ECLOUD´12

Novel Types of Anti-e Cloud Surfaces

I. Montero[1], V. Nistor[2], L.Aguilera[1], L.Galán[2], D. Raboso[3], L.A. González[2], M.E. Dávila[1], P. Costa Pinto[4], M.Taborelli[4] and F.Caspers[4]

[1]ICMM-CSIC

[2]UAM, [3]ESA, [4]CERN

Outline

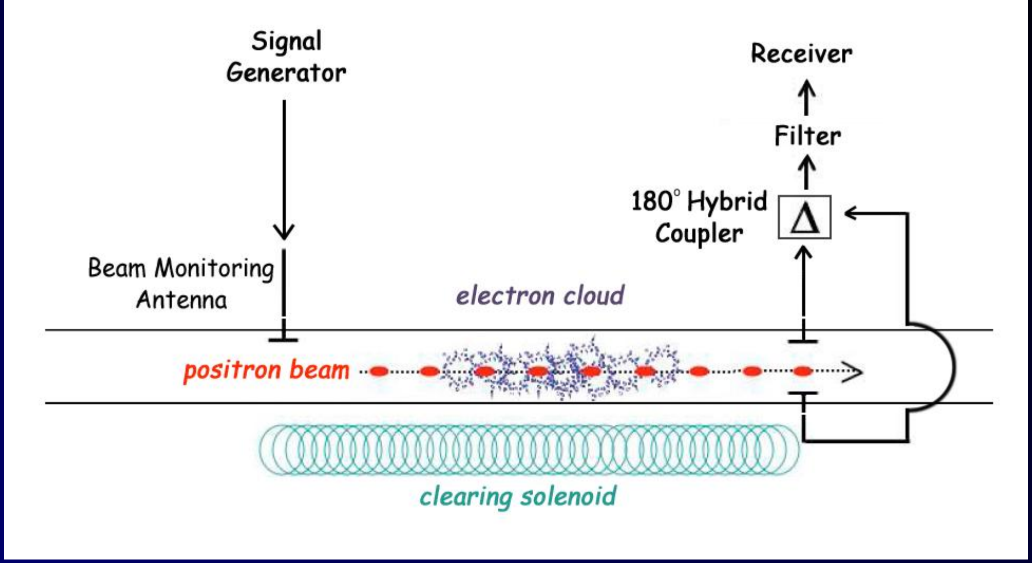
- **Main goals**
- **Basic Objectives and Concepts**
- **Critical Experimental Activities**
- **Anti-ecloud-Multipactor Coatings:**

  SEY Research
- **Summary and Conclusions**

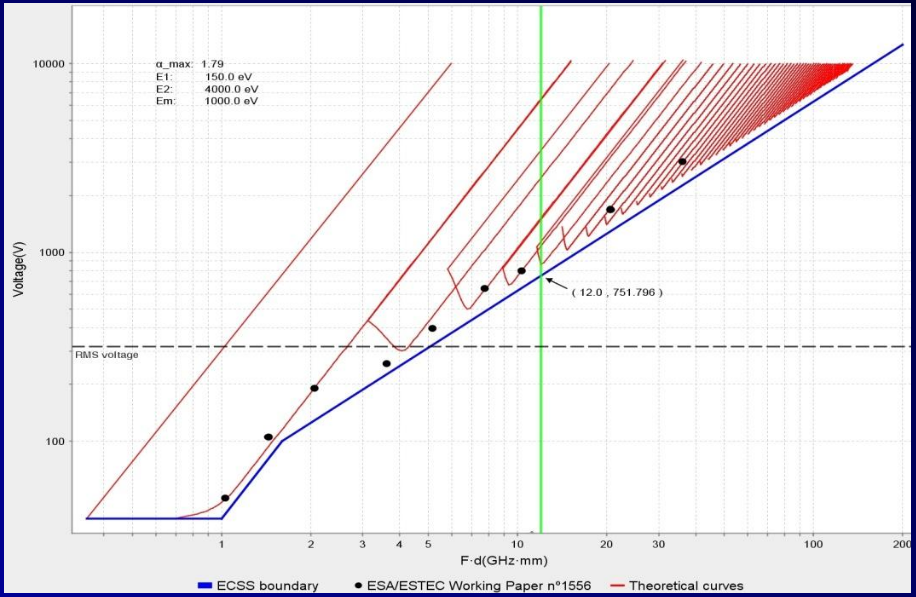
Main goals

To mitigate:

1. **The electron cloud and its adverse consequences**



2. **The multipactor effect in space-related high-power RF hardware**



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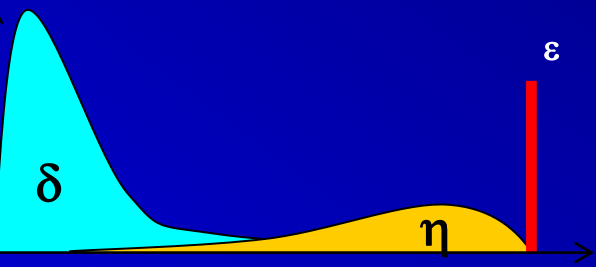
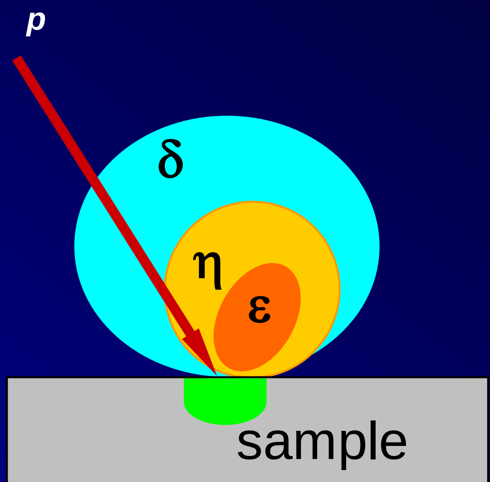
Basic Objectives and Concepts

Development of coatings with low secondary electron emission yield (SEY)





Basic Objectives and Concepts

MAIN OBJECTIVES:

Very low SEY — **by surface material** of low SEY
by surface roughness of high aspect ratio and density

Very low RF surface resistance ► **by optimization of depth** of surface roughness

Very slow aging in air — **by stable surface material**

Basic Objectives and Concepts

MAIN OBJECTIVES:

Very low SEY

like Au / roughAg
$\sigma_{max} < 1.5$
$E_1 > 200$ eV

Very low RF surface resistance ►

close to Ag
$R_s < 3x$ Rsurf(Ag)

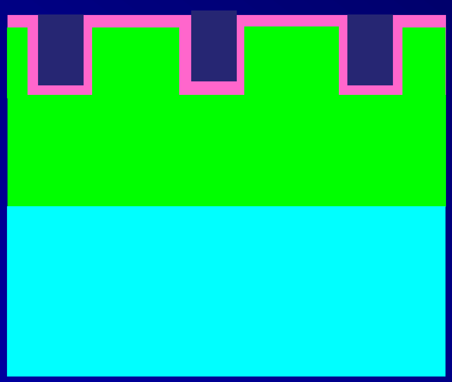
Very slow aging in air

Stability one year

Critical experimental activities

MAIN CONCEPTS: Multilayer coating

Multilayer coating



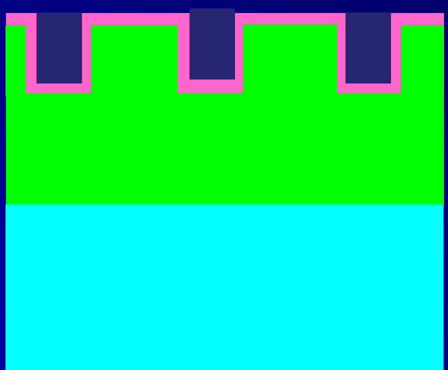
low-SEY layer

roughness layer

conductive layer

Critical experimental activities

MAIN CONCEPTS: Multilayer coating



Multilayer coating	Material	Thickness
low-SEY layer	Au, Rh, Ir, TiN, BC,…	5 – 50 nm
roughness layer	Ag, Cu, Au Rh, TiN, …,	50 – 1000 nm 50 – 500 nm
conductive layer	Ag, Cu	5 – 20 µm

SEY suppression increases with roughness shape (aspect ratio, density, profile)

RF surface resistance increases with roughness size

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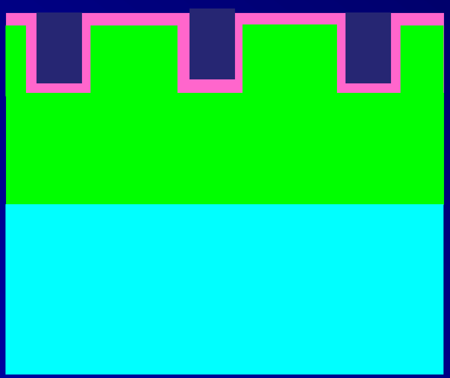
Critical experimental activities

MAIN CONCEPTS: Multilayer coating



Multilayer coating	Material	Thickness
low-SEY layer	Au, Rh, Ir, TiN, BC,…	5 – 50 nm
roughness layer	Ag, Cu, Au Rh, TiN, …,	50 – 1000 nm 50 – 500 nm
conductive layer	Ag, Cu	5 – 20 µm

SEY and Roughness

to be optimized

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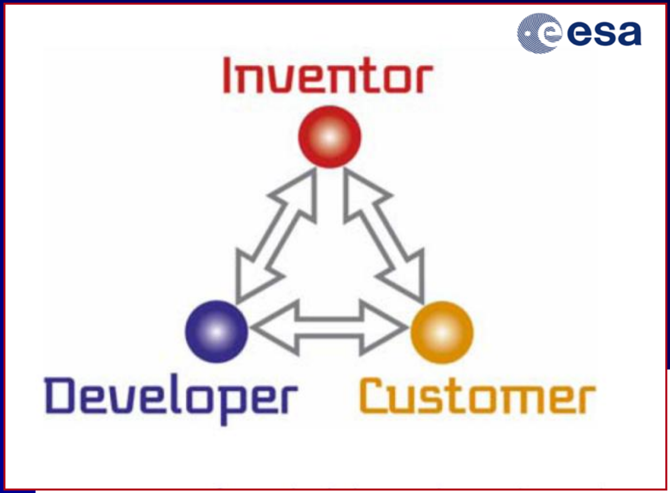
Critical experimental activities



ESA PROJECT

UAM
Departamento de
Física Aplicada

TESAT
SPACECOM
PIONEERING WITH PASSION

CSIC
Consejo Superior de Investigaciones Científicas
INSTITUTO DE CIENCIA DE MATERIALES
DE MADRID (ICMM)

ITI

Innovation Triangle Initiative

Optimization of Surface Roughness of Anti-Multipactor Coatings for Low Insertion Losses and Secondary Emission Suppression for High Power RF Components in Satellite Systems

GOBIERNO
DE ESPAÑA

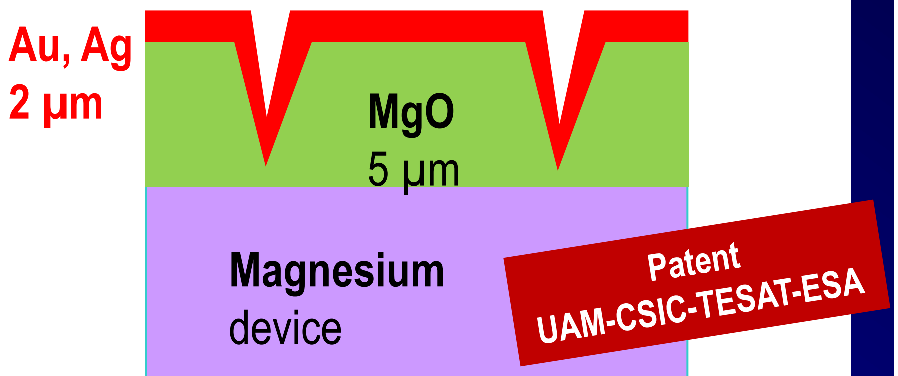
MINISTERIO
DE CIENCIA
E INNOVACIÓN

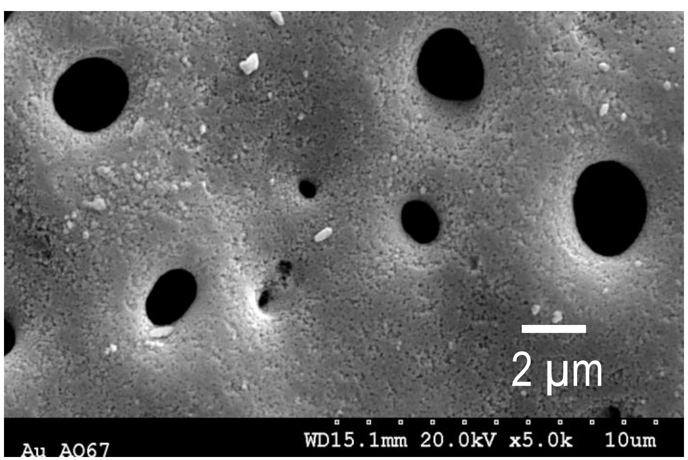
Critical experimental activities

Anti-Multipactor Coatings

Two different kinds tested

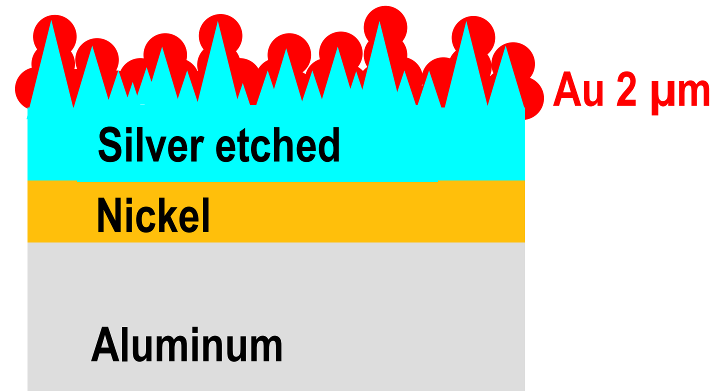
Gold-coated anomag

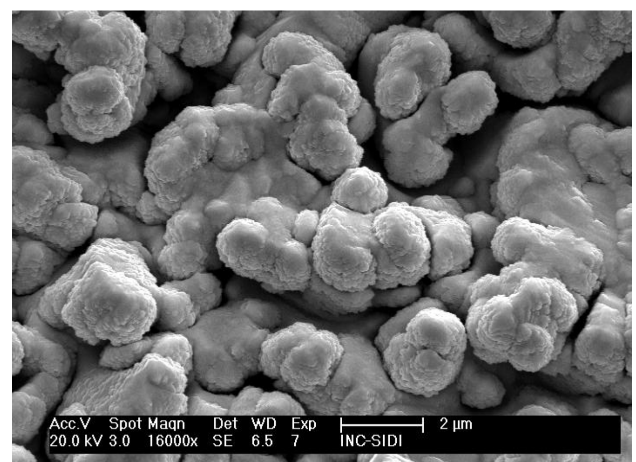




$\Delta \approx 1\mu m$ $R_r/R_s = 2.2$ @ 9.5 GHz

Gold-coated etched silver

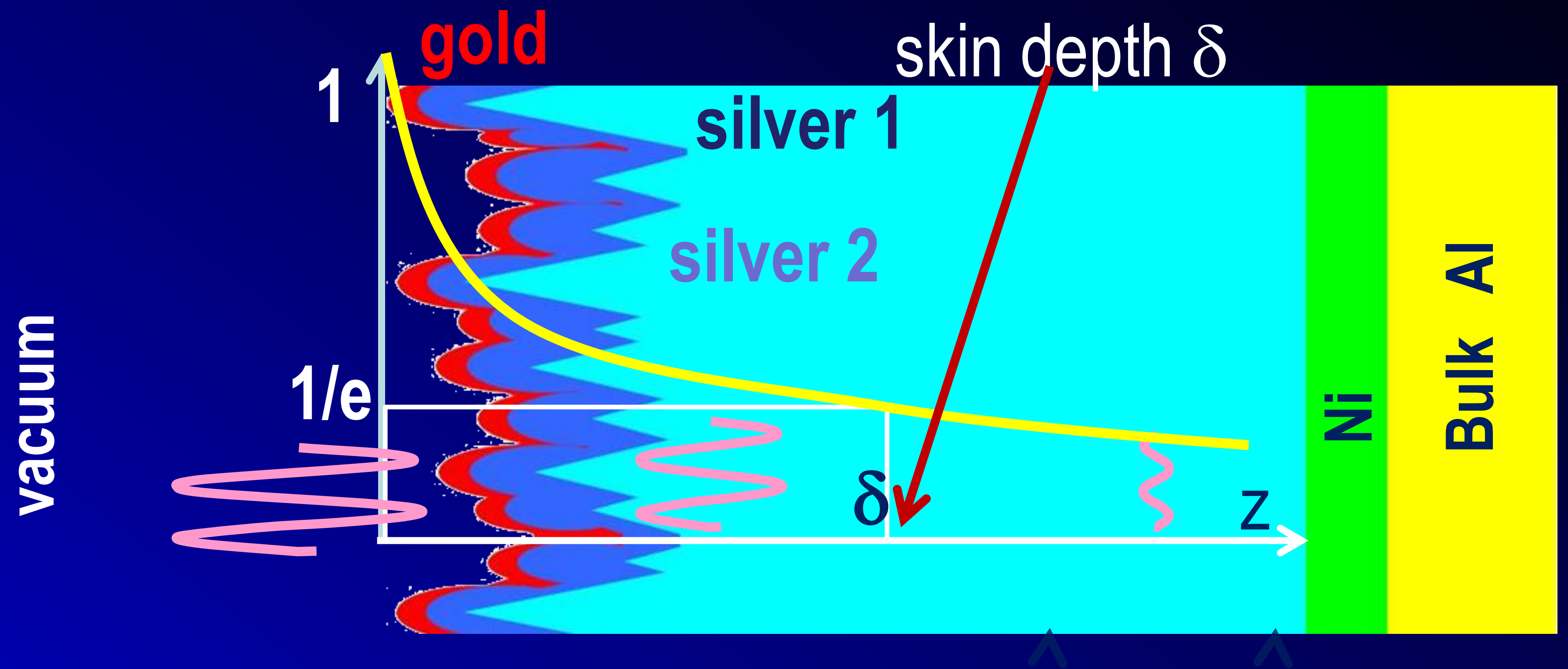




$\Delta \approx 1\mu m$ $R_r/R_s = 2.4$ @ 12 GHz

Critical experimental activities

Insertion losses /surface rough. is a crucial issue



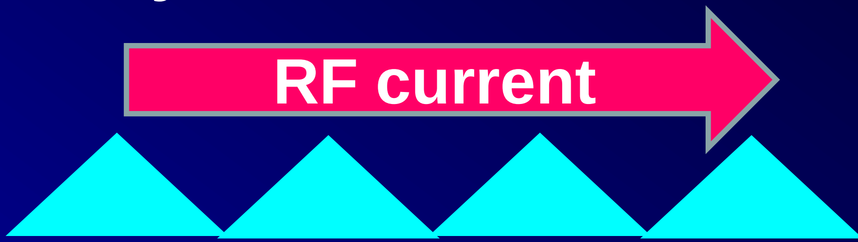
At sufficient high ω, the induced Is are confined by the skin effect to a surface region of poor σ because of surface roughness

surface region formed by a coating of thickness d_{coat} over a substrate,

$\delta = \sqrt{\frac{\rho_{dc}}{\pi\mu_o f}}$

Critical experimental activities

A Layered Model for RF Surface Resistance Calculation

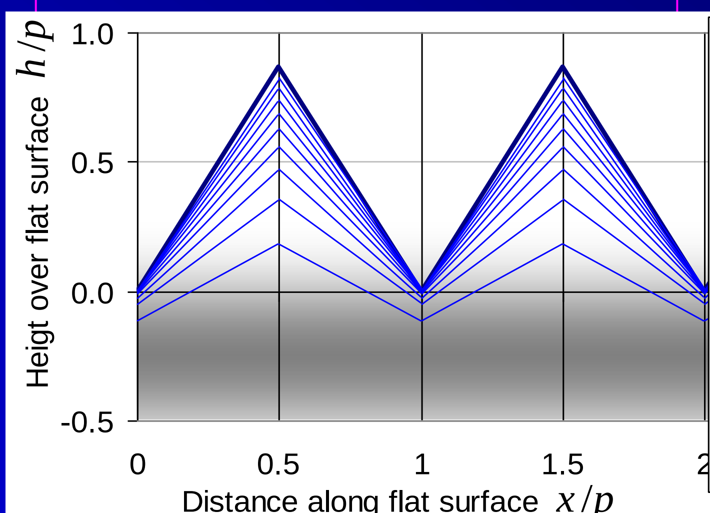


R_s = RF SURFACE RESISTANCE

Resonant circuit

$$\delta = \sqrt{\frac{\rho_{dc}}{\pi \mu_o f}}$$

$$R_s = \frac{1}{\sigma_{dc}\,\delta} = \sqrt{\pi \mu_o \rho_{dc} f}$$



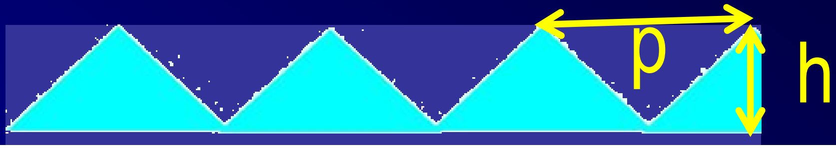
$$\frac{1}{R_s} = \int_0^{\infty} \frac{1}{\rho \cdot A(z, \delta, geometry)} e^{-\frac{z}{\delta}} dz$$

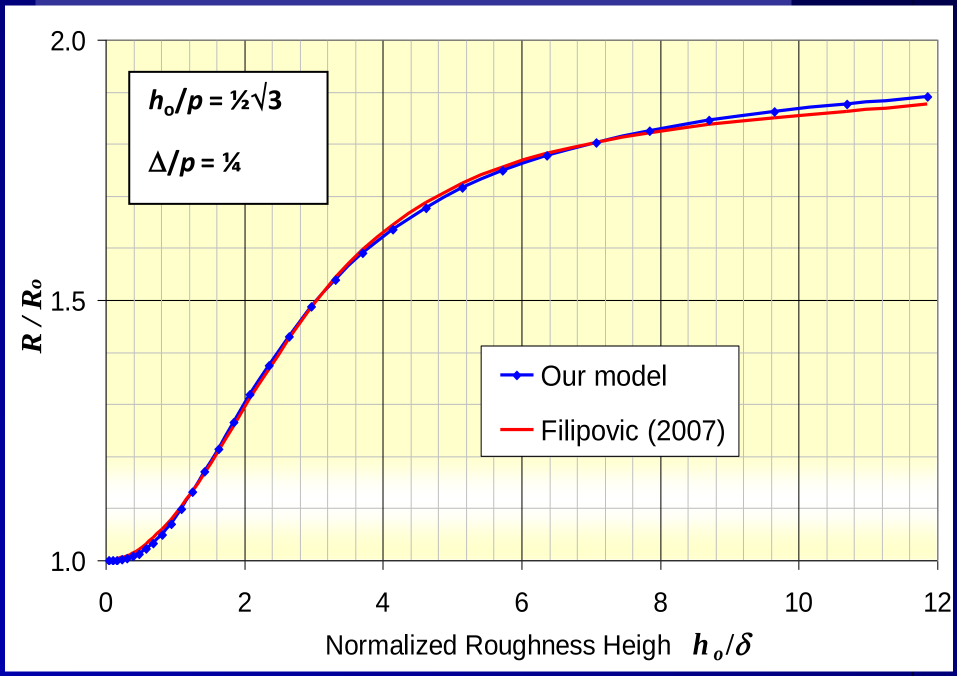
A: Factor of increased current path at depth z due to roughness

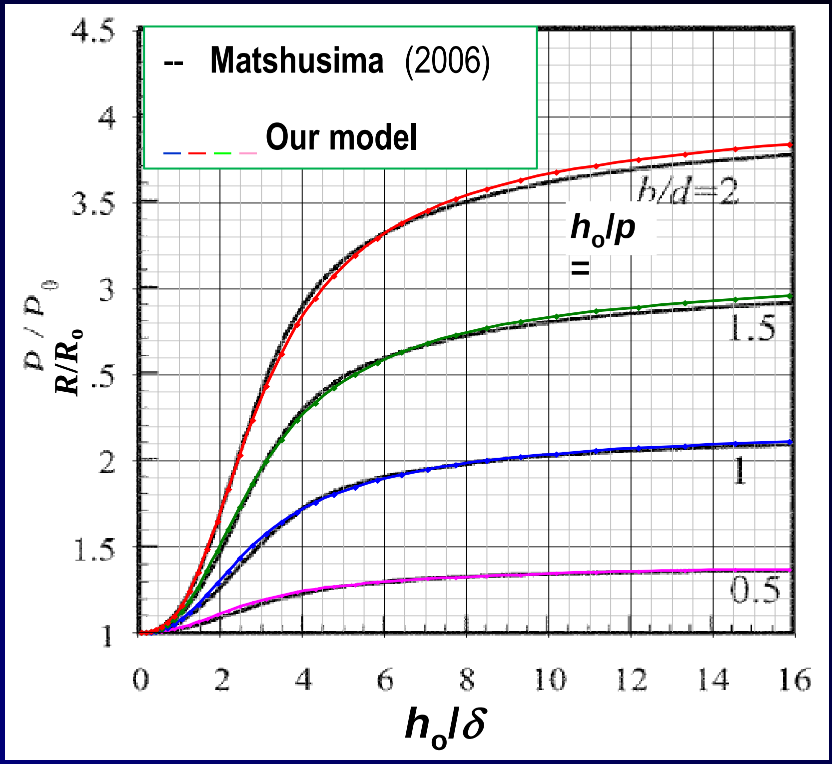
Anti-ecloud Coatings

$$\frac{1}{R}=\int_0^\infty \frac{1}{\rho \cdot A} e^{-\frac{z}{\delta}} dz$$

A Layered Model for RF Surface Resistance Calculation







Using this function with three fitting parameters it is possible to fit the results of Filopovic or Matsushima

M V Lukic, D S Filipovic:; IEEE, 55, 518-525 (2007)

A. Matsushima and K. Nakata: Elect. Commun. Jpn. 89 (1) 1 (2006).

Anti-ecloud Coatings

Anti-Multipactor Coatings
Deposition Methods

Gas (UHV)

Physical Vapor Deposition

Evaporation

Ion implantation

Sputtering

Liquid

Chemical Bath Deposition

Chemical Etching

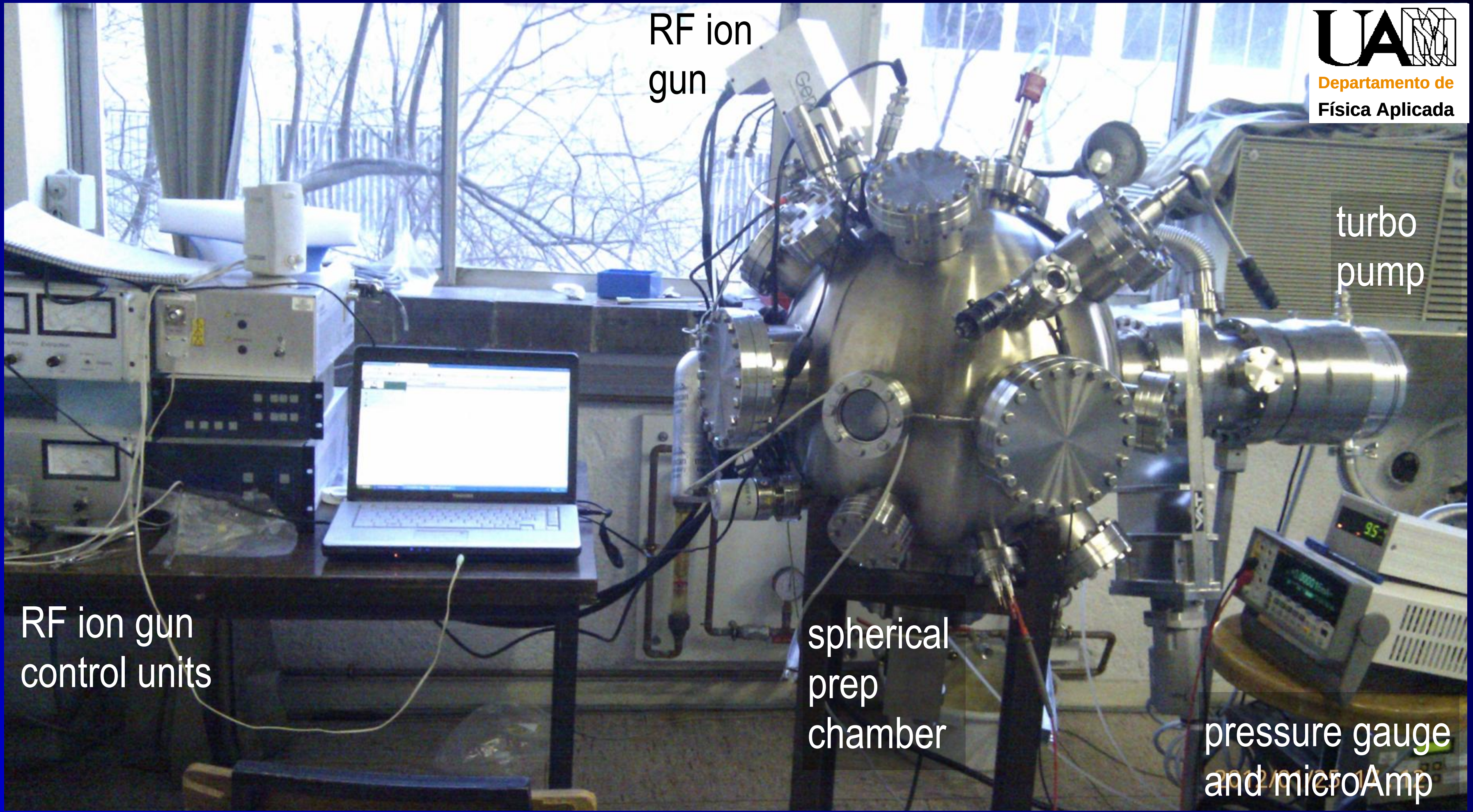
Anodization

Solid

Particle Deposition

Anti-ecloud Coatings

UHV preparation chamber with RF ion gun for deposition of anti-multipactor coatings



Anti-ecloud Coatings

Selected materials

- Silver
- Gold
- NEG
- Graphene like coatings
- Magnetic and dielectric/metal composites: particulated surfaces

Anti-ecloud Coatings

Selected materials

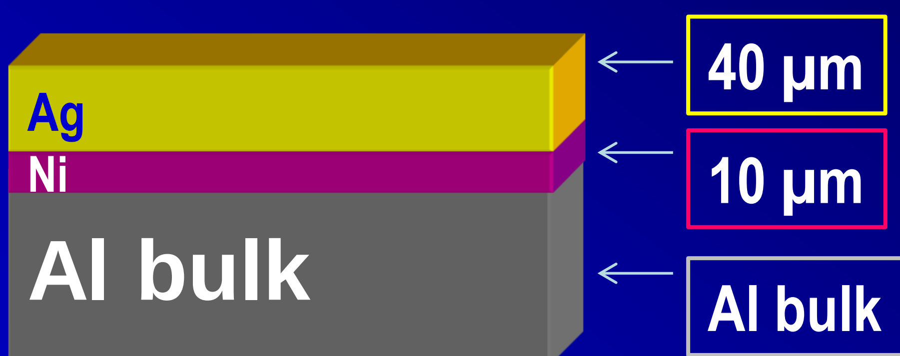
- Silver

Anti-ecloud Coatings

SEY Characteristics of Mo-Masked, Ion-Textured Silver

Method for producing

1. uniform,
2. highly textured surface on high-conductivity Ag



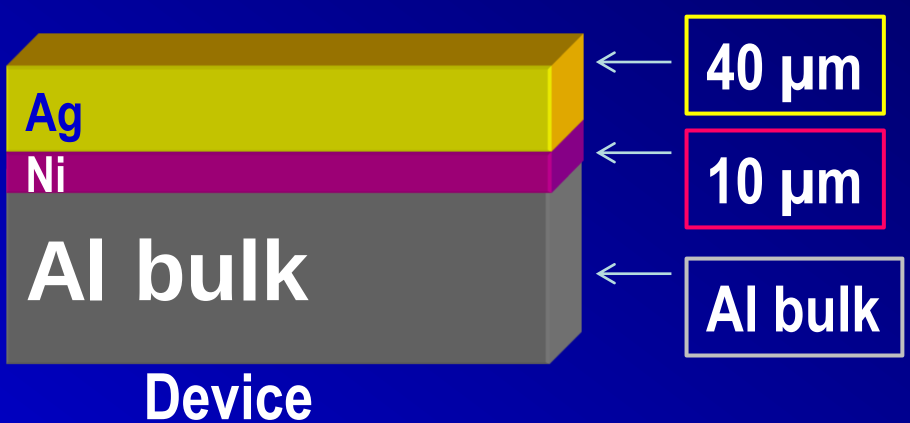
Device

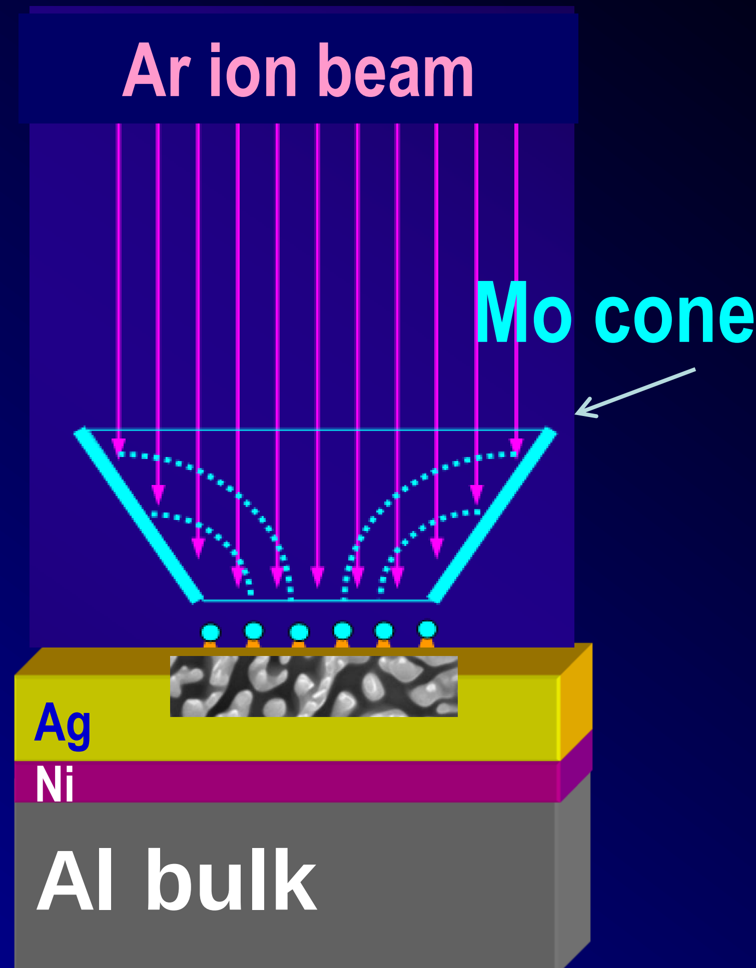
Anti-ecloud Coatings

SEY Characteristics
of Mo-Masked, Ion-Textured Silver

Method for producing

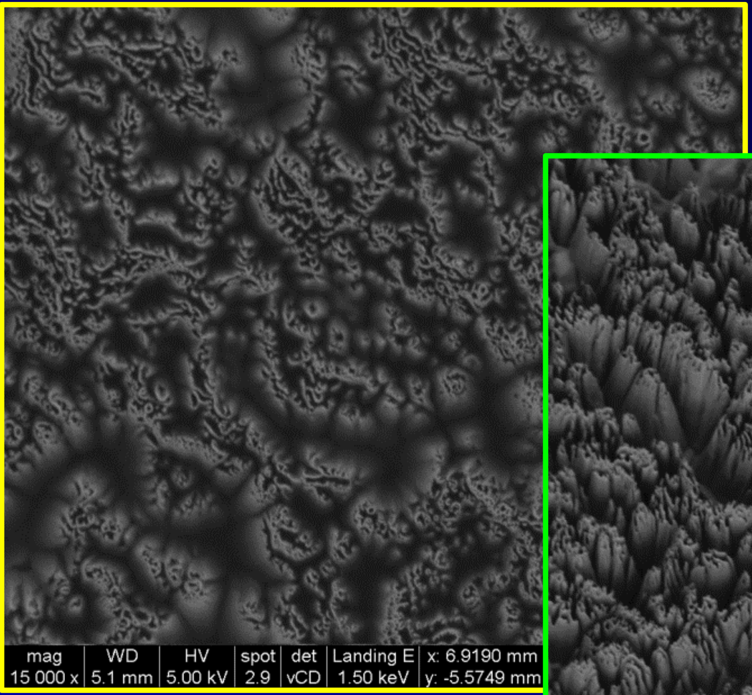
1. uniform,
2. highly textured surface on high-conductivity Ag

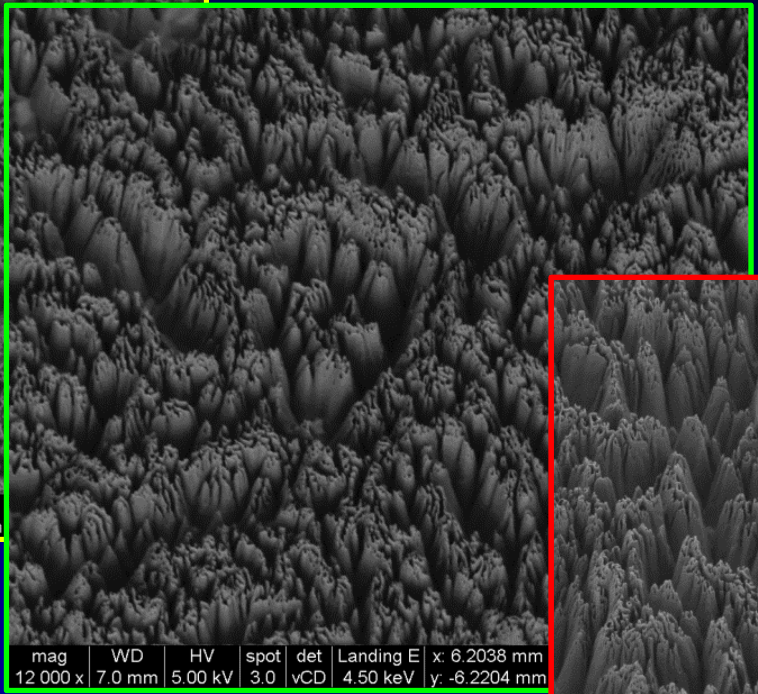


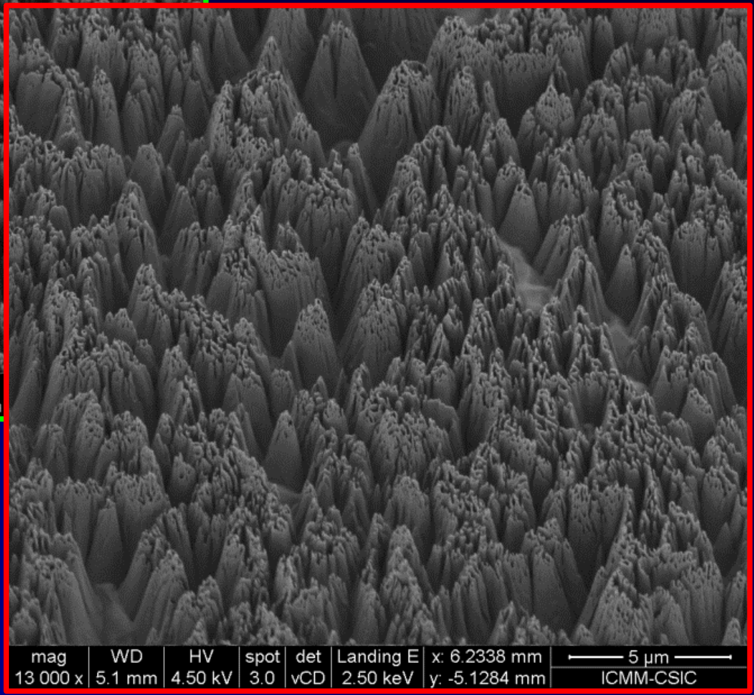


Anti-ecloud Coatings

SEM of Ag treated coating







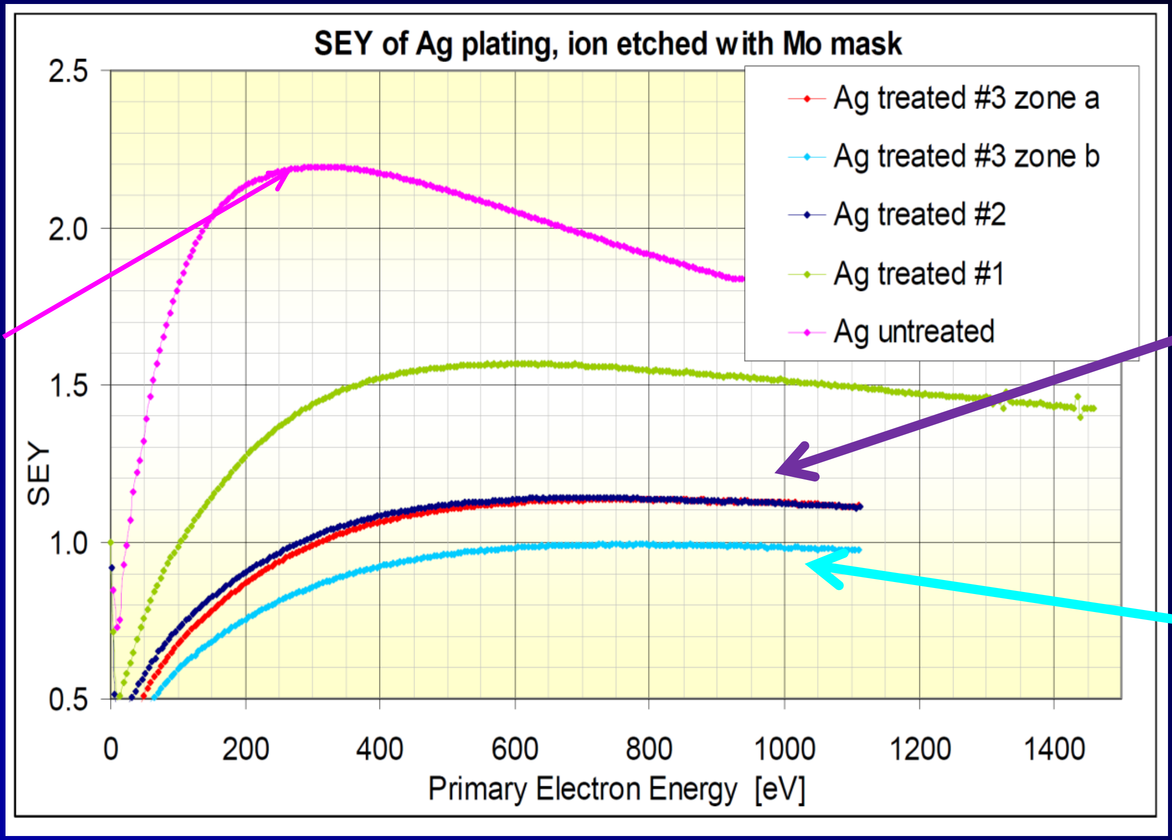
Surface roughness depends on

1. **Ion density**
2. **Ion energy**
3. **Time**

Anti-ecloud Coatings

SEY of Ag treated coating

Its untreated surface displays relatively very high levels of SEY



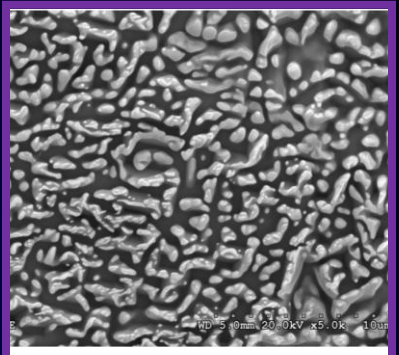
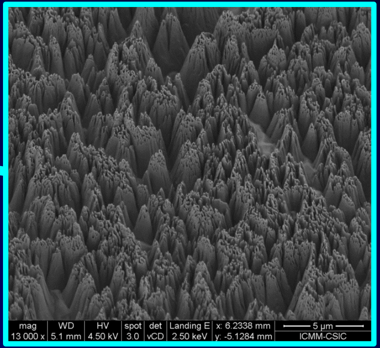


Fig.2 SEM of sample Ag treated #2.



SEY of Ag plating after treatment and exposure to the air.

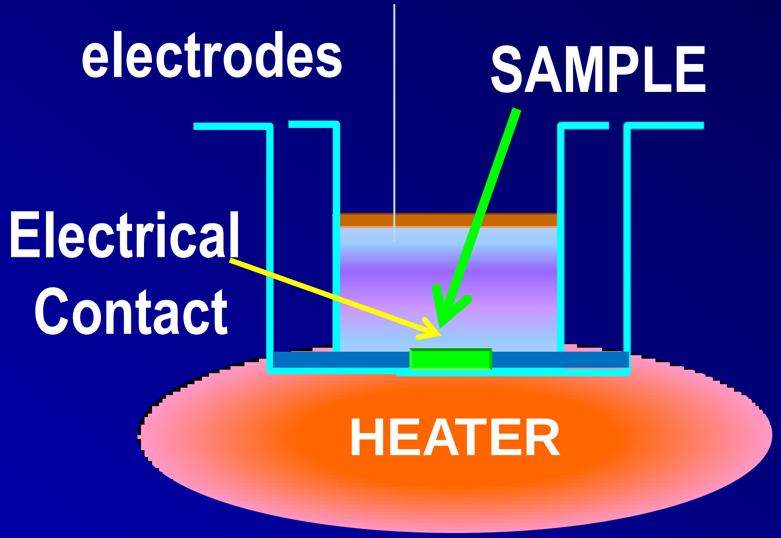
The purpose was to develop a basically Ag surface having very low-SEY characteristics.

Anti-ecloud Coatings

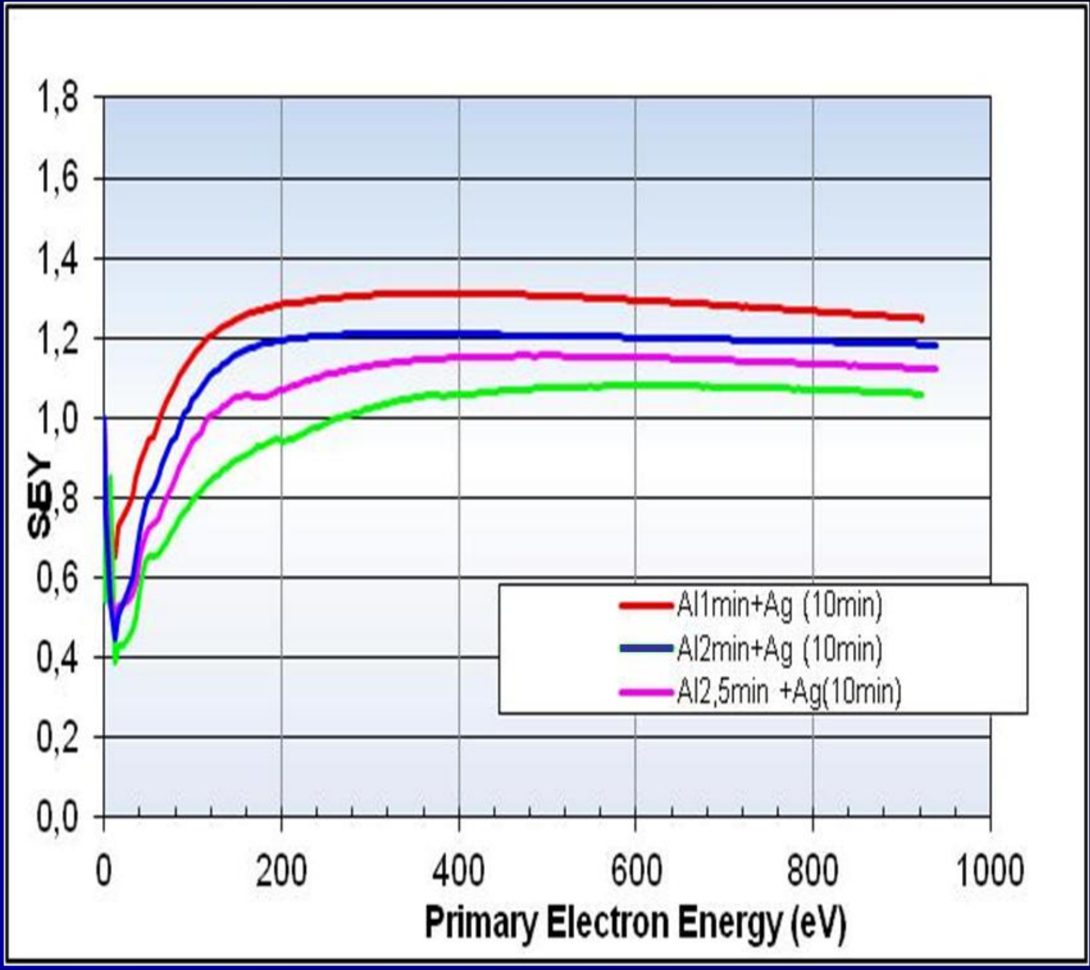
CBD Chemical Bath Deposition Method

Growing rough Ag coating

With and without Efield



Preparation conditions
Growth Temperature 50ºC
TEA
$AgNO_3$
$SnCl_x$



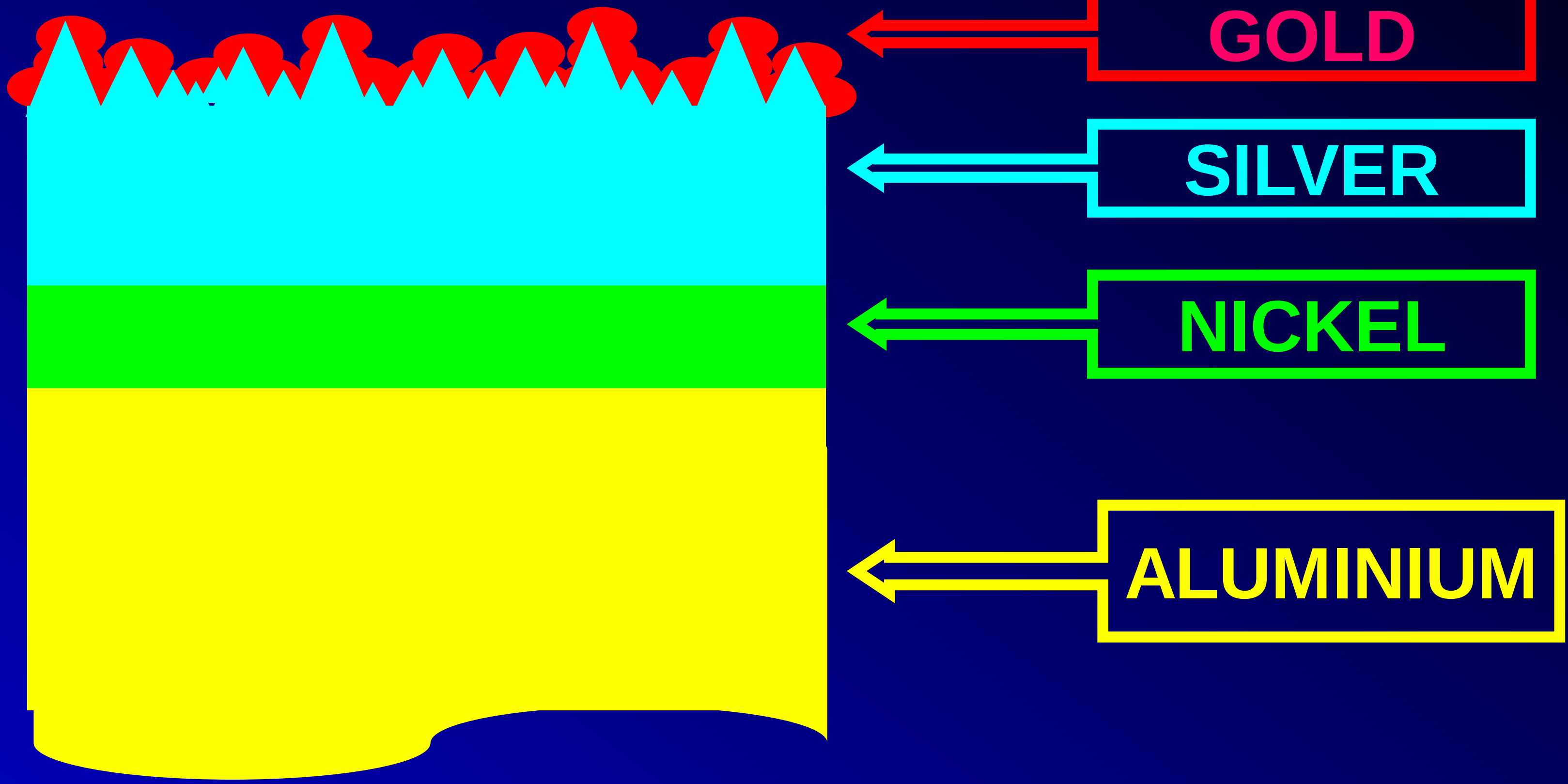
Anti-ecloud Coatings

Selected materials

- Gold

Anti-ecloud Coatings

Nanometric Au layer to prevent aging process
to decrease SEY



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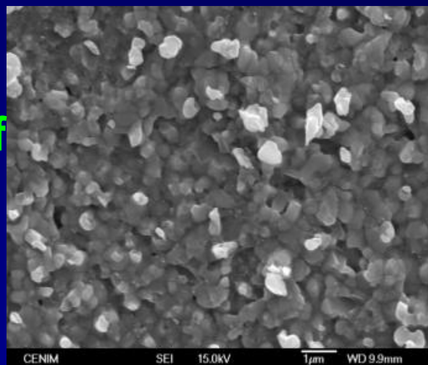
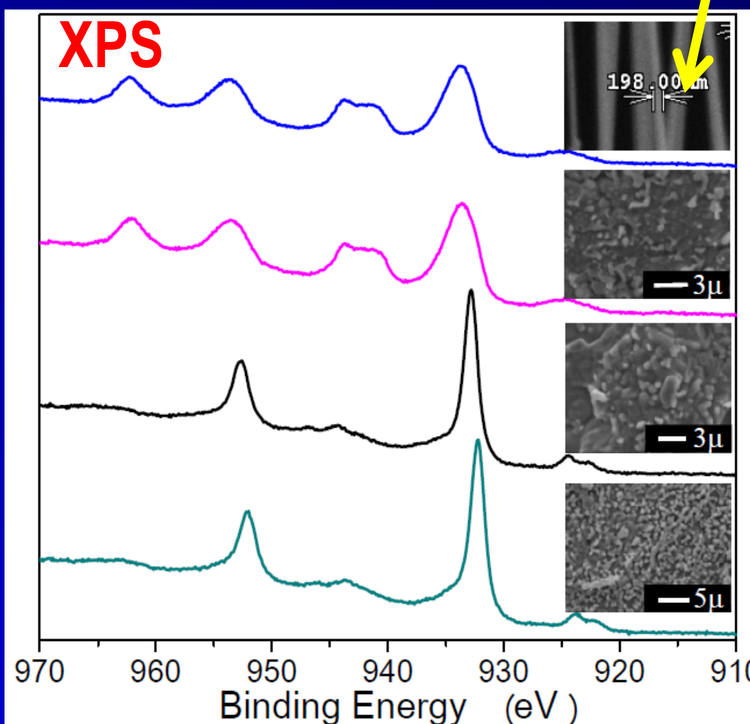
Anti-ecloud Coatings

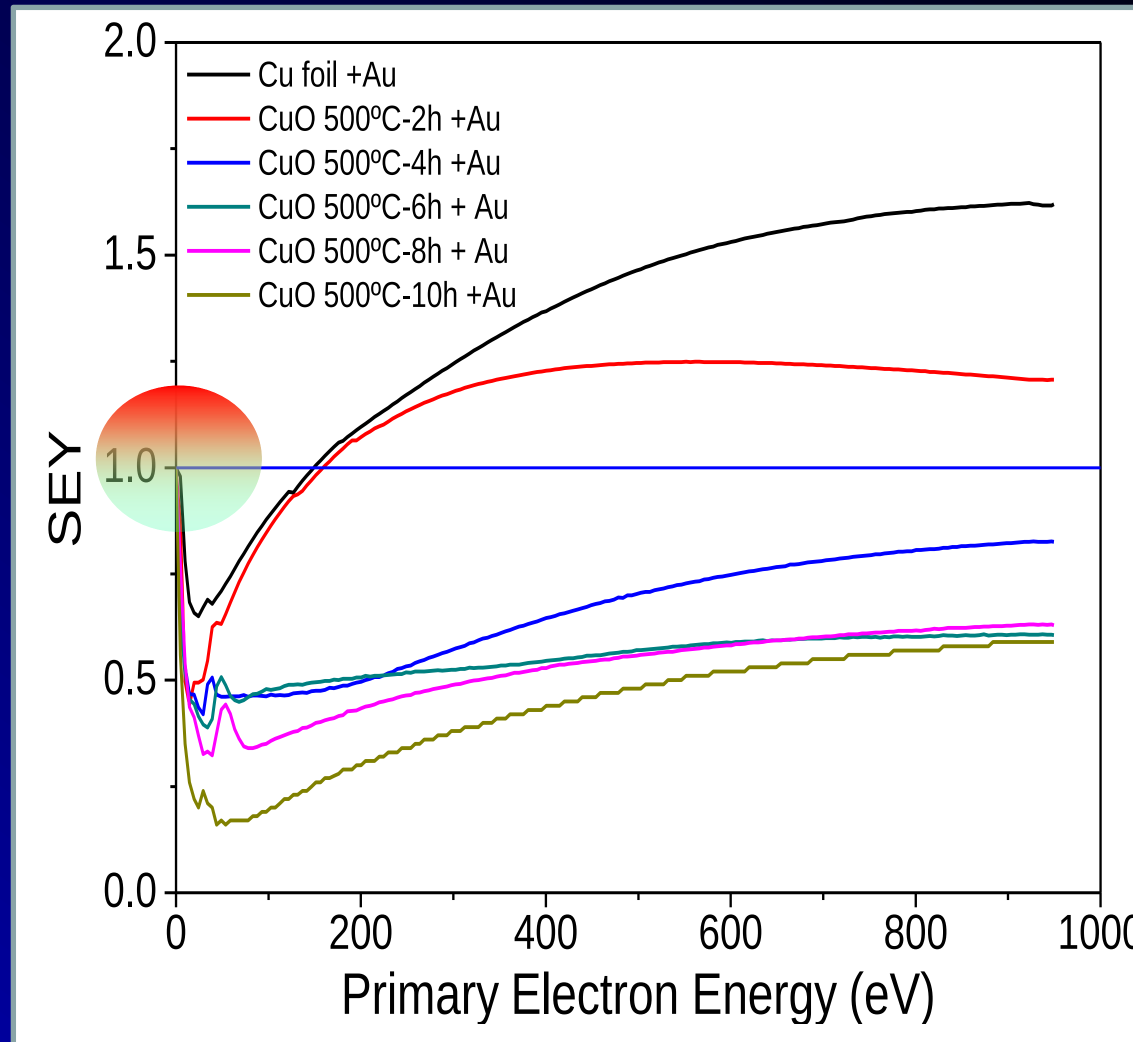
Au coated CuO nanowires

First stadies of NW growth



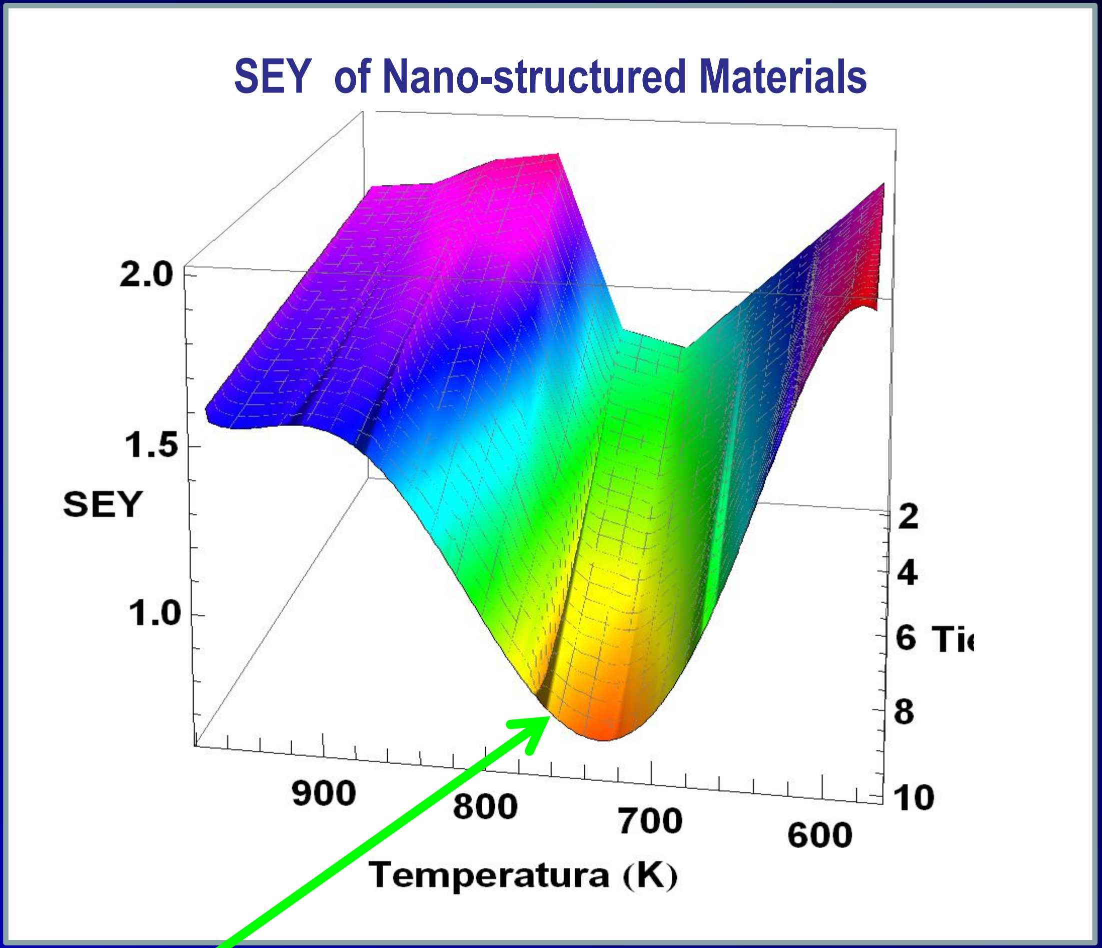
NW





Anti-ecloud Coatings

SEY experimental measurements
Au coated CuO nanowires



aspect ratio 1:1000

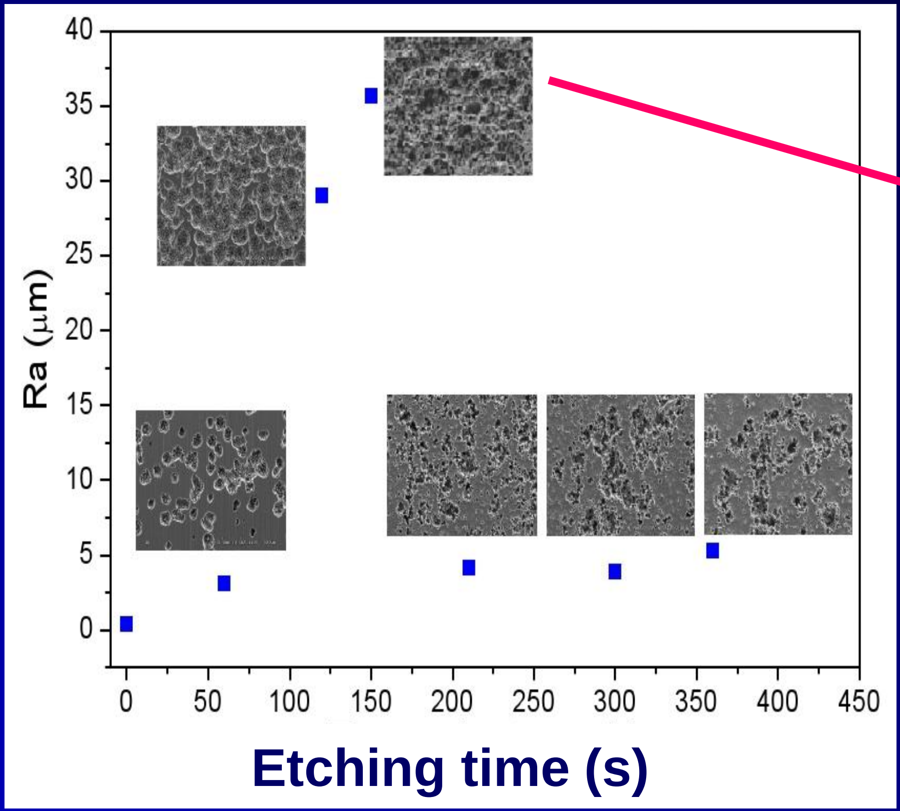
Anti-ecloud Coatings

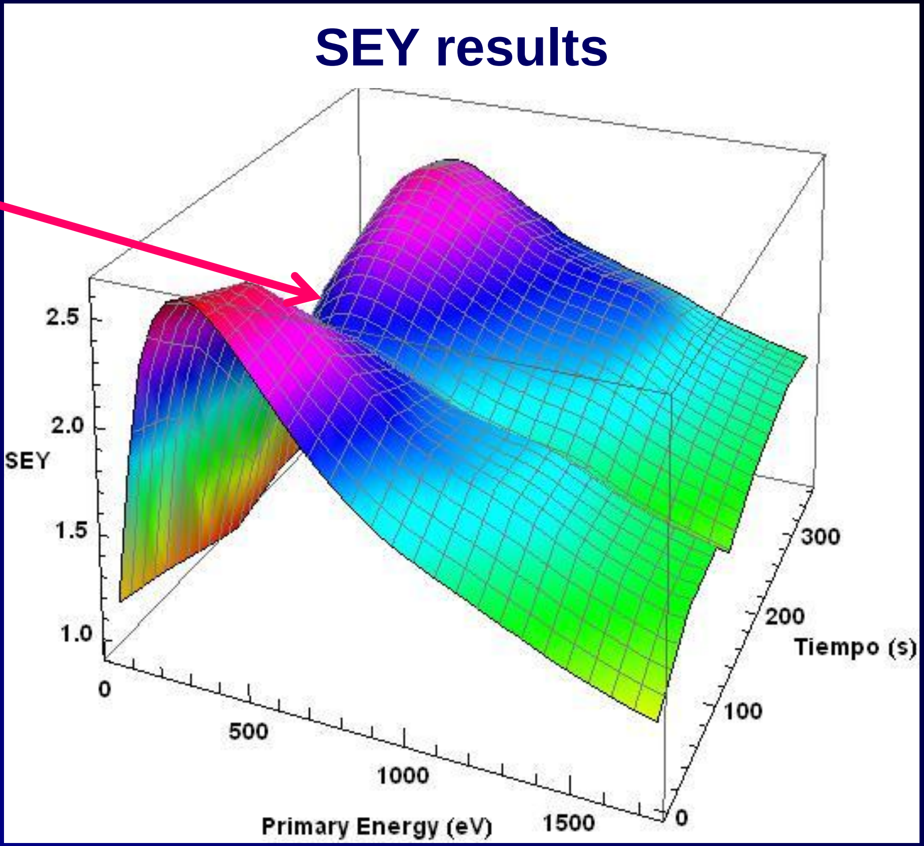
Selected materials

- **NEG**
  Non-Evaporable Getter

Anti-ecloud Coatings

Substrate: Rough Al





Correlation between SEY and Ra

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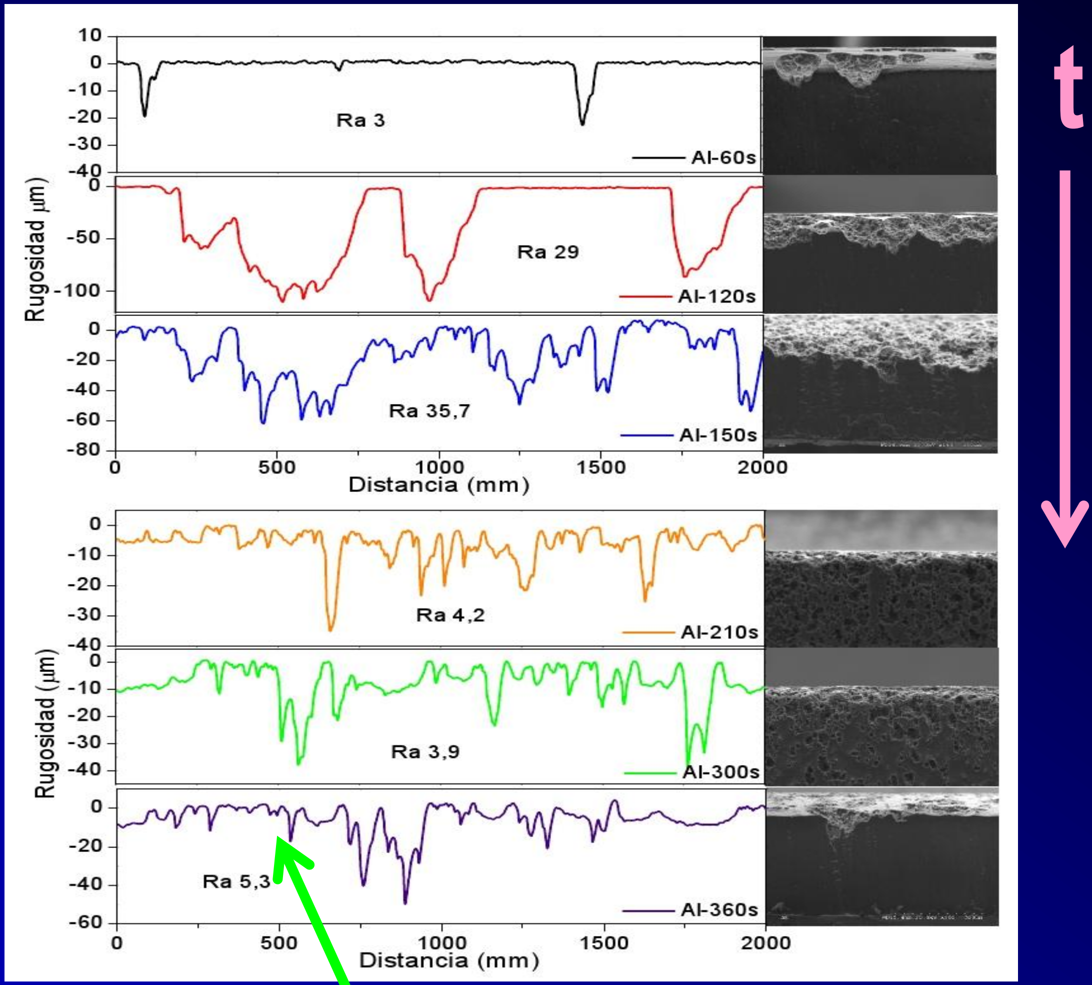
Anti-ecloud Coatings

Aluminium etched, HCl



profilometry measurements

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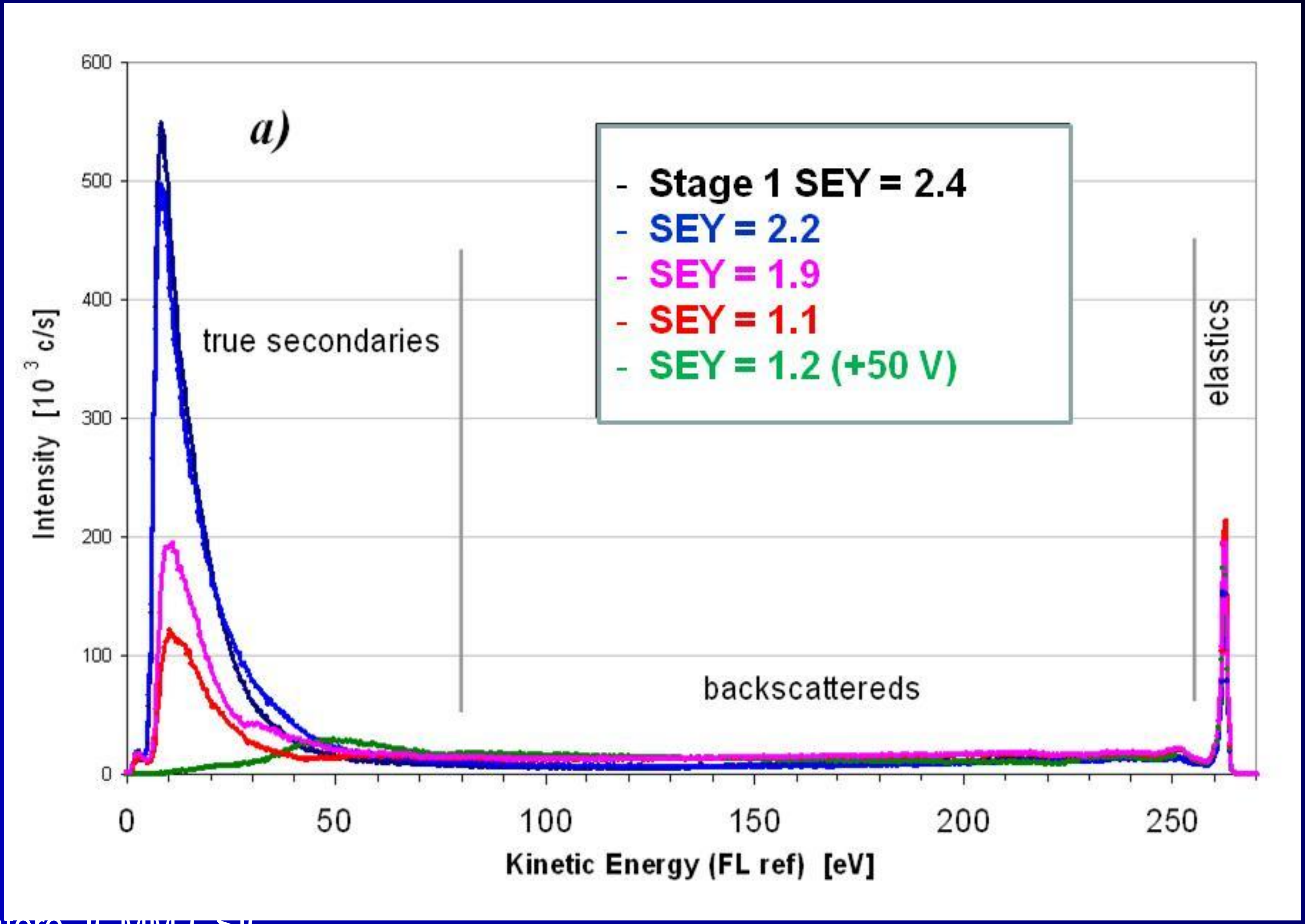
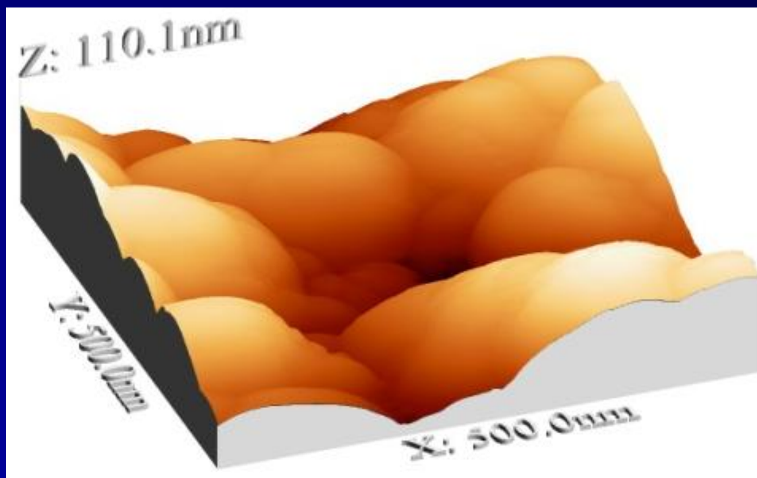
Anti-ecloud Coatings

Anti-Multipactor Coatings
EDC curves for Al

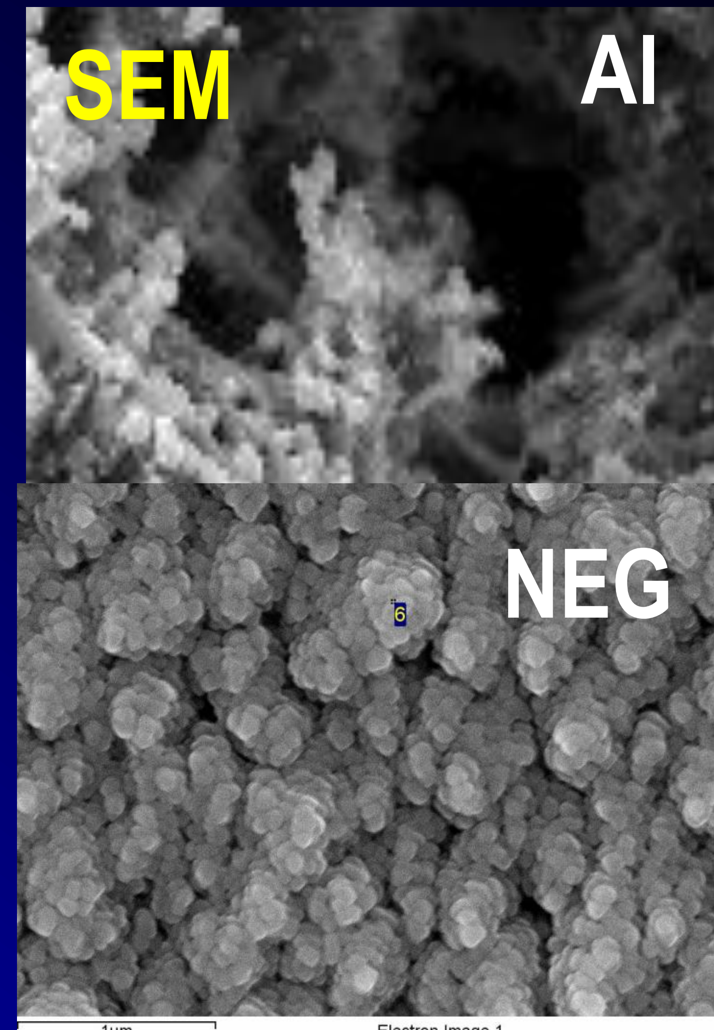


Anti-ecloud Coatings

NEG coated rough Al



AFM image
NEG/flat Al



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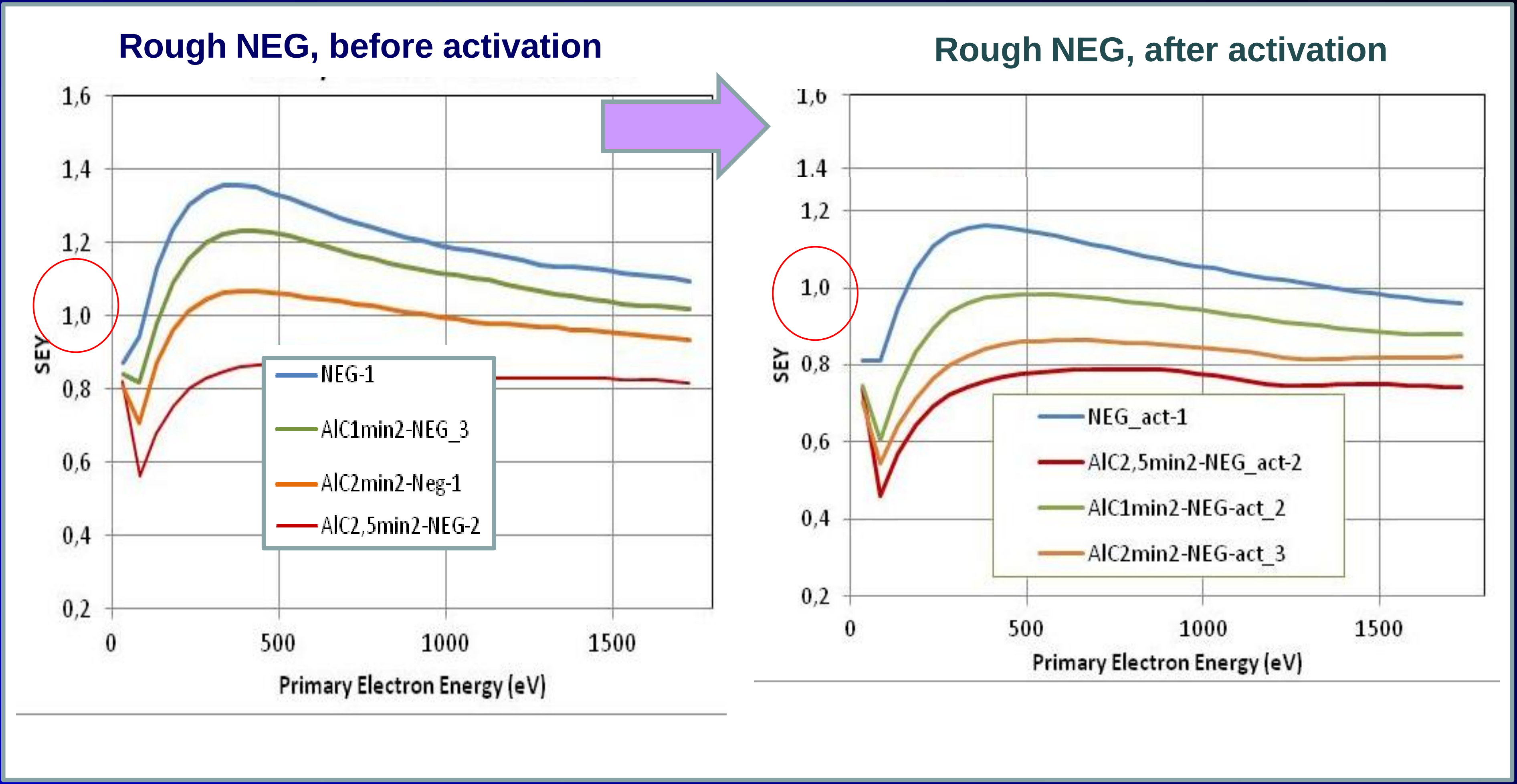
Critical experimental activities

SEY of Rough NEG



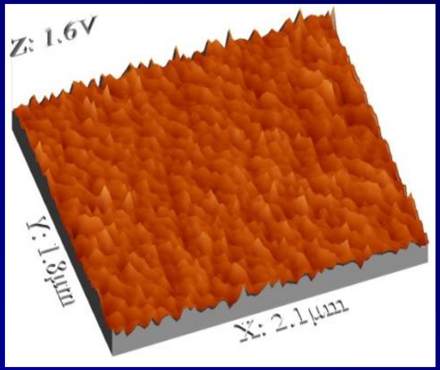
Critical experimental activities

Selected materials

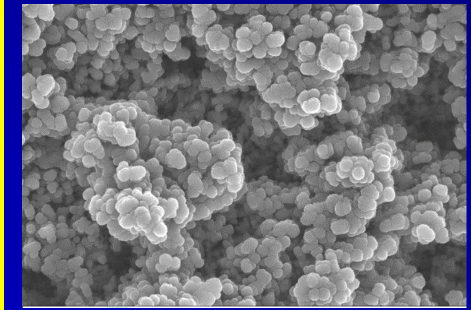
- Graphene like coatings

Critical experimental activities

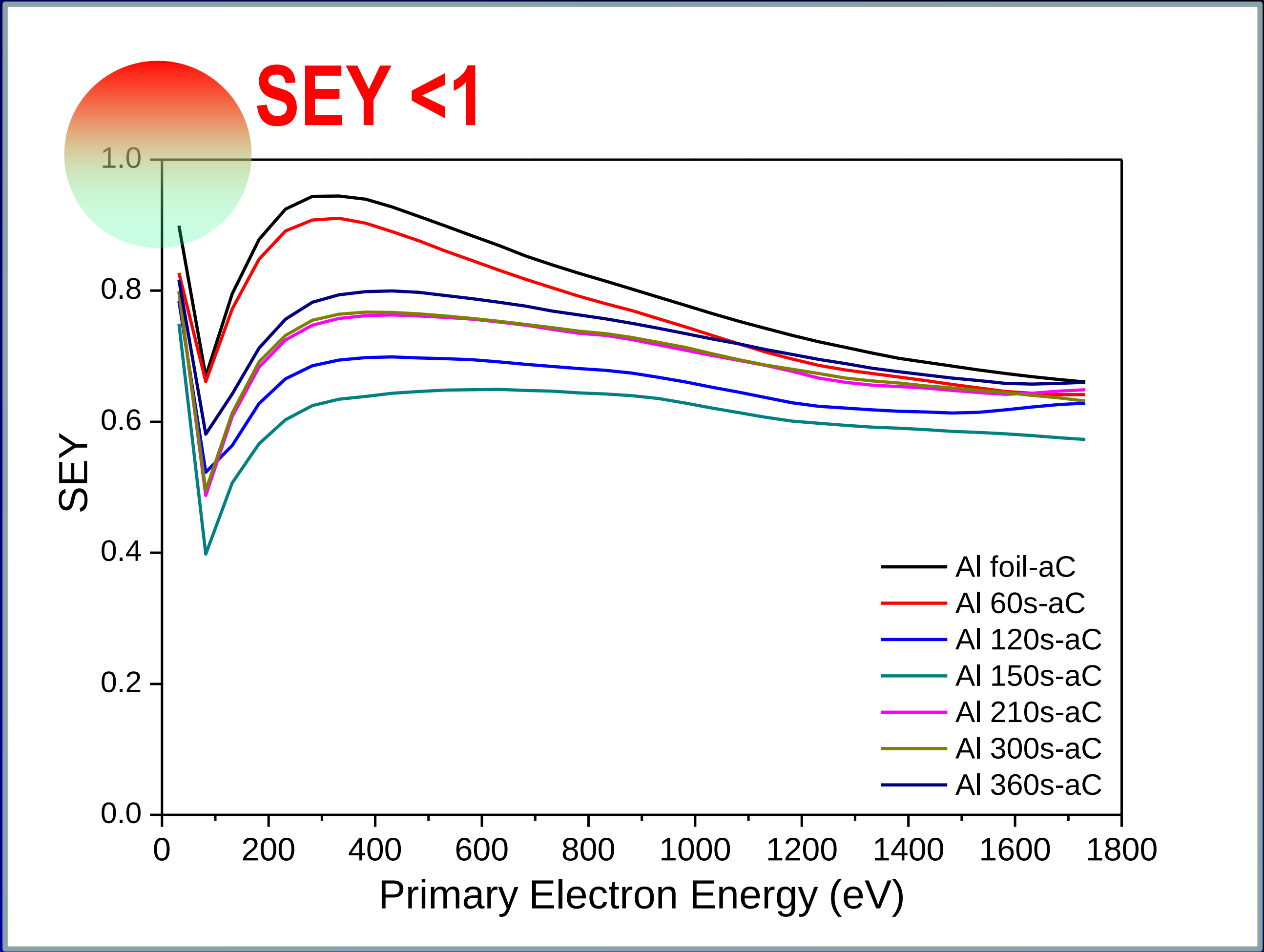
Introduction: a-C coated rough Al



AFM image
aC/flat Al

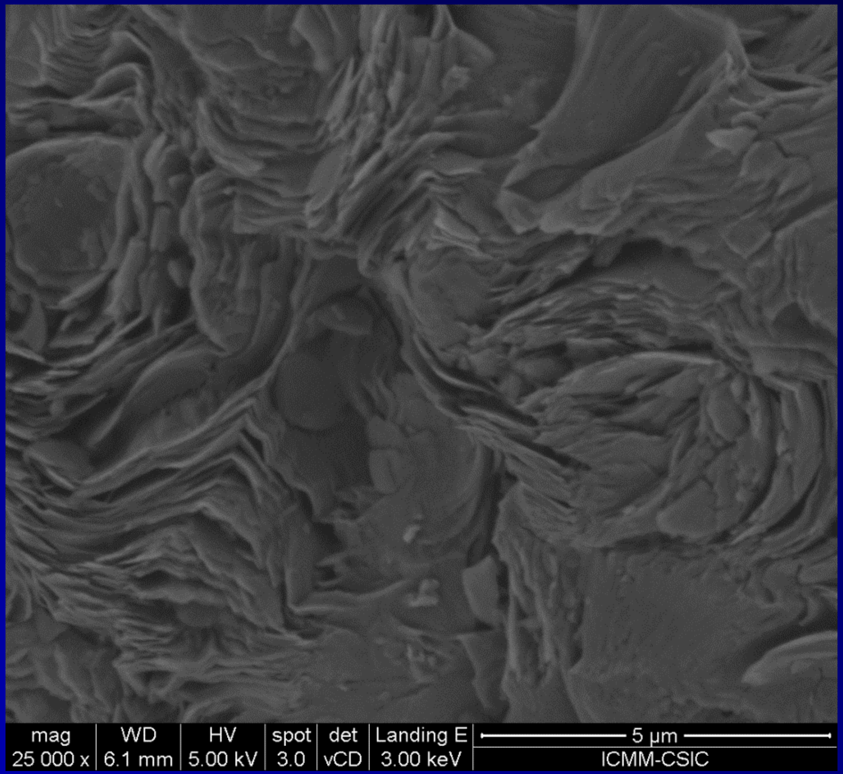


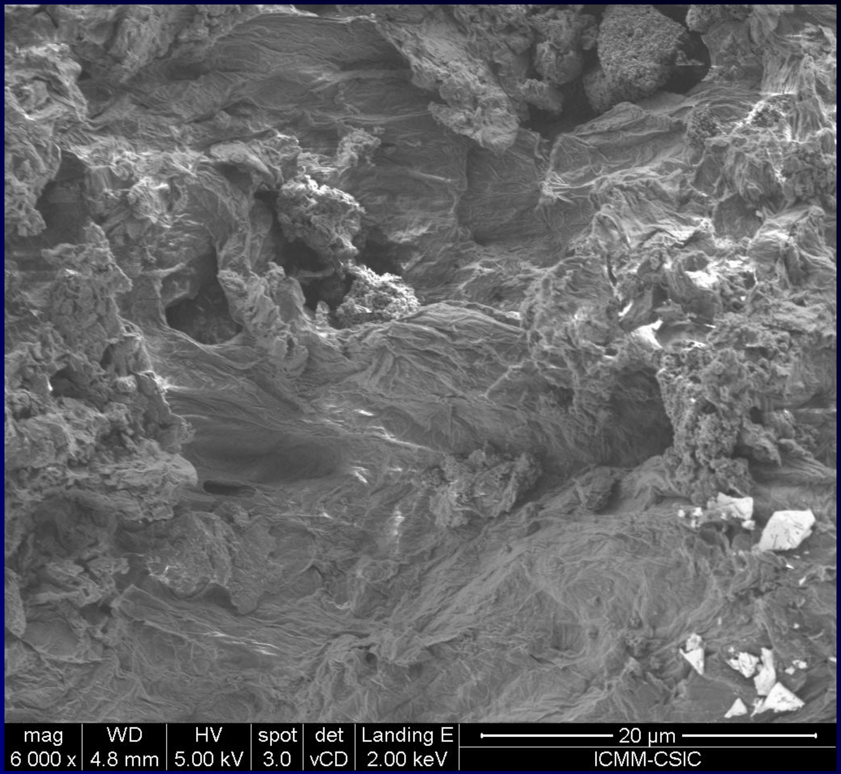
SEM image
aC/roughAl



Critical experimental activities

Graphite and Graphene Oxide (GO)





The results reveal that the GO sheets are rough and the structure is predominantly amorphous due to distortions from the high fraction of sp^3 C−O bonds.

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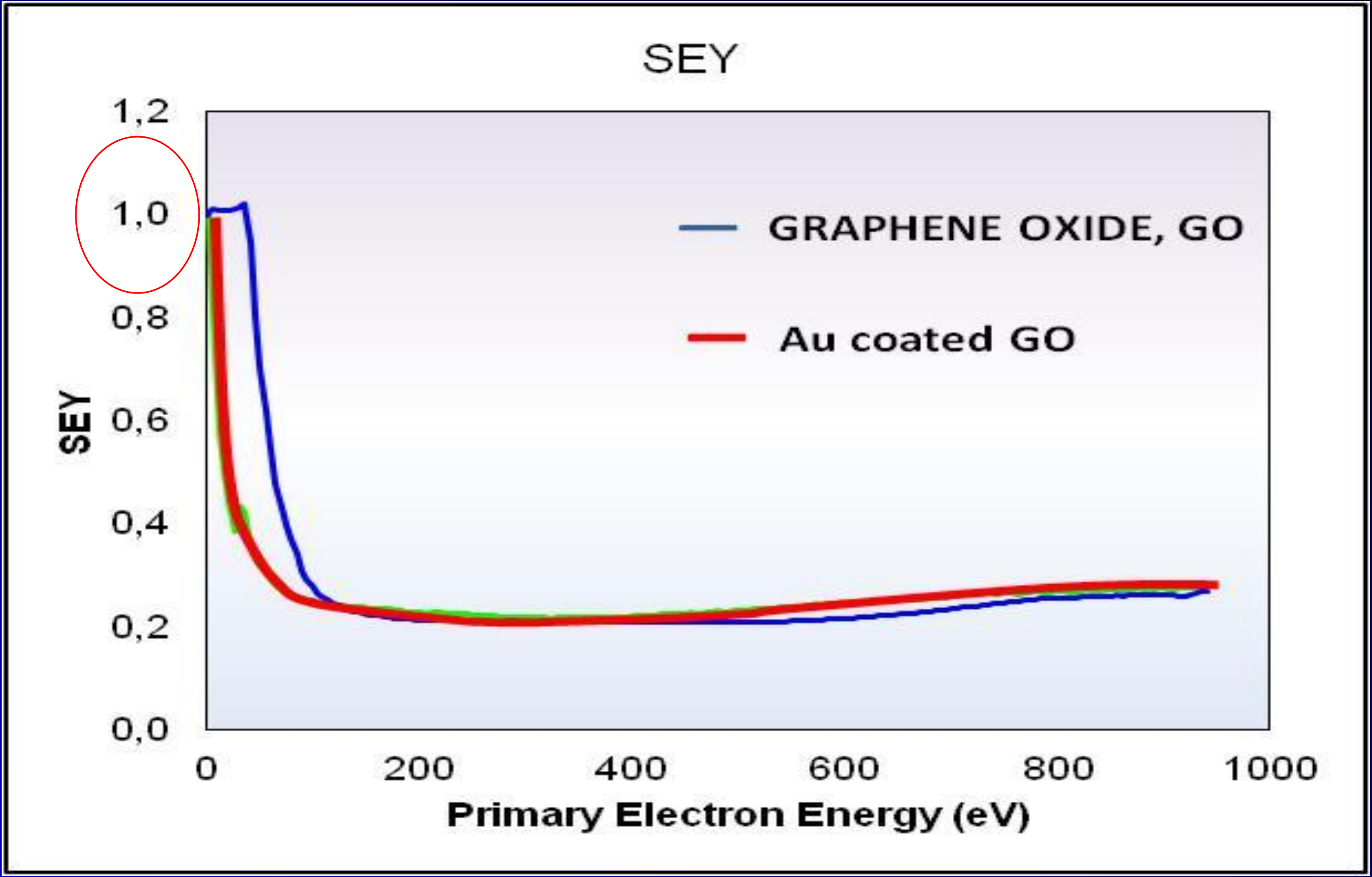
Critical experimental activities

SEY of graphene oxide



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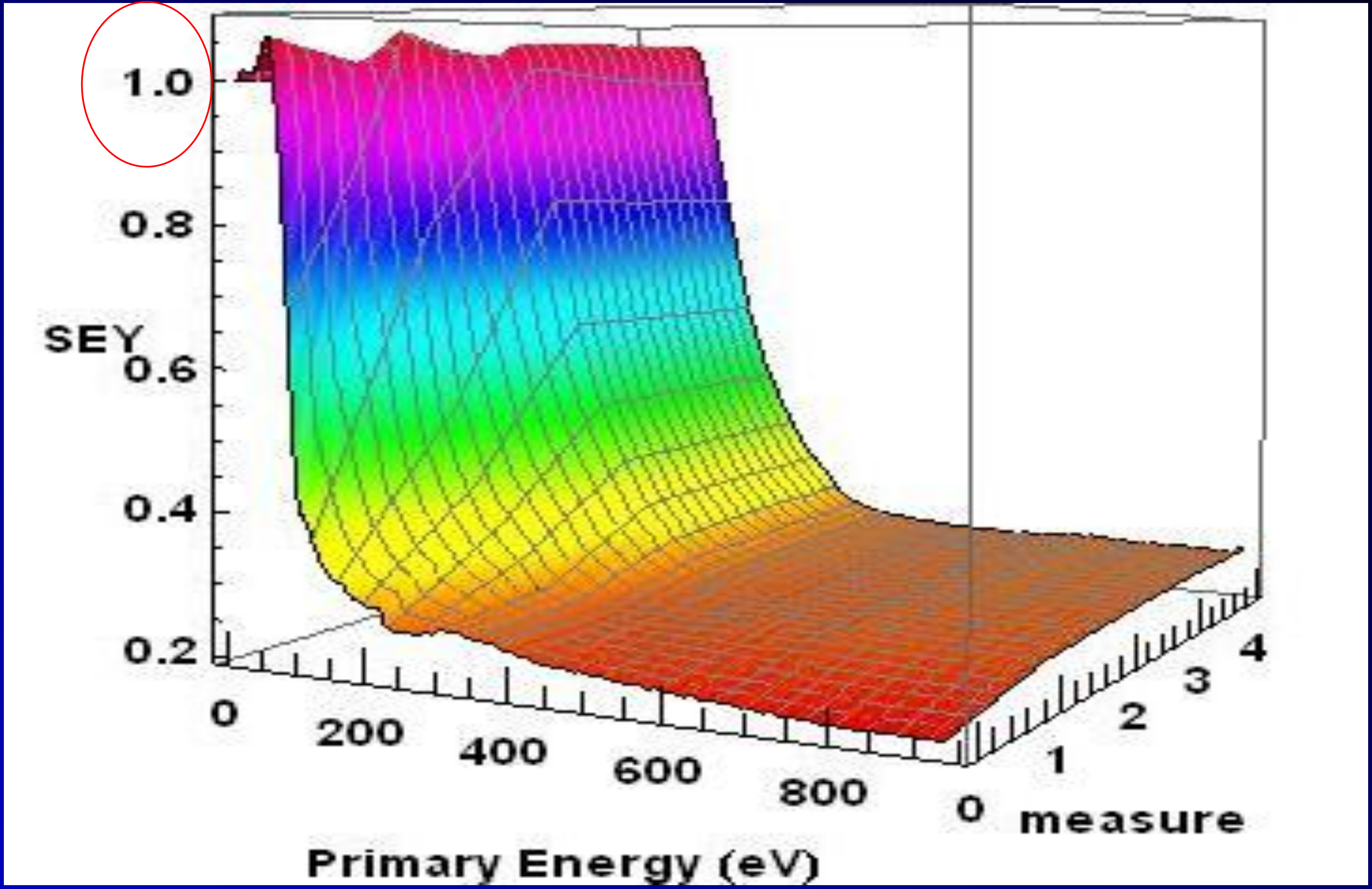
Critical experimental activities

SEY of graphene oxide



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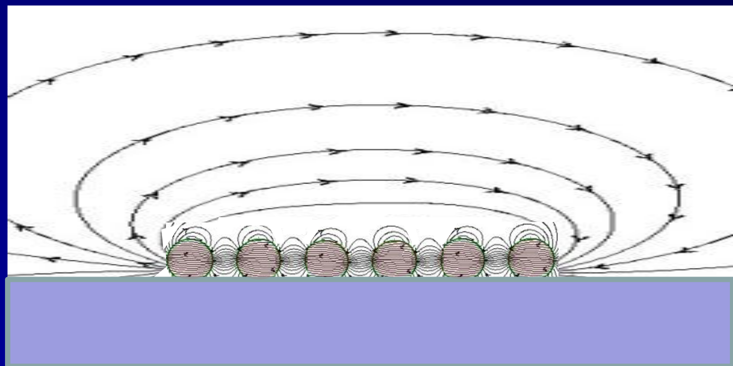
Critical experimental activities

Selected materials

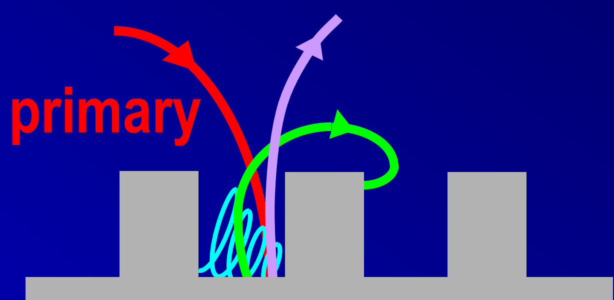
- Magnetic particulated surfaces: ferrites

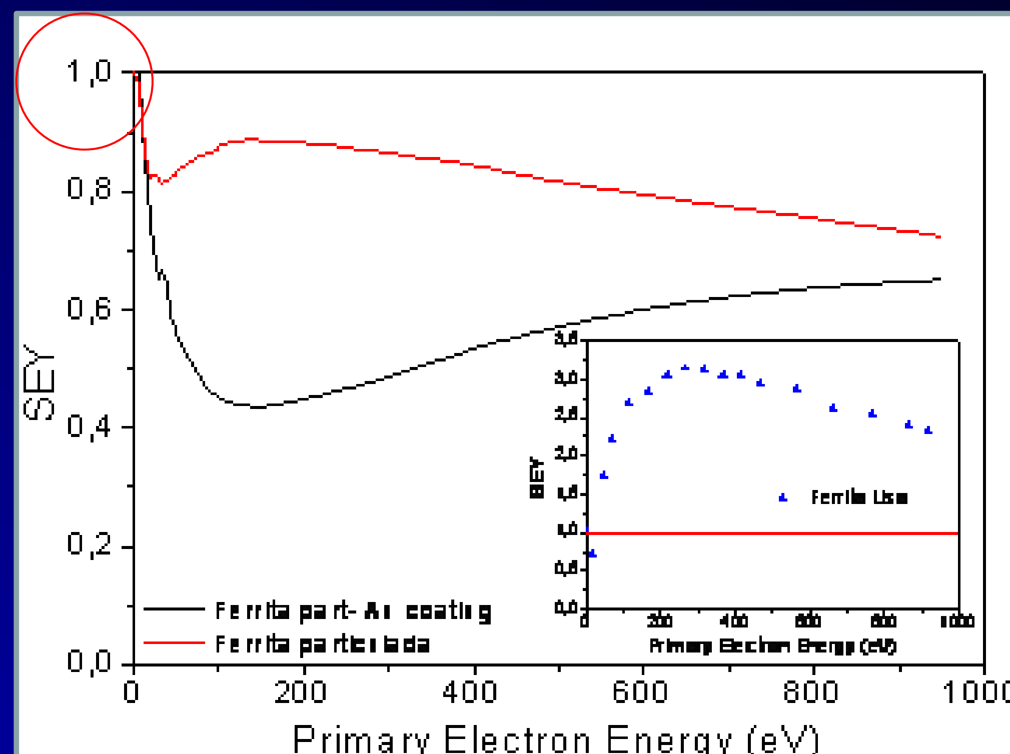
Critical experimental activities

SEY OF MAGNETIC PARTICULATED SURFACES: ferrites



Reexamining the effects of magnetized surfaces on the SEY properties





the surface coating including a multitude of particles sized

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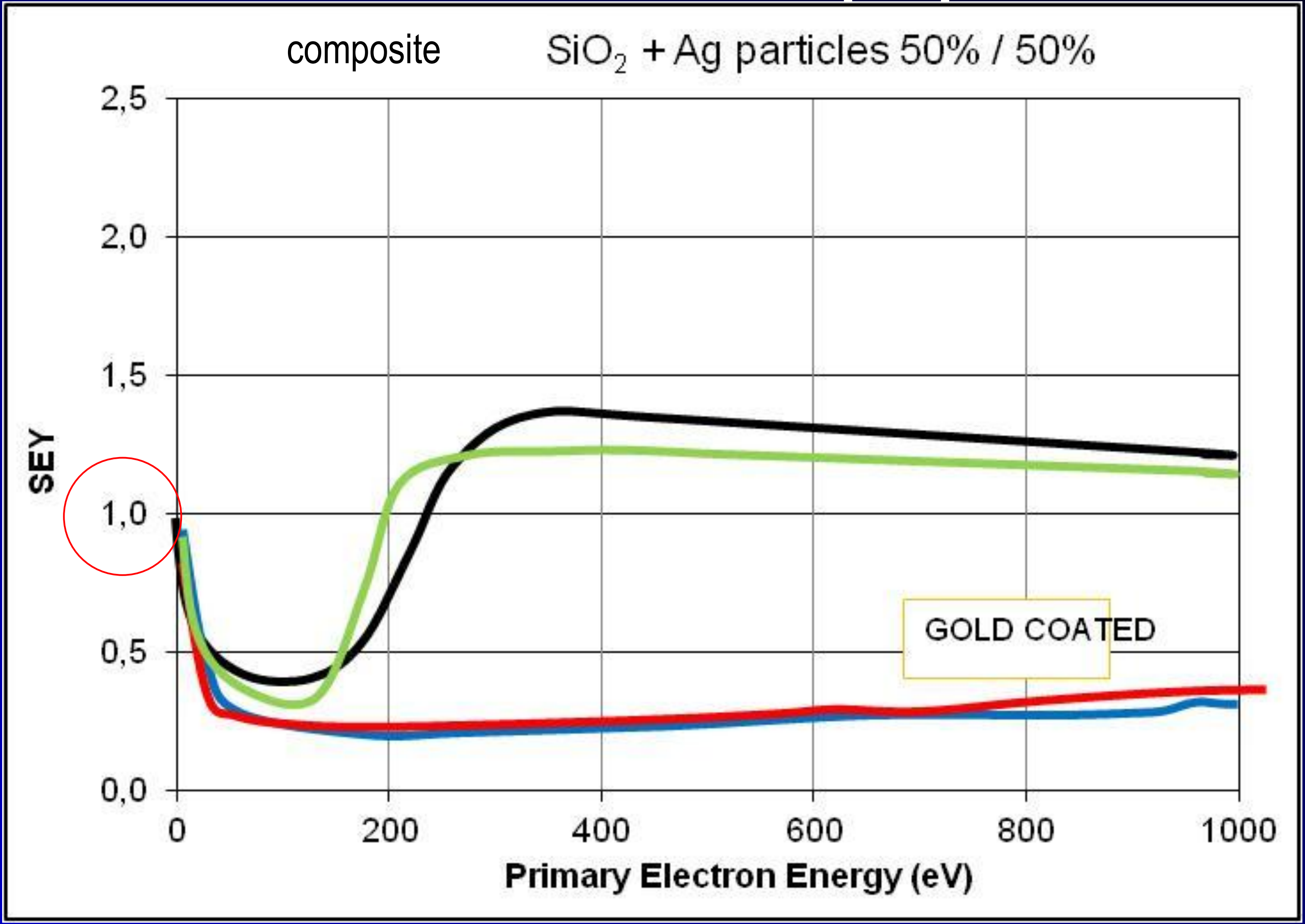
Critical experimental activities

Selected materials

- Composites: dielectric/metal

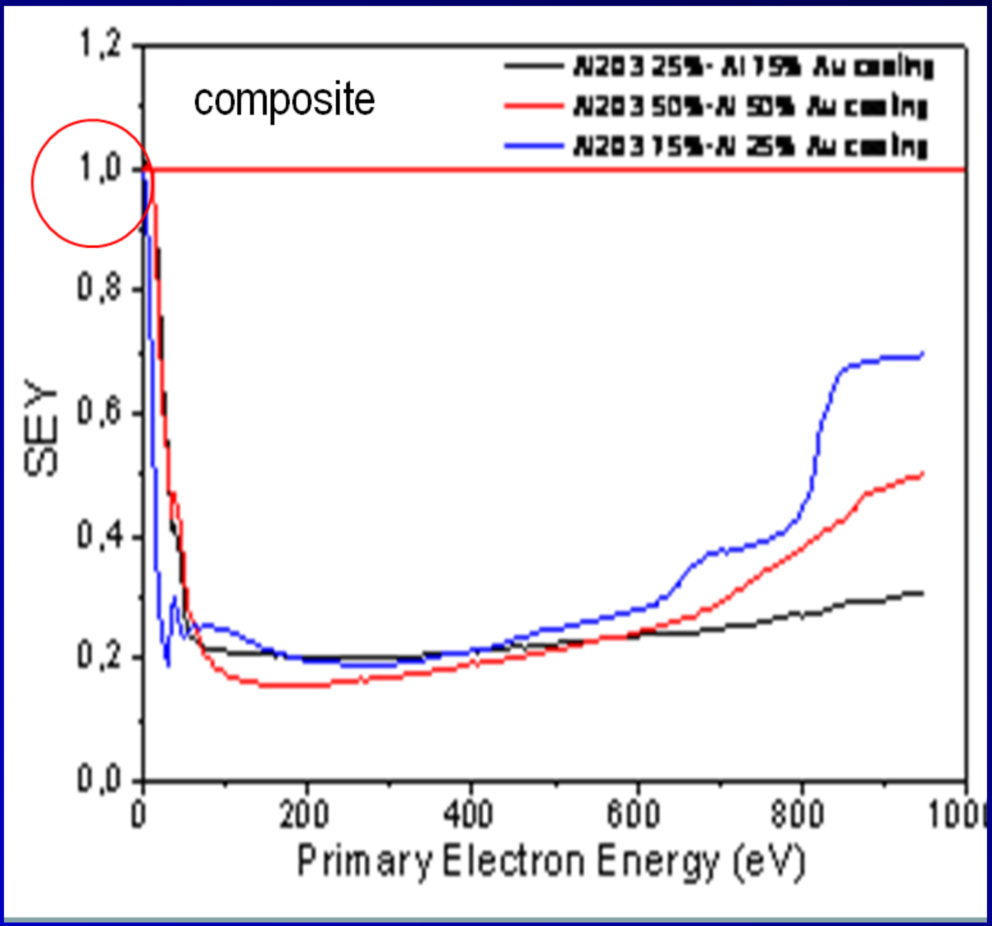
Critical experimental activities

New Insights into metal/dielectric particulated surfaces and their SEY properties

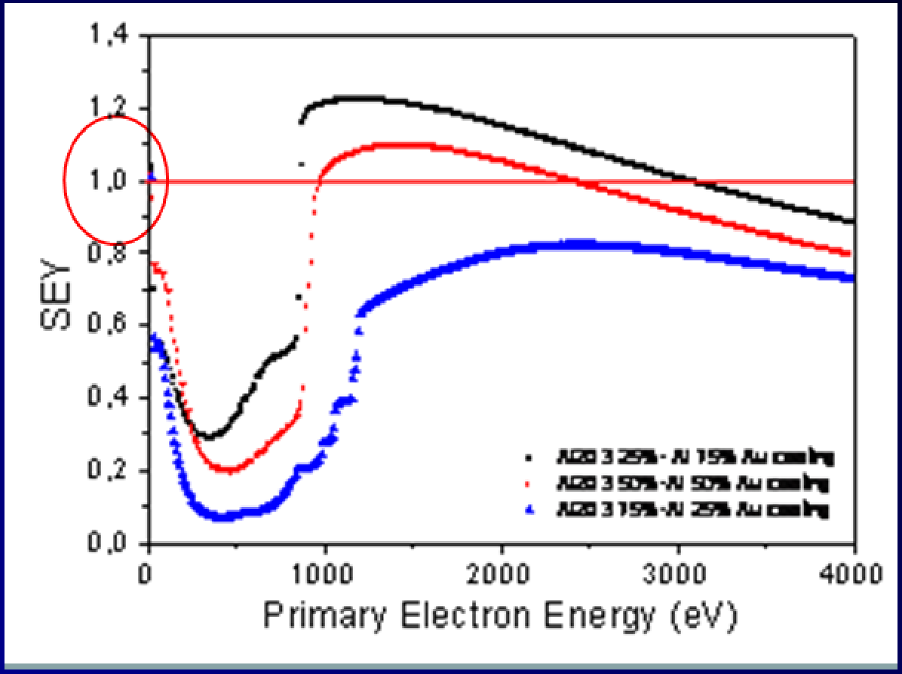


Critical experimental activities

New Insights into metal/dielectric particulated surfaces and their SEY properties



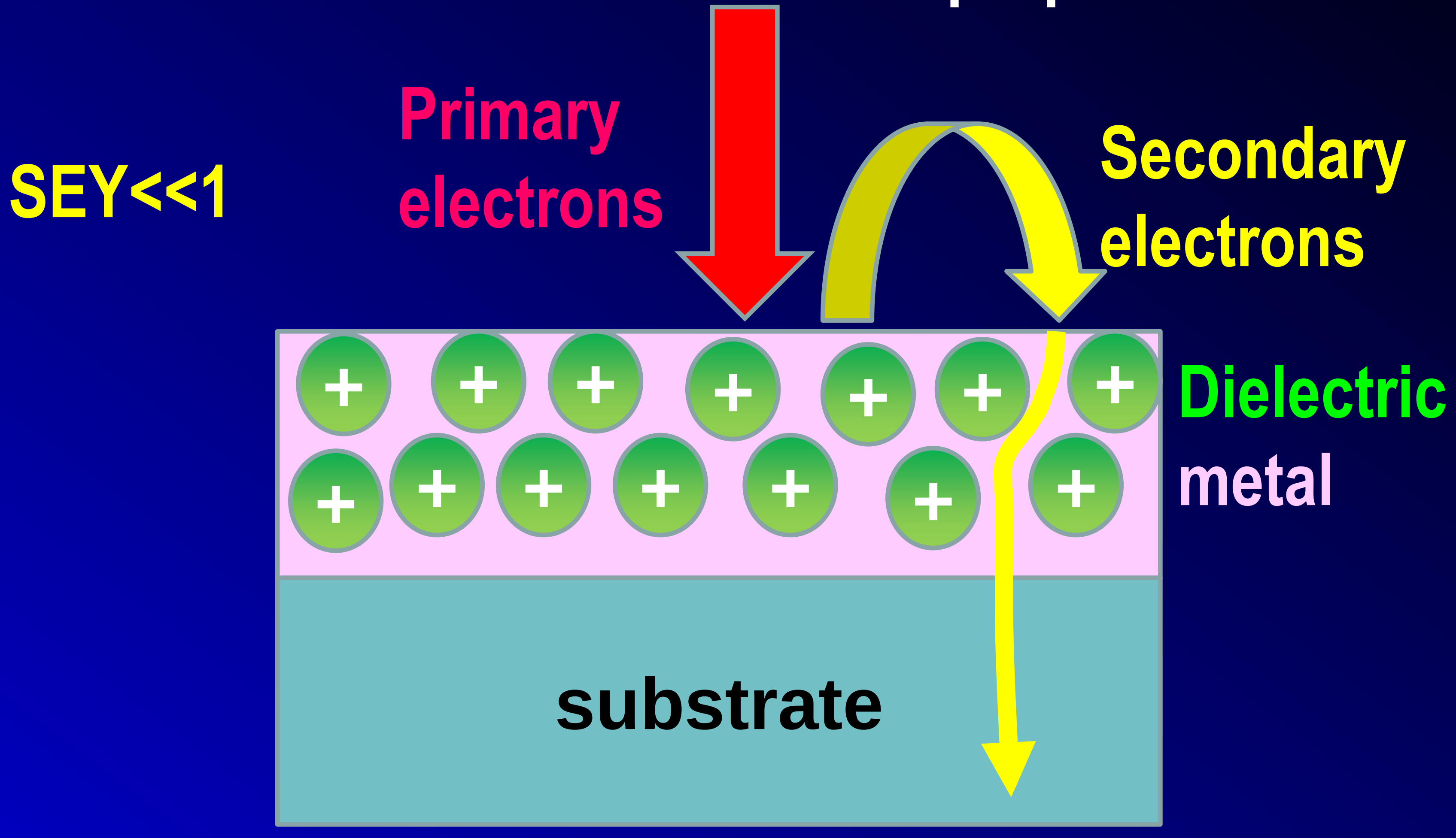
Composite Alumina/aluminium



Isabel Montero, ICMM-CSIC

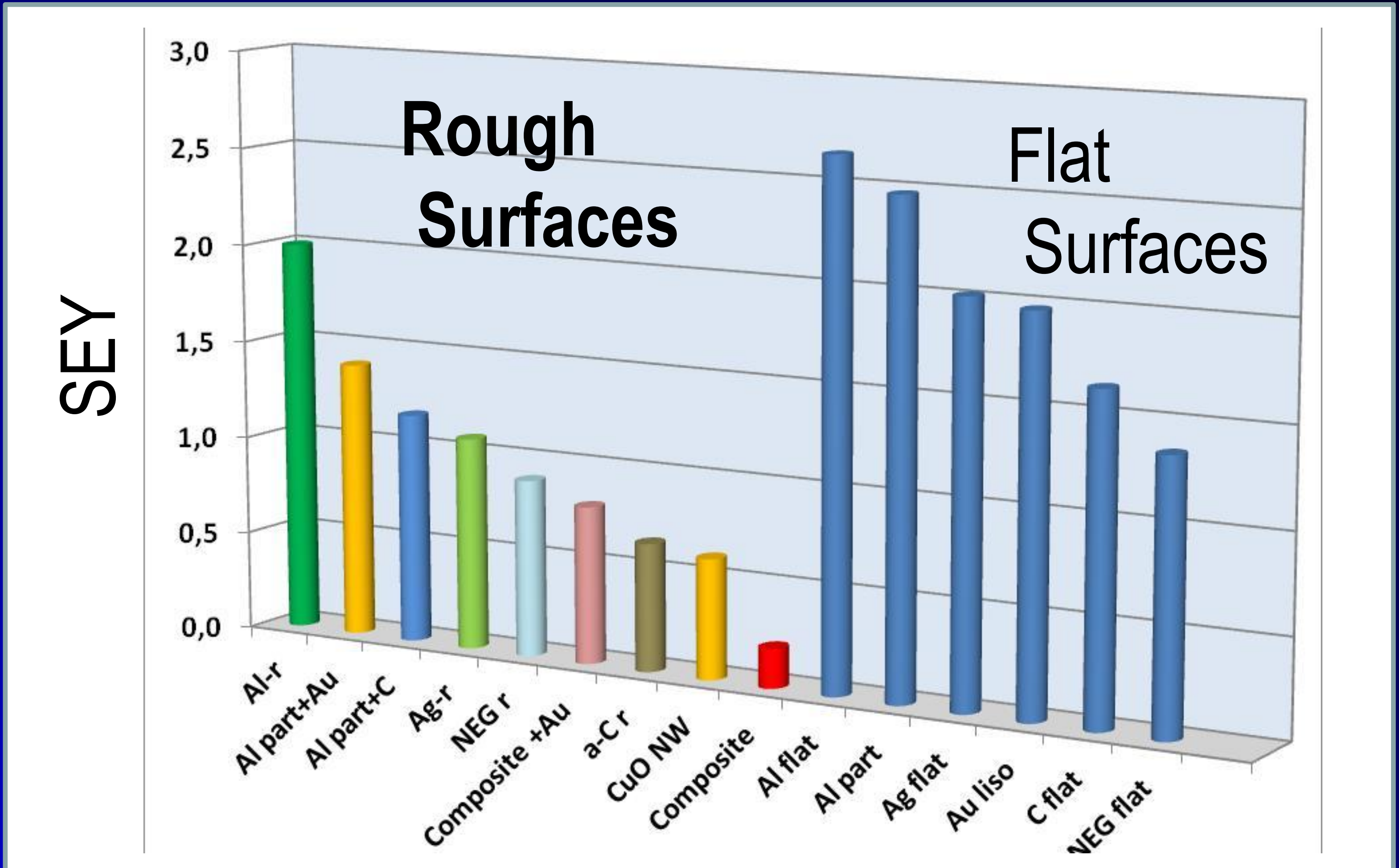
Critical experimental activities

New Insights into metal/dielectric particulated surfaces and their SEY properties



SUMMARY

Anti-eCloud coatings exposed to the air.



Summary and Conclusions

Future work

Summary and Conclusions

This work is directed to providing surfaces having extremely low secondary electron emissions.

The molybdenum-masked, ion-textured silver surface will be a promising material for inhibiting multipactor.

Extremely reduction of SEY is observed in different particulated metal/dielectric systems.

Summary and Conclusions

As far as the achievement of low SEY coatings should rely heavily on surface morphologies with roughness of high aspect ratio, insertion losses due to surface resistance become a crucial issue.

It is necessary the optimization of surface roughness of anti-multipactor coatings for low insertion losses and secondary emission suppression for high power RF components in satellite systems

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Thank you for your attention