MULCOPIM conference: impressions and highlights

P. Dijkstal, G. Rumolo

E-cloud meeting, 10.04.2017

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MULCOPIM 2017

9th INTERNATIONAL WORKSHOP ON MULTIPACTOR, CORONA AND PASSIVE INTERMODULATION

esa MULCOPIM 5 - 7 April 2017 European Space Agency

- MULCOPIM conference organized by the European Space Agency (ESA), took place 5-7 April in Noordwijk (NE)
- It is devoted to MULtipacting, COrona, Passive Inter Modulation (PIM)
  - Strong synergy with electron cloud activities in the multipacting part
  - However, for satellite application, the concern lies mainly in avoiding occurrence of multipacting in high power RF cavities (no beam)
  - 5 sessions were entirely devoted to SEY modeling and measurements, many contributors mainly from Spanish institutes, ONERA (France), Frascati, China

MULCOPIM: SEY sessions

SESSION 6B: SEY-1
Chairman: Isabel MONTERO
Co-chairman: Rafael MATA

- Extrapolated range formula for low energy electrons in various elements (Dr. Inguimbert, C.I. / ONERA)
- Preliminary results of research on new rough Ag anti-multipactor coatings with no insertion loss and aging drawbacks (Prof. Soriano, Leonardo / Universidad Autónoma de Madrid)
- An analytical model for secondary electron emission (Dr. Inguimbert, C.I. / ONERA)

SESSION 7B: SEY-2
Chairman: Rafael MATA
Co-chairman: Mohamed BELHAJ

- Monte Carlo simulations of low energy electron emission and its dependence on surface morphology for aluminum and silver (Ms. Pierron, Juliette / ONERA)
- Improvement of suppression efficiency of total secondary electron emission yield of metal surface by micro/nano composite structure (Dr. D, Wang / Xi'an Jiaotong University)
- Study of the charge processes involved in the secondary electron emission yield measurements of dielectric materials (Dr. Mata Sanz, Rafael / VAL Space Consortium)
- Effects of sample conductivity on the SEY test, a simple model (Prof. Galán, Luis / Universidad Autónoma de Madrid)
- SEY in additively manufactured surfaces (Ms. Montero Herrero, Isabel / ICMM-CSIC)
- Structure of steady towards the thermal and vibrational load nano-carbon film providing of long-term metallic surface protection against the multipactor formation (Russian Federation)

SESSION 8B: SEY-3
Chairman: Giovanni RUMOLO
Co-chairman: Benito GIMENO

- Secondary electron emission yield measurements on devices and Aluminium surface as a function of temperature (Dr. Mata Sanz, Rafael / VAL Space Consortium)
- Experimental and numerical study on secondary electron yield of artificially roughened metal surfaces (Wang, Dan / Xi'an Jiaotong University)
- About the electron emission properties of dielectric materials (Dr. Belhaj, Mohamed / ONERA)
- Dynamic secondary electron emission in dielectric/conductor mixed coatings (Mr. Olano García, Leandro / Instituto de Ciencia de Materiales de Madrid - CSIC)

Surface modeling
Coating
SEY Measurement Techniques
SEY Measurements

MULCOPIM: SEY sessions

SESSION 9B: SEY-4
Chairman: Mohamed BELHAJ
Co-chairman: Isabel MONTERO

Influence of the angle of incidence of primary electrons on the total secondary electron yield
(Dr. Bronchalo, Enrique / University Miguel Hernández of Elche)

SEY of chromate-free treatments of aluminum for RF devices
(Prof. Montero, Isabel / ICMM-CSIC)

Analytical model of secondary electron yield from metal surface with reentrant polygonal groove
(Mrs. Zhang, Z.N. / China Academy of Space Technology)

Secondary Emission Yield and Electron Emission Spectra of Pt: Experimental Study and Comparison with Models in the Multipactor Energy Range
(Dr. Bronchalo, Enrique / University Miguel Hernández of Elche)

RF devices without Multipactor discharge
(Prof. Montero, Isabel / ICMM-CSIC)

Engineering and modeling micro-porous surfaces for secondary electron emission control
(Mr. Sattler, James / Air Force Institute of Technology)

Electric discharge in alcohol as the method of stable nano-composite colloid using for metallic surface protection from multipactor production
(Mr. Anpilov / Co.Ltd.Plazma-Sk)

SESSION 10B: SEY-5
Chairman: Rafael MATA
Co-chairman: Giovanni RUMOLO

SEY and LE-SEY studies on different materials of relevant interest for Multipacting and e-Cloud mitigation
(Dr. Angelucci, Marco / INFN / LNF)

SEY studies of physisorbed gases on Copper at cryogenic temperature
(Dr. Angelucci, Marco / INFN / LNF)

Computation of geometric secondary electron yield suppression in metals using novel material processing
(Dr. Smith, Jonathan / Tech-X UK Ltd)

Surface modeling
Coating
SEY Measurement Techniques
SEY Measurements

Some general impressions

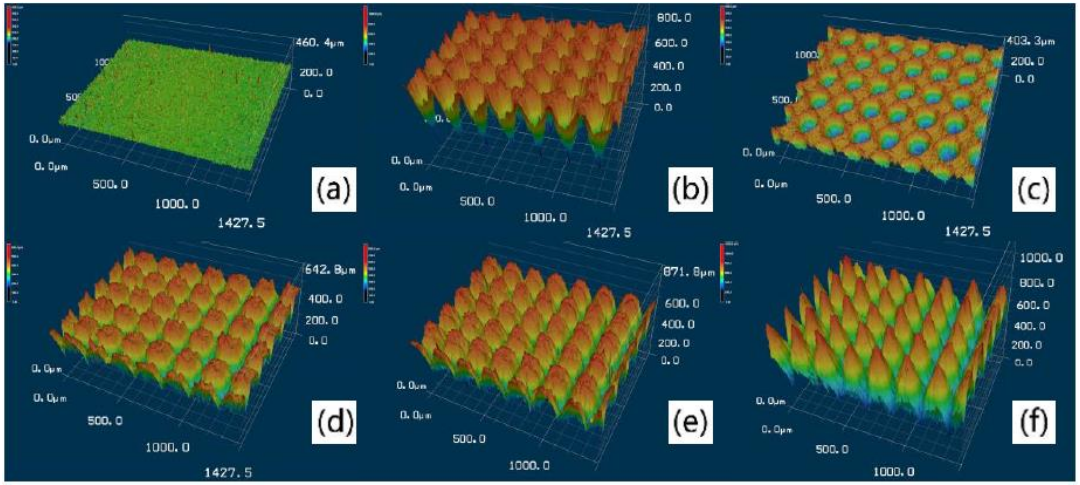
- Lots of ongoing work on SEY physics and modeling
  - Physics of secondary electron emission process for both conductors and dielectrics (and mixed structures used for coating)
  - Detailed modeling of roughness at different scales
  - Fitting with existing models, dependence on incidence angle

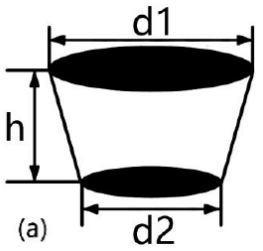
- No mention (interest) in surface conditioning or scrubbing
  - Main goal is to reduce SEY in order NOT to have multipacting – which would prevent the RF device from working!
    - In accelerators, we can 'afford' living with e-cloud, at least for some time (if beam is stable enough, heat load is within limits and scrubbing works)
  - Conditioning is an 'issue' to be avoided in lab measurements
  - Aging (change of surface properties in time without e^- bombardment) is relevant for space applications

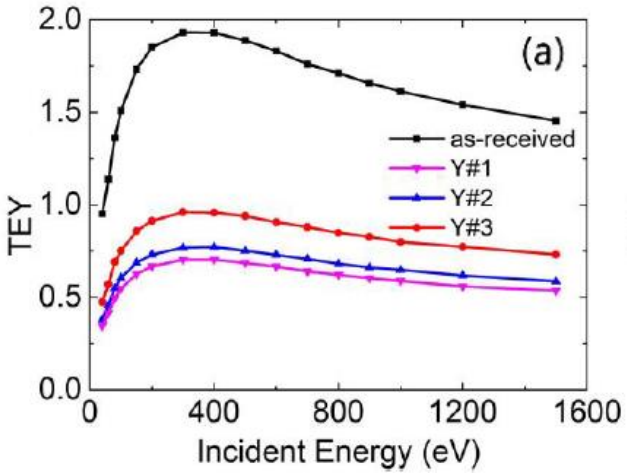
- Usual SEY parameters like E_{max} and SEY_{max} are important, however lots of emphasis on E_1 ('first crossover point', it is the lower energy at which SEY=1) and little interest in the behaviour of low energy electrons

Some highlights

- Since interest is mainly in low SEY surfaces, surface geometry is simulated in detail to explain the property of lowering SEY (e.g., D. Wang, J. Smith)
  - Modeling of laser etched surfaces to assess whether the SEY reduction depends on change of chemical or geometric properties
  - Modeling of porous surface
  - Machined surfaces



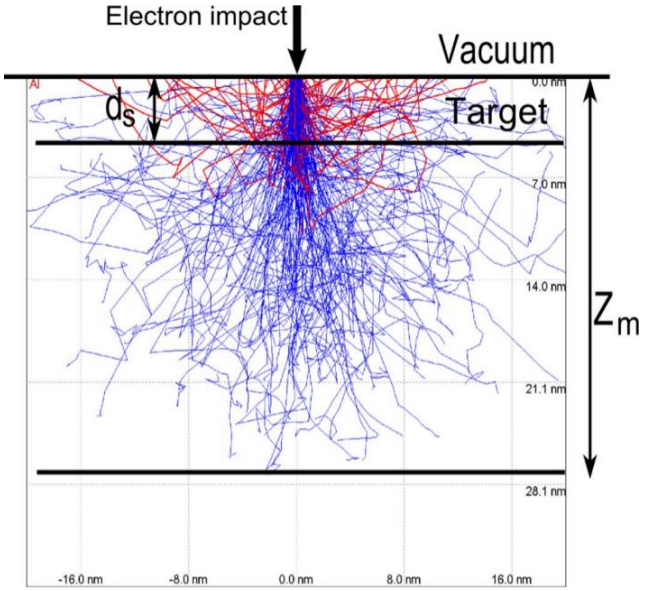




Some highlights

- SEY of dielectric materials (M. Belhaj, ONERA)
  - Usually assumed to be very high (>>1)
  - However, when secondary emission occurs, the dielectric charges up and there are internal and external space charge forces changing the SEY behaviour
  - For mono-energetic electron bombardment, SEY tends to become 1 for basically all energies of incident electron → Implications for our cases of ferrites, ceramic tubes, dielectric exposed to the beam?

Some highlights



Monte-Carlo simulations of SEY

Secondary Electron Emission on Space Materials: Evaluation of the Total Secondary Electron Yield from Surface Potential Measurements
M. Belhaj, V. Inguimbert et al., 2012

Some highlights

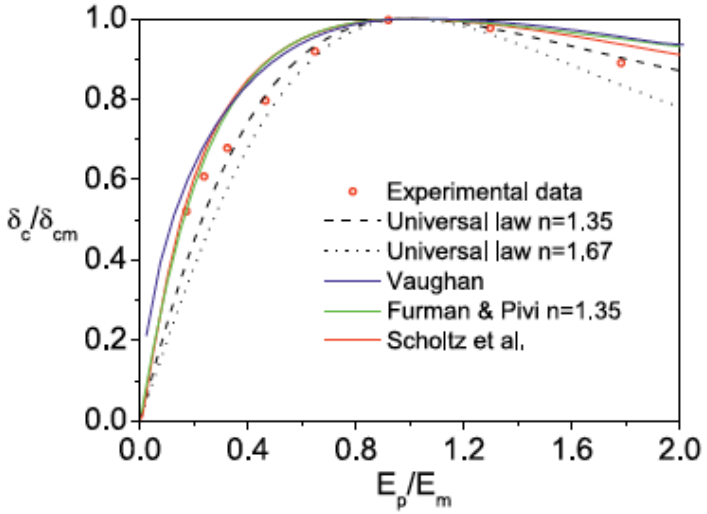
- Interesting measurements, e.g. dependence of SEY on temperature (R. Mata, M. Angelucci)
  - Measurements at Valencia Space Consortium (VSC) between -150 and 150º C (relevant due to the temperature fluctuations of satellites in space) → suggest lower SEY curves at lower temperatures, however very preliminary
  - Measurements at LNFL, focusing especially on the SEY curve in the low energy region (towards the work function of the metal)
    - Tends to vanish for cleaned metal surface, independently of temperature
    - Remains high for 'as received' samples, confirming that reflection is mainly due to the non-metallic nature of the contaminant layer

Some highlights

- Fitting the best modeling analytical description to experimental data (E. Bronchalo, University of Elche)
  - SEY curve: universal law with n=1.35
  - Energy distribution of secondaries (which does not depend on the incident energy): Scholtz
  - Angular dependence of SEY for different incident energies (Pt surface, for Cu in future?) → Philipp will receive the slides/papers

$$\frac{\delta(E)}{\delta_{\max}} = Au^{1-n}\left[1-\exp\left(-bu^{n}\right)\right]$$

$$\text{with} \quad u = E/E_{\max}$$



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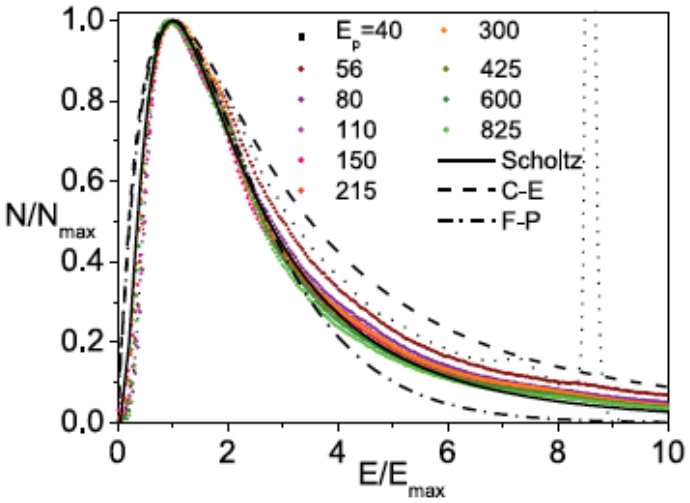
$$\frac{dN_{\mathrm{sec}}}{dE} = \exp\left(-\frac{\ln^2 u}{2\tau^2}\right)$$

$$\text{with} \quad u = E/E_{\max} \quad \text{and} \quad \tau = 1.6$$

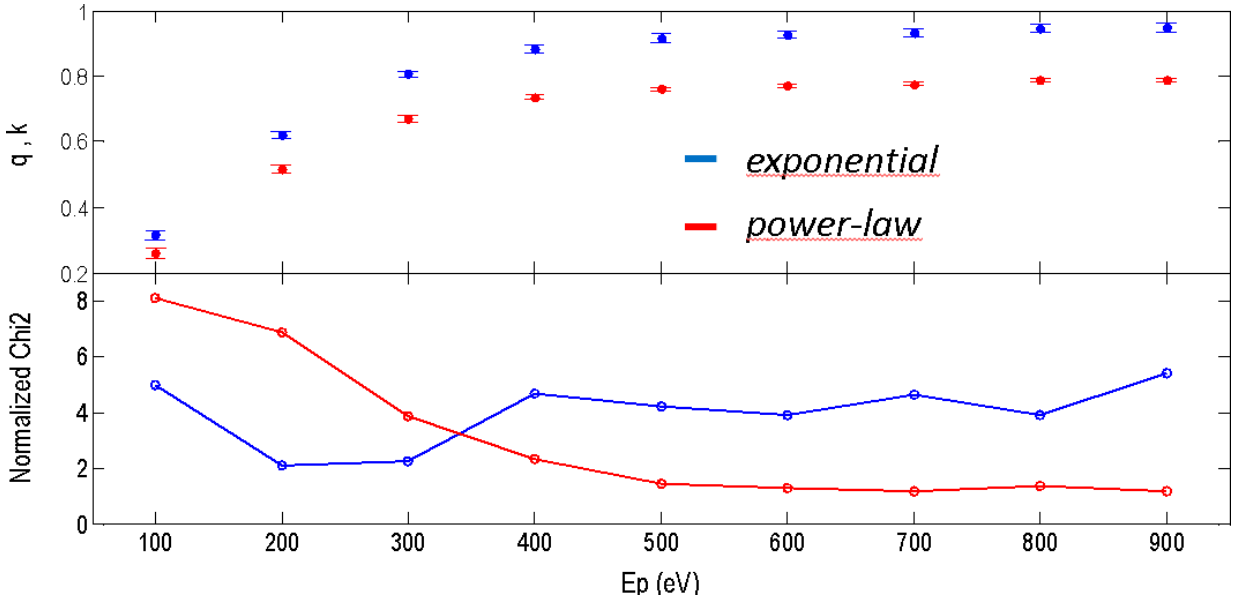


Some highlights

- Angular dependence of SEY up to 55 degrees (for Pt only ☹)
- In PyECLOUD: Exponential with q=0.5 independent of energy

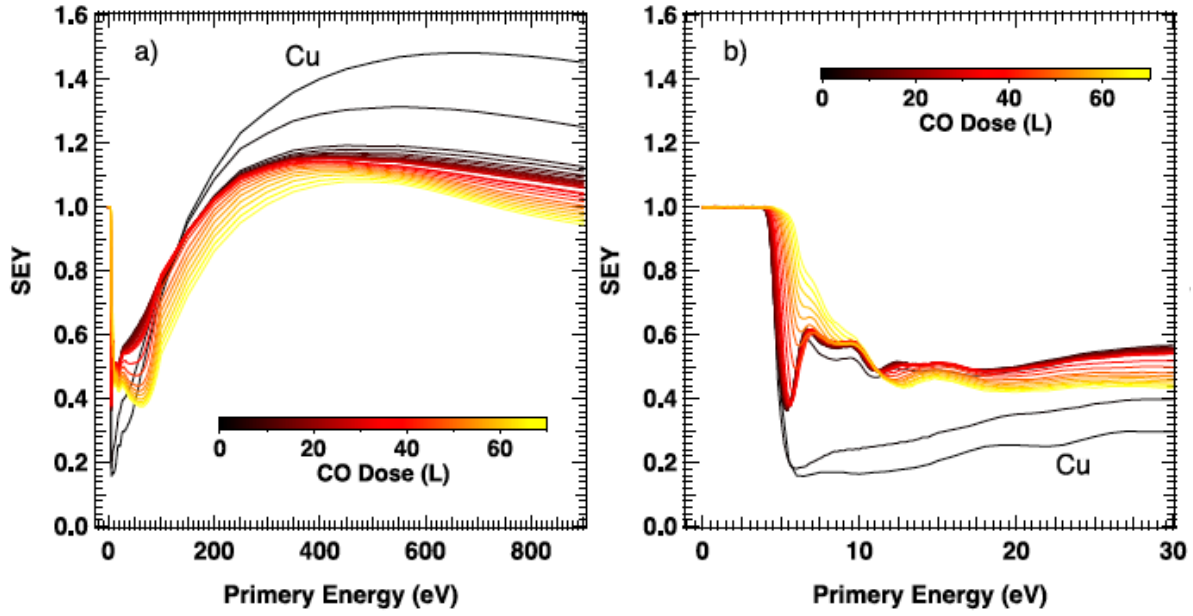
Power-law: $\log[\,\delta/\delta(0)\,] = -k \log(\cos\theta)$

Exponential: $\log[\,\delta/\delta(0)\,] = q\,(1-\cos\theta)$



Some highlights

- Measurements of SEY with different amounts of condensed gas on cryogenic Cu surface (M. Angelucci, LNFL)
  - Measurements were done at 10 K
  - Different values of monolayers (L) of condensed Ar or CO
  - Interesting observation that SEY goes rapidly below 1.2 when physisorbing CO (amount ≥ 1 ML is enough!) → Shall we condense CO on the beam screen surfaces of LHC? ☺



And finally …

- Very interesting experience, next **MULCOPIM** in three years in Valencia
- Many many thanks to Frank Zimmermann and Eucard for inviting us to participate in this conference and for supporting our participation!
- Meanwhile, **ECLOUD'18** at Elba island, tentatively 3-6 June, 2018, possibly in the ARIES framework
  - Organised by R. Cimino, myself, F. Zimmermann, G. Franchetti
  - We could ask Benito Gimeno (VSC, University of Valencia) to be in the International Advisory Committee and propose speakers on the SEY modeling and measurements

Some People

[30] J. de Lara *et al.*, "Multipactor prediction for on-board spacecraft RF equipment with the MEST software tool," *IEEE Trans. Plasma Sci.*, vol. 34, no. 2, pp. 476–484, Apr. 2006.

[31] M. M. El Gomati, C. G. H. Walker, A. M. D. Assa'd, and M. Zadražil, "Theory experiment comparison of the electron backscattering factor from solids at low electron energy (250–5,000 eV)," *Scanning*, vol. 30, no. 1, pp. 2–15, 2008.

[32] M. Dapor, "Theory of the interaction between an electron beam and a thin solid film," *Surf. Sci.*, vols. 269–270, pp. 753–762, May 1992.

[33] R. K. Yadav and R. Shanker, "Backscattering of 8–28 keV electrons from a thick Al, Ti, Ag and Pt targets," *J. Electron Spectrosc. Rel. Phenomena*, vol. 151, no. 1, pp. 71–77, 2006.

Isabel Montero is currently a Research Professor o the Spanish National Research Council (CSIC). She is the Head of the Group Surface Nanostructuring for Space and Terrestrial Communications with the Materials Science Institute of Madrid. She is the Director of the Spanish Laboratory on Secondary Electron Emission withCSIC. She is an Exper in surface spectroscopic techniques and in low secondary electron emission surfaces and coatings.

Enrique Bronchalo received the Physics degree from the Universidad Complutense de Madrid, Madrid, Spain, in 1986, and the Ph.D. degree in physics from the Universidad de Alcalá, Alcalá de Henares, Spain, in 1996.

He joined the Universidad Miguel Hernández, Elche, Spain, in 2001, where he is Associated professor. His current research interests include passive microwave devices and multipactor processes in waveguides.

Luis Galán received the Ph.D. degree in materials science and engineering from Stanford University, Stanford, CA, USA, in 1980.

He is an Associate Professor with the Universidad Autnoma de Madrid, Madrid, Spain. He has published over 80 research papers. His current research interests include the secondary emission properties of materials with application in space hardware, in relation with multipactor breakdown, including micro and nanostructured surfaces.

Ángela Coves received the Licenciado degree in physics and the Ph.D. degree in physics from the Universidad de Valencia, Valencia, Spain, in 1999 and 2004, respectively.

She became a Lecturer with the Universidad Miguel Hernández Elche, in 2001. Her current research interests include the analysis and design of microwave passive components, periodic structures, and RF breakdown high power effects.

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Rafael Mata received the Physics degree and the Ph.D. degree from the University of Valencia, Valencia, Spain, in 2006 and 2011, respectively.

He was a Researcher/Technician with the Val Space Consortium in 2012. His current research interests include the secondary electron emission properties, outgassing, and venting processes in RF high power space materials.

Laura Mercadé received the Physics degree from the University of Valencia, Valencia, Spain, in 2015, where she is currently pursuing the master's degree in advanced physics.

She obtained a technical student position at CERN in 2016. Her current research interests include the RF breakdown phenomena in dc and RF structures and the secondary electron emission properties.

Benito Gimeno (M'01) received the Licenciado degree in physics and the Ph.D. degree from the University of Valencia, Valencia, Spain, in 1987 and 1992, respectively.

He became a Full Professor with the University of Valencia in 2010. His current research interests include the electromagnetic analysis and design of microwave passive components, and RF breakdown high-power effects.

Esteban Sanchís-Kilders (M'00–SM'14) was born in Valencia, Spain. He received the M.Sc. degree in physics, with a specialization in electronics, and the Ph.D. degree from the University of Valencia, Valencia, in 1990 and 1997, respectively.

He is currently an Associate Professor with the University of Valencia. His current research interests include space systems and new electronic devices applied to space applications.