NTA - IMCA (Innovative Materials and Coatings for Accelerator)

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The IMCA experiment was started in 2010 in order to develop new materials and coatings with stable and low enough SEY (Secondary Electron Yield) to guarantee full operation of present and future accelerator machines. This issue, in fact, is crucial in controlling Electron Cloud formation and in reducing its effects, that are well known to be a potential bottle-neck to the performances obtainable from particles accelerators. Frascati has a long-standing experience in qualifying materials in terms of surface parameters of interest to e-cloud issues. We are routinely measuring SEY, its dependence from electron energy, temperature and scrubbing dose. We are now able to characterize "in situ" the surface chemical composition and eventual modifications occurring during electron or photon irradiation by using XPS with conventional X-ray source and we are ready to exploit for this purpose the synchrotron radiation beamlines in construction at DAΦNE [1]. Our experimental measurements of the relevant parameters can be also confidently compared to simulations, performed by running the EC codes, in order to elucidate the final consequences on machine performances. Such a combined characterization effort is also suggesting ways to produce low SEY materials coatings. This issue is particularly important in view of the foreseen LHC luminosity upgrades and ILC- Damping ring studies, where e-cloud issues are expected to be present.
The previous experimental and theoretical results obtained with the "Nuvola" experiment during the past years, are the scientific base of this project [2, 3]. Indeed during these years in the Surface Laboratory in Frascati, we measured SEY reduction versus dose (the number of impinging electrons per unit area on sample surfaces). This process is usually called "Scrubbing". We now can correlate the SEY reduction obtained by electron bombardment with the surface chemical composition by using X-ray photoemission spectroscopy, confirming that the electron bombardment results in the graphitization of the carbon impurities on the copper surface [2]. Such characterizations have suggested also ways to produce low SEY materials, which are still under study. We have two running setups: both are now routinely working. They both operate in UHV conditions being steadily in a vacuum better than 1×10^{-10} Torr after bake-out. Both are based on a UHV μ-metal chamber, with less than 5 mG residual magnetic field at the sample position. Both are equipped with an Omicron LEED; an electron gun to measure SEY; a Faraday cup to characterize beam currents and beam profiles and both can produce samples with different growing technique inserting them in the measuring system without breaking the vacuum.

One system is designed to deposit thin films and analyze their SEY in connection with XPS at room or higher temperature. This is done by using an Omicron electron analyzer (which is the main contribution to the collaboration from R. Larciprete institute) and an X-Ray and a UV Lamps to acquire photoemission spectra and to obtain chemical information on the studied surface. The other system is optimized to perform SEY experiment at cryogenic temperature (down to 8 K) and in connection to angle resolved VUV photoemission studies. For this reason has been equipped over the years with an OMICRON AR65 angle resolving analyzer and a monochromatic VUV source.
In 2012, in collaboration with the major laboratories which are playing an international leading role on the study and characterization of e-cloud effects, we have addressed a series of issues studying

different materials. Such activity not only is promoting our Material Science Laboratory in Frascati as one of the most advanced Laboratory in this field, but also provided a quite comprehensive understanding on the physical phenomena governing the SEY and its variations during the various surface modifications.
Some of the most relevant scientific 2012 results are here reported.

1. In close collaboration with CERN, we studied the chemical origin of the scrubbing process of Cu surface representative of LCH beam screen and its dependence on the energy of the primary electrons. We observe a lower efficiency in reducing the SEY when the energy of the scrubbing electrons is less than 20 eV. This may have an impact on the scrubbing strategies for LHC. Also, we finally understand the chemical modification occurring at the surface during electron bombardment. SEY reduction can be assigned to the formation of graphitic carbon on the surface and low energy electrons seem not to be able to promote such graphitization as the higher energy electrons do. Those results have been published on Physical Review Letters [4)] and Physical Review ST-AB [5)]and presented in different conferences [6)]. The XPS data are shown together with the SEY data for the case studied and partial or more complete graphitization is shown by C 1s core level shift towards lower binding energies and corresponds to a systematic reduction of the measured SEY.

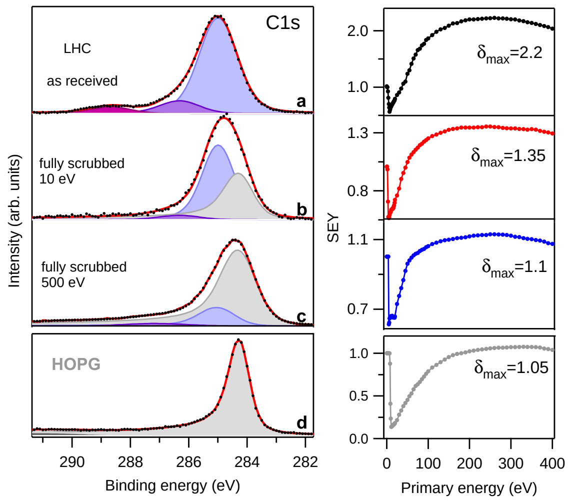

Figure 1: C1s XPS spectra and SEY curves measured on the LHC Cu sample: a) "as received" ; b) after a dose of 3×10^{-2} Cmm^{-2} at 10 eV; c) after a dose of 3×10^{-2} Cmm^{-2} at 500 eV; d) on a freshly cleaved HOPG surface [4)].

2. In collaboration with the DAΦNE accelerator division and the DESY vacuum group running PETRA III, we have studied the SEY and the chemical variations of Al samples representative of the two accelerators. PETRA III is a positron ring for very low emittance Synchrotron Radiation and its actual performances seems to be affected by ECE (Electron Cloud Effects). Our study confirms the high SEY value of the Al and that its reduction during scrubbing can vary even due to subtle differences in the experimental conditions. The combined SEY and XPS analysis identify in the extremely high reactivity of Al to oxygen the main cause of

variability. Due to this reactivity, C does not undergo the graphitization process, as it does on other surfaces, suggesting that Al is not suitable for the construction of accelerators with potential ECE [7, 8].

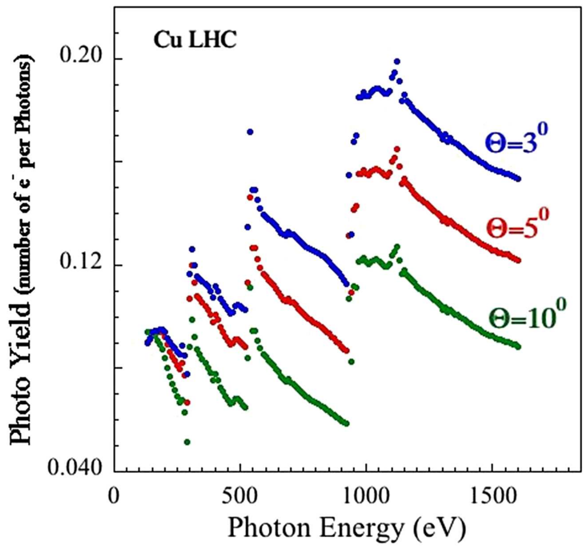

Figure 2: C1s XPS spectra and SEY curves measured on the LHC Cu sample: a) "as received" ; b) after a dose of $3{\times}10^{-2}$ Cmm^{-2} at 10 eV; c) after a dose of $3{\times}10^{-2}$ Cmm^{-2} at 500 eV; d) on a freshly cleaved HOPG surface. [9]

3. In collaboration with F. Schäfers from the optic group at BESSYII we pursue an extensive work to study in details reflectivity and Photoelectric Yield (PY, ie. the number of electrons produced per incident photon) [9]. Those parameters are essential ingredients to be used in the simulation codes of electron cloud related instabilities and have been rarely studied with the required precision and parameter space. It has been shown that the mere existence of a certain electron density in the accelerator is able to detrimentally affect the beam quality by the so called single beam instabilities. The electron density present in a vacuum chamber, even in the absence of resonant phenomena, is indeed due to the number of photoelectrons produced to their actual geometrical location. Such essential parameters (especially for LHC consolidation and upgrade) has to be carefully simulated, controlled and careful material choice is needed for its mitigation. One example of this research line is shown in fig.2, where Cu PY has been measured as function of photon energy at different incidence angles.

Last but not least, R. Cimino and F. Zimmermann chaired the fifth electron-cloud workshop ECLOUD12. More than 60 physicists and engineers from around the world gathered at La Biodola, Elba, on 5-8 June, to discuss the state of the art and review recent electron-cloud experience. Fig.2 shows the group photo of the event. ECLOUD12 was jointly organized and co-sponsored by INFN-Frascati, INFN-Pisa, CERN, EuCARD-AccNet and the Low Emittance Ring (LER) study at CERN. R. Cimino was chairing also the local organizing committee, being heavily involved in the organization of this workshop. It was very successful and gave the correct visibility to INFN. A brief report on this workshop can be found in the September issue of the CERN Courrier and the proceedings, edited by R.Cimino, G. Rumolo and F. Zimmermann will be published as CERN yellow book in 2013. [11].

Figure 3: Group Picture of the 5th International workshop on Electron cloud (ECLOUD-12) [11] chaired by R. Cimino and F. Zimmermann; (Courtesy of: V. Tullio).

Conference Talks

- R. Larciprete: The chemical origin of SEY at technical surfaces presented at Ecloud-12, Isola Elba, 2012.
- F. Schäfers: Soft X-Ray Reflectivity: from Quasi Perfect mirrors to Accelerator Walls" presented at Ecloud-12, Isola Elba, 2012.
- R. Flammini: "XPS and SEY Measurements Upon Scrubbing at Different Electron Kinetic Energies: the Case of TiN' presented at Ecloud-12, Isola Elba, 2012.
- R. Cimino: "ECLOUD12 concluding remarks", presented at Ecloud-12, Isola Elba, 2012.
- R. Cimino: "Material Science for next generation Accelerator Vacuum systems", LAL 12-12-2012.

References

1. LNF Annual Report. This and previous issues.
2. R. Cimino et al., "Experimental efforts at LNF to reduce secondary electron yield in particle accelerators", proceedings of ECLOUD10, 2010.
3. R. Cimino et al., "Can Low-Energy Electrons Affect High-Energy Physics Accelerators?" Phys. Rev. Lett. 93, 14801 (2004).
4. R. Cimino et al., Nature of the Decrease of the Secondary-Electron Yield by Electron Bombardment and its Energy Dependence Phys. Rev. Lett. 109 (2012) 064801
5. R. Larciprete et al. : "Secondary electron yield of Cu technical surfaces: dependence on electron irradiation Phys. Rev. ST-AT, 16 (2013) 011002.

6. R. Larciprete et al., The chemical origin of SEY at technical surfaces Proc. ECloud-12, Isola Elba, 2012.

7. D.R. Grosso et al.: "SEY of Al Samples from the Dipole Chamber of PETRA III at DESY", proceedings of IPAC11.

8. D. R. Grosso et al. :Effect of the surface processing on the secondary electron yield of Al samples" submitted to Phys. Rev. ST-AT.

9. F. Schäfers and R. Cimino, Soft X-Ray Reflectivity: from Quasi Perfect mirrors to Accelerator Walls Proc. ECloud-12, Isola Elba, 2012.

10. R. Cimino, G. Rumolo and F. Zimmermann editors: Proceedings of the:"International Workshop on Electron-Cloud Effects (ECLOUD '12)". To be published as CERN Report No. CERN-2013.

11. R. Cimino, and F. Zimmermann "ECLOUD12 sheds light on electron clouds" CERN Courier September, 2012.