4-8-2016

Extremely low secondary electron emission from metal/dielectric particulate coatings

Isabel Montero  
*Instituto de Ciencia de Materiales de Madrid*

L Aguilera  
*Instituto de Ciencia de Materiales de Madrid*

Leandro Olano  
*Instituto de Ciencia de Materiales de Madrid*

María E. Dávila  
*Instituto de Ciencia de Materiales de Madrid*

Luis Galán  
*Instituto de Ciencia de Materiales de Madrid*

JR Dennison  
*Utah State University*

*See next page for additional authors*

Follow this and additional works at: [https://digitalcommons.usu.edu/mp_presentations](https://digitalcommons.usu.edu/mp_presentations)

Part of the *Condensed Matter Physics Commons*

**Recommended Citation**  
Montero, Isabel; Aguilera, L; Olano, Leandro; Dávila, María E.; Galán, Luis; Dennison, JR; and Wilson, Gregory, "Extremely low secondary electron emission from metal/dielectric particulate coatings" (2016). 14th Spacecraft Charging Technology Conference. Presentations. Paper 135.  
[https://digitalcommons.usu.edu/mp_presentations/135](https://digitalcommons.usu.edu/mp_presentations/135)
Authors
Isabel Montero, L Aguilera, Leandro Olano, María E. Dávila, Luis Galán, JR Dennison, and Gregory Wilson
Extremely low secondary electron emission from metal/dielectric particulate coatings

I. Montero, L. Aguilera, L. Olano, M. E. Dávila,
Instituto de Ciencia de Materiales de Madrid. CSIC. 28049-Madrid. Spain

V. Nistor, L. Galán
Applied Physics Dep., UAM

J. R. Dennison, G. Wilson
Materials Physics Group, Utah State University, Logan, Utah, 84322, USA
CONTENT

• Main goals
• Introduction: Antimultipactor coatings
• Antimultipactor coatings for ESA
• Micrometric dielectric particulate coatings
• Extremely low secondary electron emission from metal/dielectric particulate coatings
  SEY simple theoretical model
• Conclusions
To mitigate:

1. The multipactor effect in space-relate high-power RF hardware

2. The electron cloud and its adverse consequences
Multipactor phenomenon characteristics

- Weak discharge
- Secondary electron emission seed and feedback (avalanche)
- Only occurring under vacuum conditions
- Threatening any RF component
- Can cause disturbances/degradation of onboard satellite equipment and even total loss of the mission
\[ I_p = I_\sigma + I_s \]

\( I_s \) is measured in the sample

\( I_p \) is measured in the Faraday cup

Collector connected to ground, 

\( I_\sigma > 0 \), \( I_p < 0 \)
Development of coatings with low secondary electron emission yield (SEY)
Main objectives:

Very low SEY

\[ \sigma_{\text{max}} < 1.5 \]

\[ E_1 > 200 \text{ eV} \]

Very low RF surface resistance

\[ < 1.5 \times R_{\text{surf}}(\text{Ag}) \]

Very slow aging in air

> one year
Secondary Emission Suppression by Surface Roughness of High Aspect Ratio Ratio

- Low SEY
- High $E_1$ value
- High stability in air  Ag, Au, ...
- High conductivity  Ag

in each generation secondary energy decreases

Sample

Roughness: aspect ratio porosity

Isabel Montero, 14th Spacecraft Charging Technology Conference
Anti-Multipactor Coatings
Deposition Methods

- **Gas (UHV)**
  - Physical Vapor Deposition
    - Evaporation
    - Ion implantation and/or reaction
    - Sputtering

- **Liquid**
  - Chemical Methods
  - Chemical Etching or Growth
  - Anodization

- **Solid**
  - Particles Deposition

*Isabel Montero, 14th Spacecraft Charging Technology Conference*
**ANTI MULTIPACTOR COATINGS**

- Aluminum
- Nickel
- Silver etched
- Etched aluminum
- Gold-coated etched silver
- NEG-coated etched Al

**Introduction**

- Different kinds tested
- Rough Neg

**Chemical Etching**

\[ \Delta \approx 1\mu m \quad R_r / R_s = 2.4 \text{ @ 12 GHz} \]

*Isabel Montero, 14th Spacecraft Charging Technology Conference*
ANTI MULTIPACTOR COATINGS

Introduction

DIFFERENT KINDS TESTED

Ag microstructured

Nanoporous templates

CuO nanowires

Isabel Montero, 14th Spacecraft Charging Technology Conference
CuO nanowires

T= 500°C,

Isabel Montero, 14th Spacecraft Charging Technology Conference
DEFINITION OF SAMPLES

Harmonic low-pass corrugated filters = Multipactor samples

for low-power RF behaviour and multipactor threshold tests

- as received Ag plating
- treated filter
- RF filter
- rectangular crossing grooves in corrugated central part

K band 10.9 - 36.0 GHz

Isabel Montero, 14th Spacecraft Charging Technology Conference
Microstructured silver

DETAIL OF THE STRUCTURE OF THE SURFACE

- Antimultipactor silver coating >10 μ
- Ni(P) alloy, 10 μ
- Al alloy device
Antimultipactor coatings for ESA

THE CHEMICAL TECHNIQUE

DETAIL OF THE STRUCTURE OF THE SURFACE

800 nm

800 nm

Ag

Antimultipactor coating >10 μ

Ni(P) alloy, 10 μ

Al alloy device

PATENT CSIC, TESAT, ESA

Isabel Montero, 14th Spacecraft Charging Technology Conference
Antimultipactor coatings for ESA

SEY curves of treated filter

PATENT CSIC, TESAT, ESA

Isabel Montero, 14th Spacecraft Charging Technology Conference
Micrometrical \( \text{Al}_2\text{O}_3 \) Particles Coating

From suspension of nanometrical \( \text{Al}_2\text{O}_3 \) particles

Indentation of micrometrical ceramic particles

Aluminum alloy substrate

SEE coefficient

Primary Electron Energy [eV]

25 nm Au coating (continuous)
as prepared (pulse)

25 nm Au coating (pulse)

Isabel Montero, 14th Spacecraft Charging Technology Conference
Micrometric dielectric particles coatings

Extremely low secondary electron emission from metal/dielectric particulate coatings

Metallic/Dielectric MicroParticle Mixture

Irregular shape

25% \( \text{Al}_2\text{O}_3 \)

50% \( \text{Al}_2\text{O}_3 \)

75% \( \text{Al}_2\text{O}_3 \)

Surface top view

Isabel Montero, 14th Spacecraft Charging Technology Conference
Extremely low secondary electron emission from metal/dielectric particulate coatings

SEY values close to 0

Isabel Montero, 14th Spacecraft Charging Technology Conference
Extremely low secondary electron emission from metal/dielectric particulate coatings

SEY Theoretical Model

a simple attempt for explaining
Secondary electron emission yield (SEY)

\[ SEY = \frac{I_\sigma}{I_p} \]

\[ I_\sigma = I_\delta + I_\eta + I_\varepsilon \]

EDC, Energy Distribution Curves
Sample current technique for SEY test

\[ \sigma_{\text{eff}} = \frac{I_{\sigma}}{I_o} = 1 - \frac{I_m}{I_o} \]

During calibration with a Faraday cup \((I_{\sigma} = 0)\), \(I_o\) is measured in the pico-amp meter. 

The apparent primary energy is:

\[ E_p = V_b - V_{e-gun} \]

(in units of eV and V)

The real primary energy is:

\[ E_o = V_s - V_{e-gun} \]

In a perfect conductive sample \(V_s = V_b\)

\[ \sigma_{\text{eff}}(E_o, V_s) = \delta_{\text{eff}}(E_o, V_s) + \eta_{\text{eff}}(E_o, V_s) + \varepsilon(E_o) \]

Isabel Montero, 14th Spacecraft Charging Technology Conference
The Cumulative Probability Functions (MEST)

For the true secondary electron emission:

\[
F_s(X) = \frac{2}{\pi} \arctan\left( \tan^2\left( \frac{\pi}{2} X^{n_s} \right) \right)
\]

where

\[
X_s = 1.5 \cdot \min\left\{ \frac{\phi}{E_o}, 0.3 \right\} \cdot \frac{\phi}{\phi + (E_o/75)}
\]

and \( n_s = 0.65, \phi = 5 \text{ eV} \) are material dependent constants \((X_{\text{max}} \approx \phi/E_o)\).

For the inelastically backscattered secondary electron emission:

\[
F_b(X) = \frac{1 - \cos\left( \pi \cdot X_b^{n_b} \cdot X^{n_b} \right)}{1 - \cos\left( \pi \cdot X_b^{n_b} \right)}
\]

where \( n_b = 1.5 \) and \( X_b = (2^{1/n_b} \cdot X_{\text{max}}) = 0.85 \) are material dependent constants.
The condition of stationary or \( dc \) SEY measurement is:

\[
\sigma_{\text{eff}}(V_s) - 1 = \frac{I_m}{|I_o|} = \left(\frac{|I_o| \cdot R_o}{|I_o| \cdot R_o}\right)^{-1} \cdot (1 + \alpha \cdot V_{\text{sample}}^2) \cdot V_{\text{sample}}
\]

**Explain atypical SEY:** to solve this equation, i.e.,

to find the possible values of \( E_p \) and \( V_{\text{sample}} \) solutions of this equation,

with \( \sigma_{\text{eff}} - 1 < 0 \), \( I_m < 0 \), and \( V_{\text{sample}} < 0 \)

\( (V_{\text{sample}} > 0 \text{ and } I_m < 0 \text{ is not possible}) \)
Secondary electron emission as a function of sample voltage, for $E_p = 400$ eV. $\text{EMISS} = \sigma_{\text{eff}}$
The **atypical** solution with $\sigma_{\text{eff}} < 1$, $V_s < 0$, and $E_o$ decreasing from $E_1$ to values close to 0

Evolution of effective SEY in an iterative procedure with

$$\Delta V_{\text{sample}} = -k \cdot (\sigma_{\text{eff}} - 1 - (I_m / |I_o|))$$

**Convergence** to $\sigma_{\text{eff}} < 1$ in a energy range $210 - 850$ eV.
The **atypical** solution with $\sigma_{\text{eff}} < 1$, $V_s < 0$, and $E_o$ decreasing from $E_1$ to values close to 0

Evolution of effective SEY in an iterative procedure with

$$\Delta V_{\text{sample}} = - k \cdot (\sigma_{\text{eff}} - 1 - (I_m/I_o))$$

**Convergence** to $\sigma_{\text{eff}} < 1$ in a energy range $210 - 850$ eV.

**Above this wide energy range with two solutions, only the normal one, $\sigma_{\text{eff}} = 1+$, is always possible.**
Real primary energy and surface potential of the high resistance coating as determined by Solver of Excel

Isabel Montero, 14th Spacecraft Charging Technology Conference
Micrometric metal/dielectric particles coatings

Energy Distribution Curves, EDC

EDC conductor

Elastic peak determined by e-gun energy
Secondary electron peak shifted by bias voltage

Intensity

Energy

EDC delta
EDC eta
EDC eps
EDC sigma
Energy Distribution Curves, EDC

EDC normal dielectric

- Elastic peak determined by e-gun energy
- Secondary electron peak shifted below cero by sample charging voltage
- Part of secondary electron peak suppressed

Isabel Montero, 14th Spacecraft Charging Technology Conference
Energy Distribution Curves, EDC

EDC atypical dielectric

Elastic peak determined by e-gun energy
Secondary electron peak shifted by sample charging voltage
MAIN CONCLUSIONS:

Coatings of micrometric surface roughness can avoid Multipactor effect.

SEY of metal/dielectric particulate coatings can be lower than 0.2 until Ep of the order of 1000 eV.

The extreme decrease of SEY of metal/dielectric particulate coatings could be explained by using a simple model:

Two different solutions were found: the normal and the atypical one with extremely low-SEY values

Why the atypical one is chosen by metal/dielectric particulate coatings?
THANK YOU
FOR YOUR ATTENTION