"SCRUBBING" PROCESS OF CU SURFACES INDUCED BY ELECTRON BOMBARDMENT

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Abstract

We studied energy distribution of electrons emitted from samples of the real Cu surface used in the Large Hadron Collider (LHC). The spectra have been detected as a function of scrubbing conditions and have been analyzed by dividing the whole energy range into three energy regions, conventionally termed reflected, rediffused and true-secondary electrons. We observe, for fixed electron impact energy, that the true secondary electrons gradually decrease for increasing electron dose, while we don't observe any variation in the EE and RE components. These results provide useful information on the electron cloud formation in particle accelerators and may shed light on the involved physical mechanisms.

INTRODUCTION

The synchrotron radiation, emitted by the bunched beams circulating in the particle accelerators, induces electrons emission from the vacuum system wall. These photoelectrons are accelerated (repelled) towards the opposite wall by the positive (negative) charge of the bunched beams, leading to further electron emission. Electron presence in the vacuum pipe (electron cloud – eC) gives rise to a multipacting process [1,2,3,4]. These phenomena may result in beam instabilities and in an undesired increment of both pressure and temperature, [2]. An important parameter that characterizes the eC production in the pipe is the secondary electron yield (SEY), i.e. the number of secondary electrons emitted from surface per incident electron. In previous work, a SEY decreasing has been observed as a function of electron bombardment (scrubbing process) [5,6,7] and, furthermore the elastic electron reflection showed a relevant influence mainly at low energies, where the SEY approaches unity, indicating that low energy electrons are long-lived in the accelerator vacuum chamber [5].

The study of SEY formation in the pipe is performed by simulation codes that take into account the behavior of different electrons forming the SEY [3]. Conventionally the SEY is divided in three energy regions [2,4,8] (fig.1): elastically reflected (EE), rediffused (RE) and true secondary electrons (SE). Simulations showed that of eC effect is strongly dependent to subtle differences in many input parameters entering the code [2]. So far, the surface conditioning (scrubbing process) have been experimental studied only for fixed energy electron beam (300-500 eV and 2.5 keV [5,6,9-12]) and without separately study the EE, RE and SE. Backscattered component (EE and RE) have been hypothesized independent from the scrubbing process, by using indirect observations [2], but no direct evidence, as given in this paper, was avaible.

In this work we present an investigation of SEY, EE, RE and SE behavior as a function of scrubbing process for 200 eV conditioned surface. We observe that the true secondary electrons gradually decrease with electron bombardment, while we don't observe any variation in the EE and RE components.

EXPERIMENTAL

The experiments were performed in a UHV chamber with a base pressure of $5*10^{-10}$ Torr. The electron beam was produced by an electron gun (Kimball Physics). Beam current were in the order of nA and had Gaussian spatial profile in both horizontal and vertical directions as measured by a Faraday cup at the target position. To measure accurately low energy electrons, the chamber is shielded with μ-metal to reduce the effect of stray magnetic fields on electron trajectories. The sample studied is part of the final production of colaminated Cu for LHC beam screen, and was mounted on a manipulator that allowed to change the angle between the surface normal and the electron beam direction (θ_i). In the present experimental layout we used an energy analyzer (GEA – Leybold) with acceptance angle of ~ 1.5°, mounted on a rotatable goniometer (~ 10 cm from the sample) for angle resolved studies. The analyser lies in the plane determined by the surface normal and the incident beam direction.

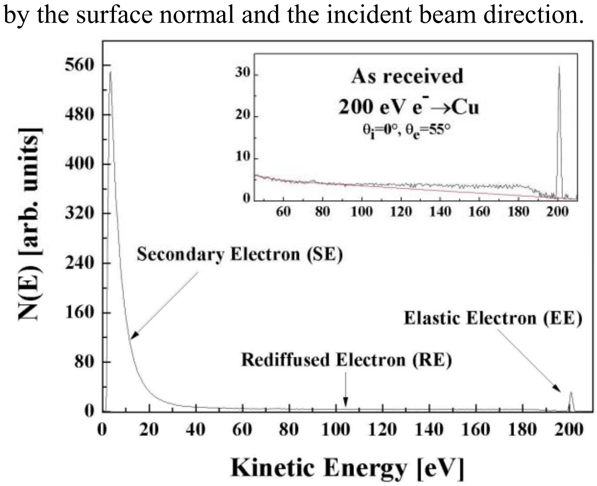

Figure 1: Energy distribution curves (EDC) from LHC Cu surface sample induced by 200 eV electrons in the angular geometry θ_i=0°, θ_e=55°. The inset shows an example of background subtraction.

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RESULTS AND DISCUSSION

Fig. 1 reports the energy spectrum of electrons emitted from a LHC type sample at room temperature bombarded by 200 eV electrons at an incident angle θ_i = 0° and at an observation angle θ_e=55° (both angles are measured with respect to the surface normal). This spectrum, measured on an as received sample, is corrected for energy analyser transmission and is normalized to the beam current and width. Figure 1 also shows the regions in which the spectra is conventionally divided: (i) elastic o reflected electrons – EE, related to electrons elastically backscattered when an electron beam impinges on a surface; (ii) rediffused electrons – RE, that are electrons emitted with energies between 50 eV and the onset of elastic peak, i.e. those electrons reflected back out by scattering from one or more atoms inside the material; (iii) true-secondary electrons – SE, constituted by electrons emitted between 0 eV up to 50 eV mainly due to electron collision cascade inside the solid. As can be seen from the data, SE overlaps the RE region.

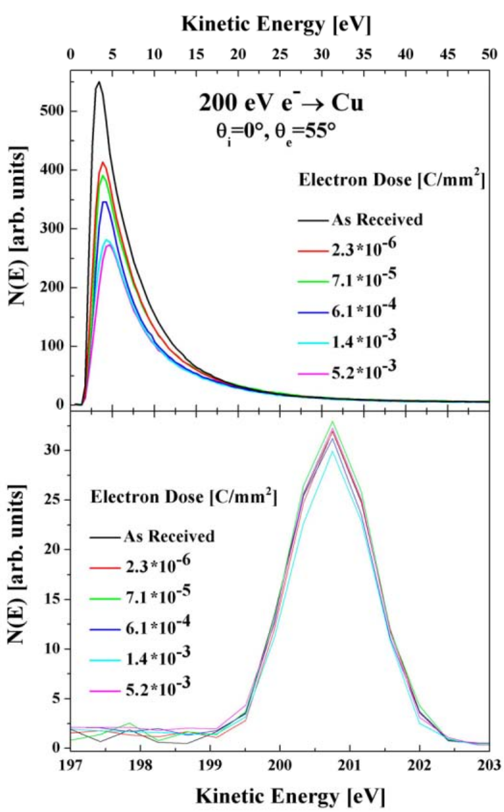

Figure 2: Evolution of the energy regions of EDC where secondary (a) and elastic electrons (b) appear as a function of electron dose bombardment.

To achieve a more reliable separation between the mentioned contributions, we subtract a background of true secondary electrons in each spectrum by fitting them over the entire energy range [13]. The inset in figure 1 shows an example of background subtraction from spectra obtained by fitting the two regions at energies above and below the rediffused and elastic energy range, with a monotonously decreasing function. The uncertainty in the background subtraction is estimated to be ± 15% by varying the function representing the background and the energy range on both side of the region to which the fitting procedure is applied.

In fig. 2 we report energy distributions of electrons emitted from sample surface under 200 eV electron bombardment as a function of electron dose. One can notice that the intensity of true secondary electron decreases, while the reflected electrons stay constant.

From the available data it is possible to extract the intensities of the various contributions to SEY, showed in figure 3 as a function of electron scrubbing process at 200 eV. In figure 3, for comparison, we report the secondary electron yields δ, obtained by measuring the current on the sample under positive and negative bias. The SEY measured is consistent with that reported in literature [9,14].

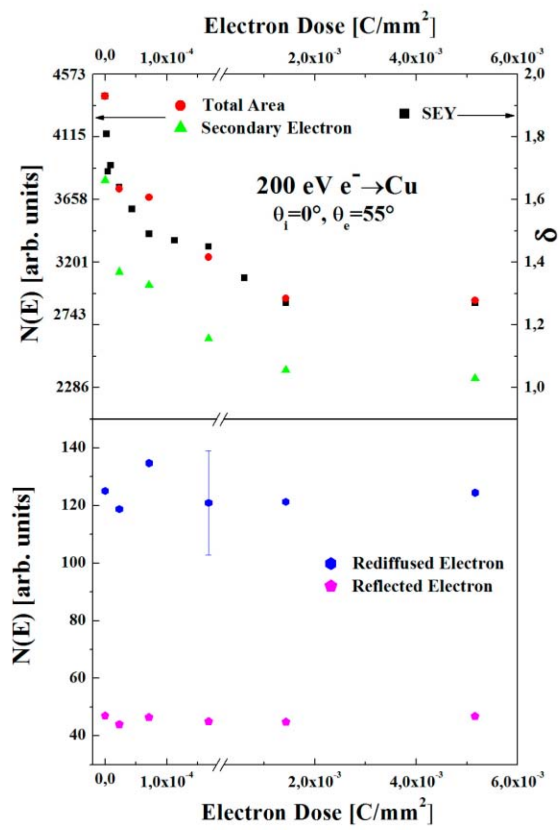

Figure 3: Top: SEY, Secondaries intensity and spectra total area as a function of electron dose bombardmet.
Bottom: Reflected and rediffused intensity as a function of electron dose bombardment, after background subtraction.

We can observe that the spectra total area have the same behaviour of SEY, even if the first is due to electron emission at a solid angle of 1,5° and the former is due to electrons emitted in whole solid angle. This confirms that the trend of EE, SE and RE as a function of electron dose can be extract from the reported spectra.

The figure 3 shows that true secondary electron emission decreases with the scrubbing process. This is probably due to molecules desorbed from surface as consequence of electron bombardment [9,11,12]. This process brings to work function variation, as we can observe by the shift of the onset and the maximum of secondary electron emitted (fig. 2). Furthermore, we can deduce that the backscattered electron (EE and RE contributions) don't change with scrubbing process, as proposed by Furman et al. [2].

CONCLUSION

In conclusion we reported the behaviour of the electron emission from LHC surface sample as a function of electron dose bombardment. This work experimentally confirms that the true secondary electrons decrease with surface conditioning, while those reflected and rediffused don't change. Our results can be implemented in scrubbing dependent simulations of the EC effect. Further studies are required to investigate more deeply the behaviour of the electrons forming the SEY as a function of scrubbing process for different scrubbing energy, and for different sample temperature.

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