalanche multiplication** effect filling the beam chamber with an **electron cloud**

e^- is emitted (photoelectric effect)



Electrons induce:

- **Heat load**
- **Secondary electrons and related instabilities (e-cloud)**
- **Electron induced desorption**

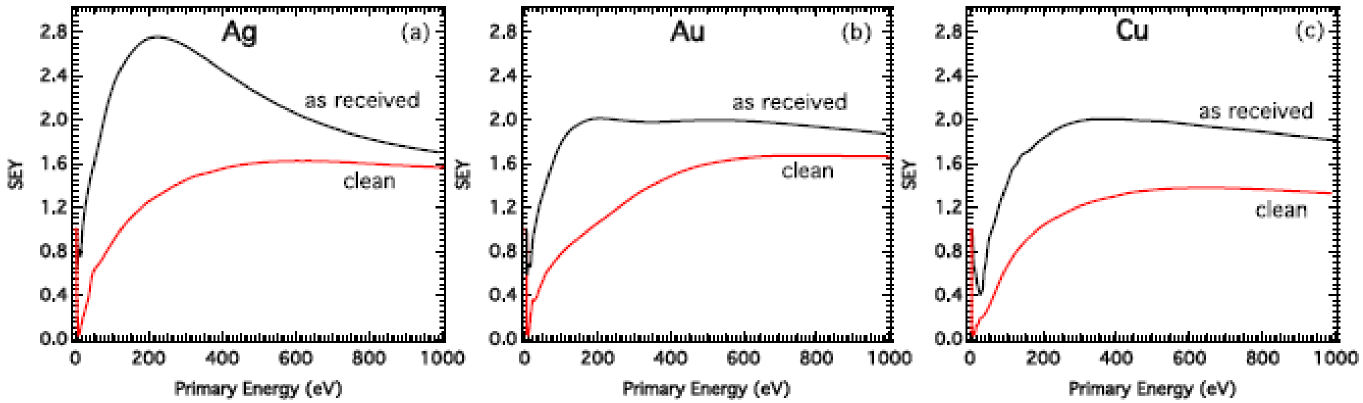
To be studied:

- **Secondary Electron Yield (SEY)**
- **Electron Stimulated Desorption (ESD)**
- **Photon Stimulated Desorption (PSD)**

Surface sensitivity of SEY

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

Effect of contaminants of the atmosphere at ambient temperature



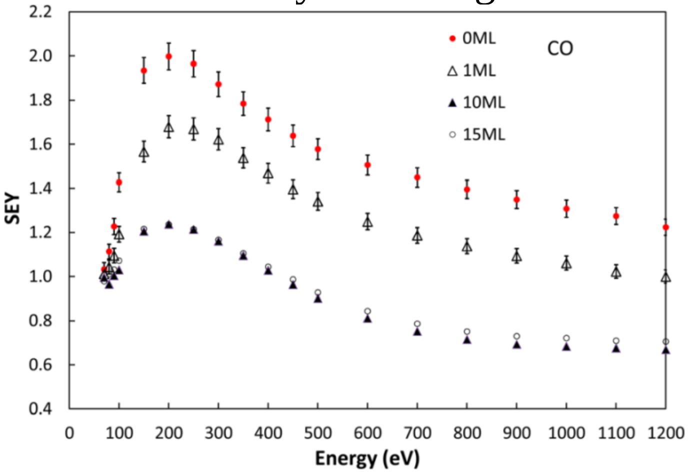
L. A. Gonzalez et al., AIP Adv. (2017)

Chemisorbed/physisorbed compounds modify the metal surface

Surface sensitivity of SEY

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

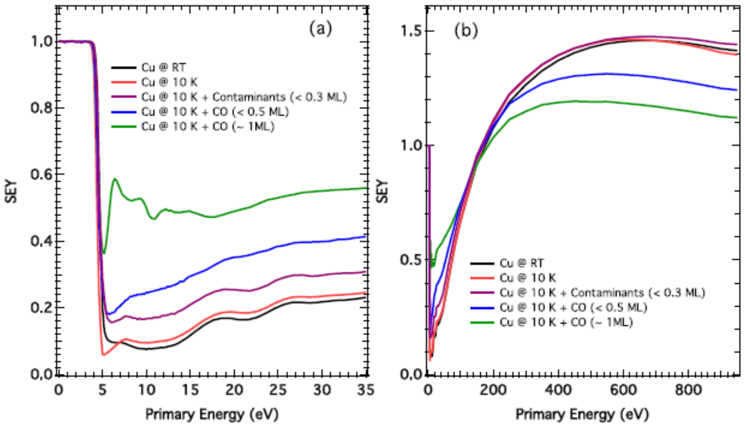
CO thick layer coverage



Kuzucan et al., J. Vac. Sci. Technol. A (2012)

SEY of cold surfaces influenced by gas physisorption

Residual gas in cryogenic vacuum



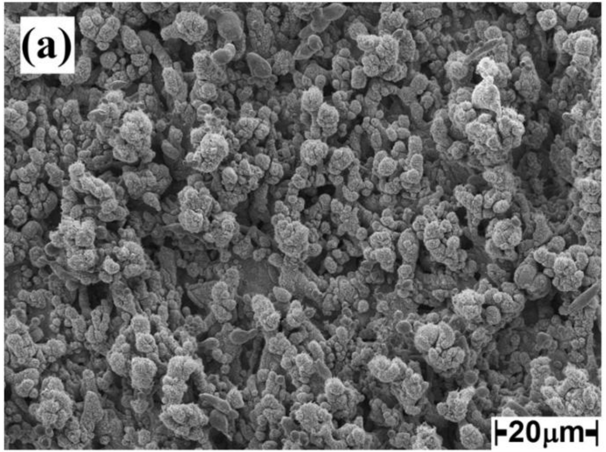
L. A. Gonzalez et al., AIP Adv. (2017)

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

Surface sensitivity of SEY

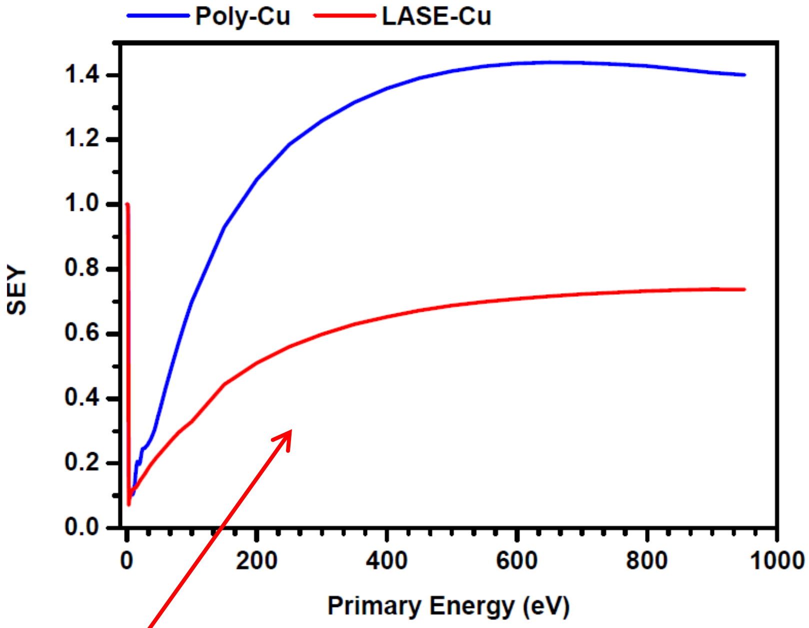
SEY is an intrinsic property of materials, strongly sensitive to the surface morphology

Engineering the surface morphology



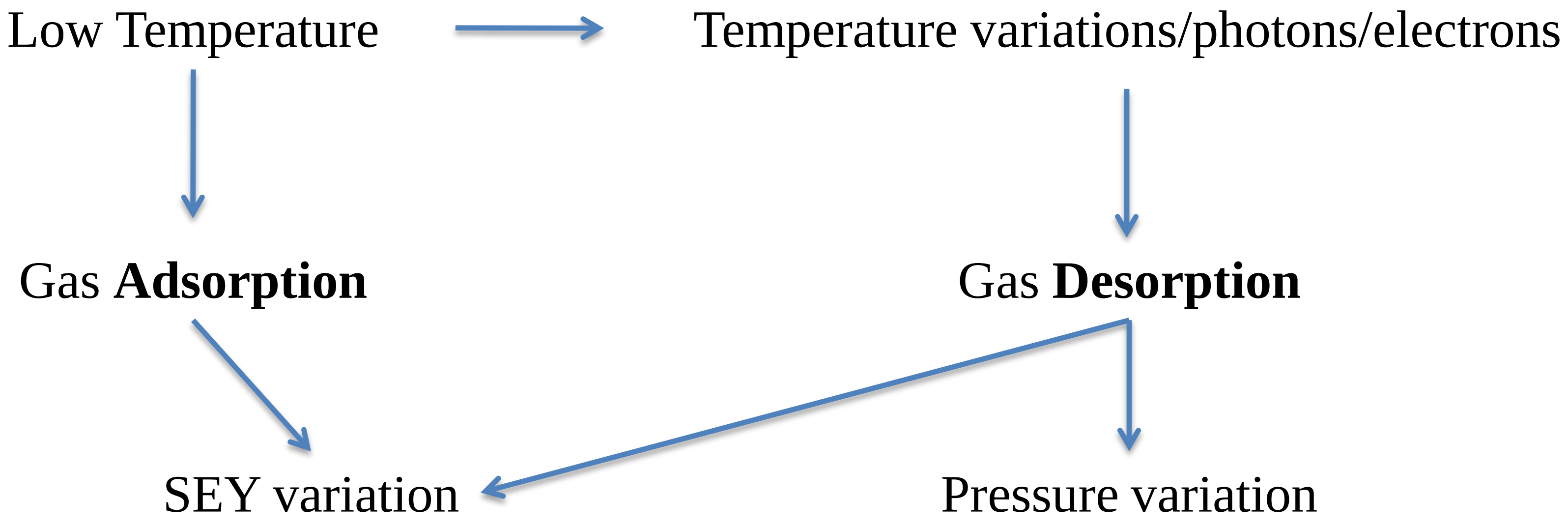
R. Valizadeh et al. , Appl. Surf. Sci. (2017)

Laser ablation on Cu substrate (LASE-Cu)



e^- cloud mitigation strategies

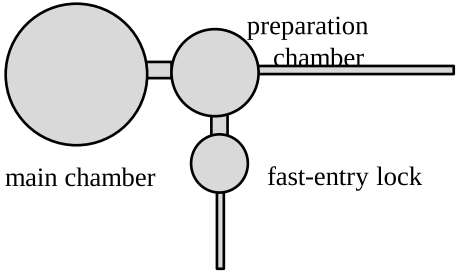
Strategy and experimental set-up at LNF



SEY, Mass Spectrometry, Thermal Programmed Desorption (TPD) and XPS (as soon) as useful techniques to quantitatively follow adsorption/desorption kinetics

Strategy and experimental set-up at LNF

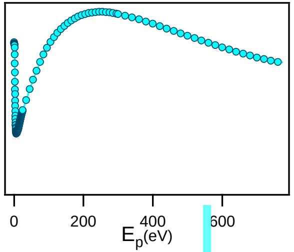
Ultra high vacuum systems

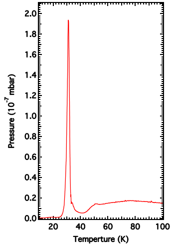


- LNF-cryogenic manipulator
- Sample at **15-300 K**

Secondary Electron Yield (SEY) measurements

Equipment : Electron gun, Faraday cup

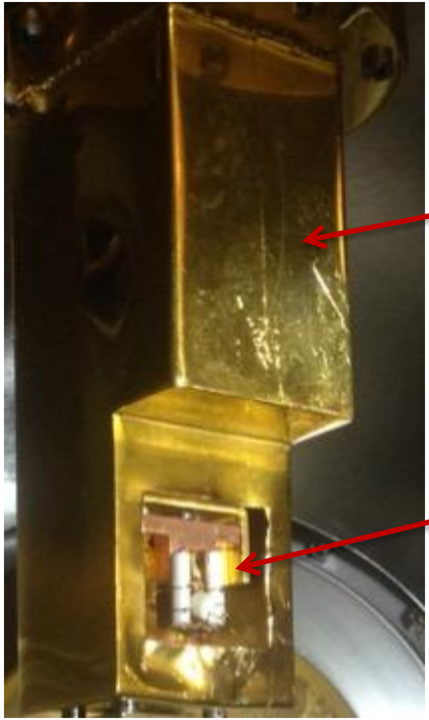




Temperature Programmed Desorption (TPD) and Mass Spectrometry measurements

Equipment : QMS (Hiden HAL 101 Pic)

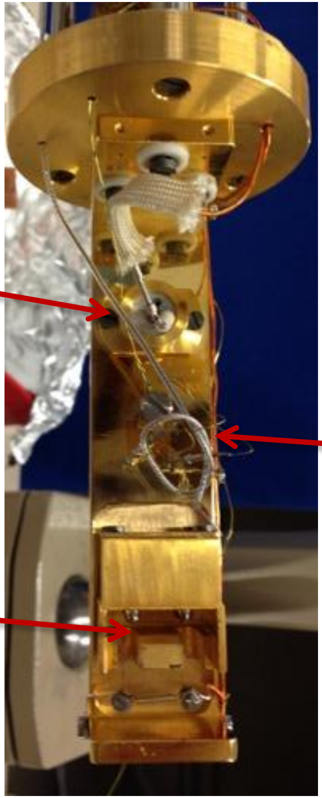
Strategy and experimental set-up at LNF



Screen

Sample

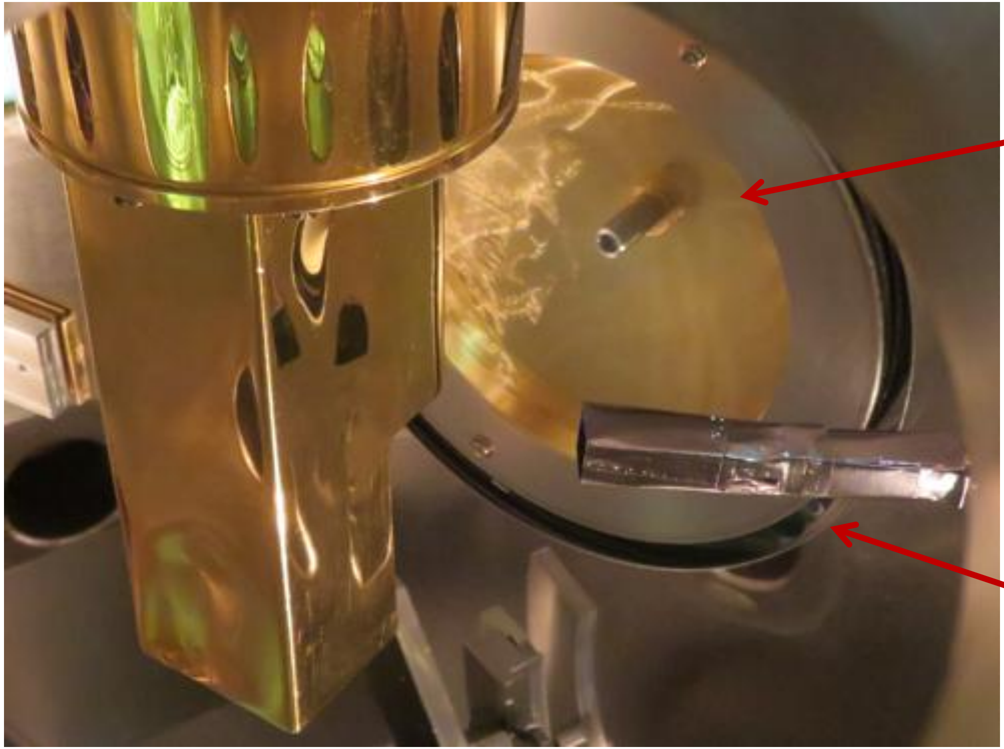
Heater



T Sensor

Sample
Holder

Strategy and experimental set-up at LNF

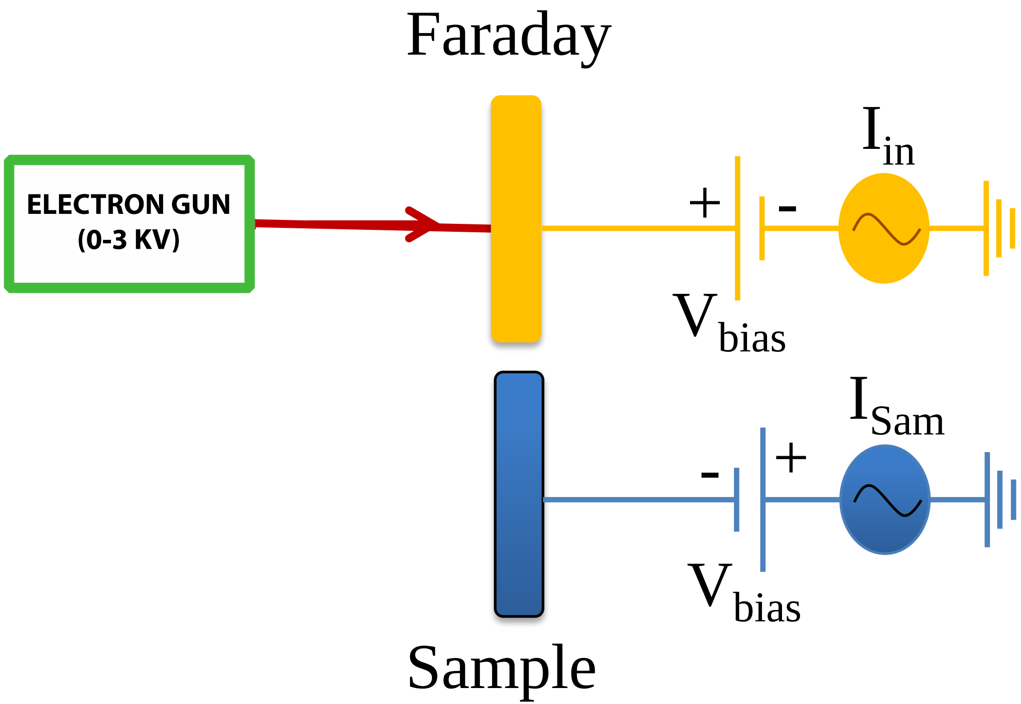


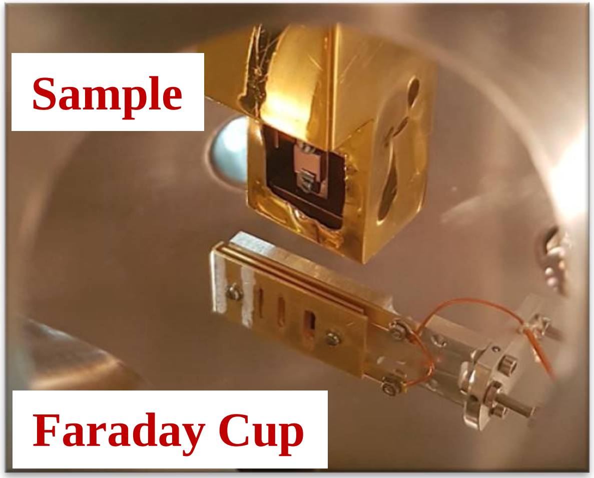
Electron gun

Retractile gas dosing system

Strategy and experimental set-up at LNF

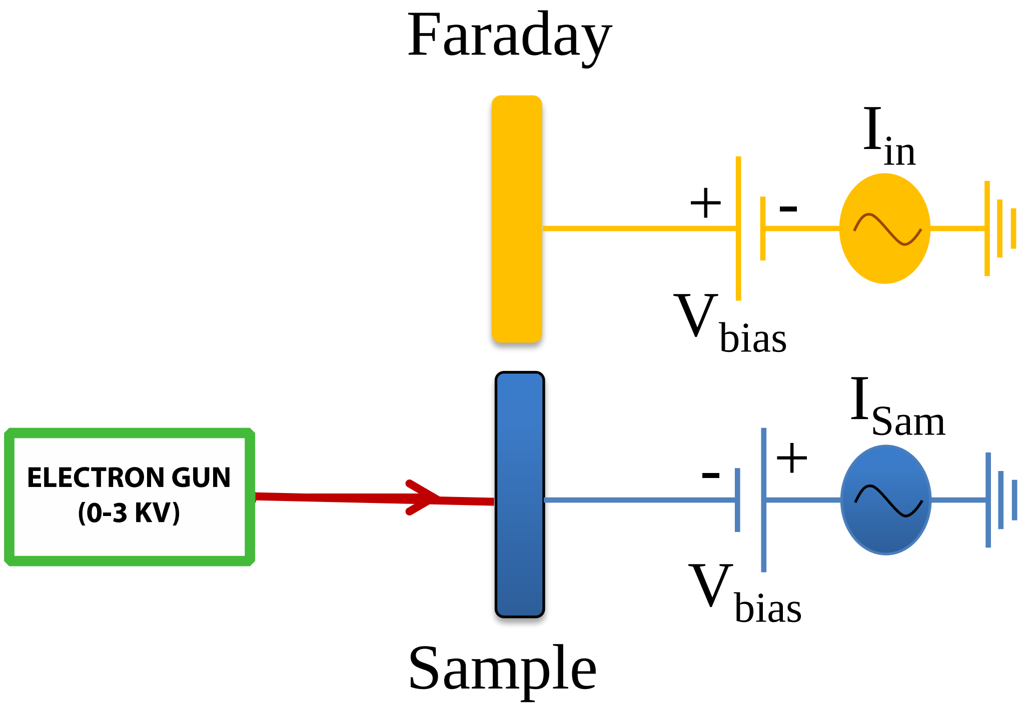
$$SEY = \delta = \frac{I_{out}}{I_{in}}$$

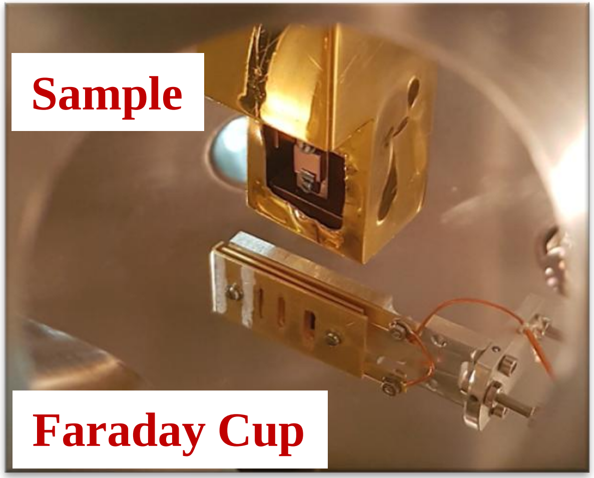




Strategy and experimental set-up at LNF

$$SEY = \delta = \frac{I_{out}}{I_{in}} = \frac{I_{in} - I_{sam}}{I_{in}}$$

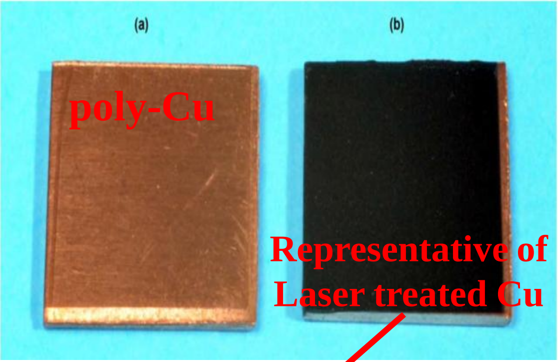


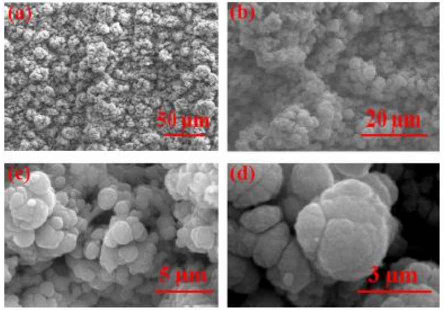


Results

- TPD from LASE-Cu for temperature induced vacuum transients study
- SEY to probe the surface coverage
- Electron desorption studies: preliminary results

TPD from LASE-Cu for temperature induced vacuum transients study





Applied Physics Letters ARTICLE scitation.org/journal/apl

On the compatibility of porous surfaces with cryogenic vacuum in future high-energy particle accelerators

Cite as: Appl. Phys. Lett. **114**, 153103 (2019); doi: 10.1063/1.5085754
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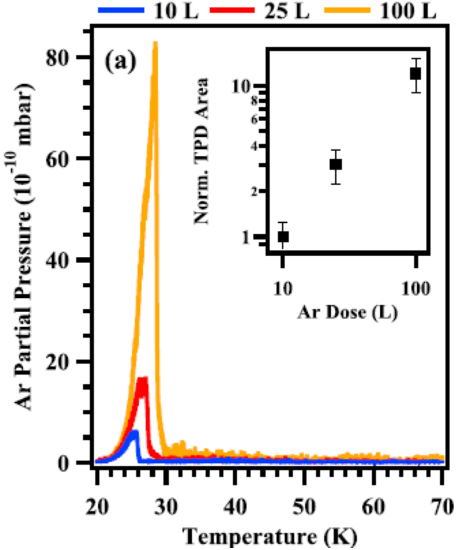
L. Spallino,[1,a)] M. Angelucci,[1] R. Larciprete,[1,2] and R. Cimino[1,3]

What about the influence of the surface features on the vacuum stability?

Comparative study of Ar TPD from flat poly-Cu and LASE-Cu samples

TPD from LASE-Cu for temperature induced vacuum transients study



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

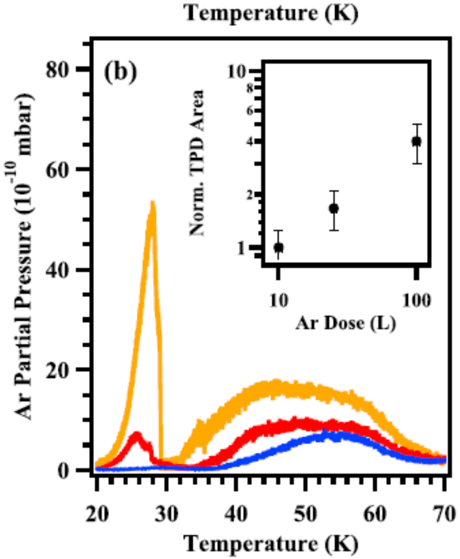
poly-Cu

L. Spallino et al. , Appl. Phys. Lett. (2019)

LASE-Cu

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

TPD characteristics determined by the sponge-like structural features



Thank you for your attention

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