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Detailed Investigation of the Low Energy Secondary Electron Yield (LE-SEY) of clean polycrystalline Cu and of its technical counterpart.

R. Cimino, A. Di Gaspare, L. A. Gonzalez and R. Larciprete.

Abstract— **The detailed study of the Secondary Electron Yield (SEY) of technical surfaces for very low electron landing energies (from 0 to 20 eV) is a very important parameter in many fields of research. Some of the devices used in all those fields of research base some of their essential functionalities on the number of electrons produced by a surface when hit by other electrons, namely its SEY, and, in most cases, its very low energy behavior (LE-SEY).**

Despite of such interest, the very low electron landing energy part of a SEY curve has been rarely addressed due to the intrinsic experimental complexity to control and detect very low energy electrons. Furthermore, several results published in the past have been recently questioned to suffer from experimental systematic errors.

In this paper, we critically review the experimental method used to study low energy SEY and define more precisely the energy region, in which the experimental data can be considered valid. By analyzing the significantly different behavior of LE-SEY in atomically clean polycrystalline Cu and in its "as received" technical counterpart, we solve most, if not all, of the apparent controversy present in the literature, producing important inputs for better understanding the devices performances related to their LE-SEY.

Keywords — Secondary Electron Yield; material properties; Electron reflectivity

I. Introduction

An extremely vast range of research fields spanning from accelerator technology [1], detectors, photon or electron multipliers, high power microwave tubes, systems for satellite applications [2], radio-frequency cavities [3], to optics for Extreme Ultraviolet lithography [4], base some of their essential functionalities on the surface Secondary Electron Yield (SEY), and, in some cases, to its very Low Energy (LE-SEY) behavior. SEY is the ratio between the number of emitted electrons to the number of incident electrons (also called primary electrons) [5], and is also commonly denoted by δ. Its value, time stability and dependence on primary electron dose and energy E_p are indeed a crucial issue and an essential ingredient in the design of many devices.

The LE-SEY curve has been rarely addressed due to the intrinsic experimental complexity to control and measure very low energy electrons. The few results published in the past, studying such SEY energy region in relation to electron cloud build up in high intensity accelerators machines, have reported on the tendency of SEY to reach 1 as the electron landing energy approaches 0 eV, and to stay significantly above 0 for quite an extended region, having a minimum SEY of about 0.5 - 0.7 at E_p as high as 10-20 eV [1, 6-9]. This low energy behavior was clearly stated to be valid for the actual technical Cu surface studied and a strong warning was given against the extrapolation of such results as being a general property of SEY [1, 6-9]. Despite such warning, these results have been questioned [10-12] and suggested to be affected by experimental artifacts, since the SEY is generally claimed to vanish at zero landing electron energies and to assume low values for the entire LE-SEY interval. This claim was based and corroborated by experimental data [13-18]. Also the theoretical framework and calculations are somehow controversial. Whereas a series of simulations agrees with a nearly zero SEY at low landing energies [11, 12] recently Cazaux [19] calculated that the electron reflectivity R_{el} is close to 1 at zero landing electron energy and decreases with increasing E_p, while the SEY at low impinging energies (from zero to some tens of eV) has values significantly higher than zero, in reasonable agreement with the data presented and discussed in [7- 9]

Scope of the present work is to finally address the detailed behavior of SEY at very low impinging electron energy (E_p < 20 eV) and to quantitatively estimate the level of confidence expected for the LE-SEY measurements in this energy range [11, 12, 20]. In fact, space charge, spurious electromagnetic fields, beam energy resolution etc. may act on the electron beam potentially affecting the detailed SEY determination. For those reasons, most of the SEY data available in the literature do not cover such LE region, starting the data acquisition well above E_p > 20 eV (see most of the references in [1]).

II. Experimental

The experiment has been performed at the 'Material Science INFN-LNF laboratory' of Frascati (Roma), with the same dedicated experimental apparatus which is described and used elsewhere [1, 6-9,21,22].

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This work was partially founded by INFN-Gr.V nta-IMCA project.

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Briefly, the ultra-high vacuum (UHV) system (background pressure below 2 10^{-10} mbar) includes a μ-metal chamber with less than 5 mG residual magnetic field at the sample position, plus various sample preparation (Ar^+ sputtering, sample load-lock etc.) and sample spectroscopic characterization techniques like X-ray (XPS) and ultraviolet (UPS) photoelectron spectroscopy and LEED-Auger [22].

A. *Setting the energy scale*

We first need to clarify the energy scale and reference, since this is essential to understand the measured data. The energetics of our system is schematically described in Fig. 1. As clearly discussed in [19, 23], in such spectroscopic experiments the energy of the different metals and systems (detectors, samples, guns etc.) align at the Fermi level, while the kinetic energy of any emitted electron is referenced to the vacuum level of the material from which it has been emitted, being the work function W the distance between the Fermi level and the vacuum level for each sample. Any applied voltage, to the gun lenses or to the sample, will then accelerate (or retard) the e^- beam. This is to say that electrons emitted by the gun will reference their kinetic energy to the cathode work function, W_G plus additional, when present, applied gun lens voltages, while electrons interacting with the sample will reference their energy to the sample work function (W_s) for metals, or Electron affinity (χ_s) plus their Energy Gap (E_G), for semiconductors and Insulators [19, 23] and obviously additional, when present, applied bias voltages. For simplicity, we will indicate in the following W_s, keeping in mind that, in case of semiconductors and insulator this quantity should be substituted by $\chi_s + E_G$.

In our set up, for instance, in order to measure low-energy impinging primary electrons, a negative bias voltage of V_{bias} ~ - 74 eV, was applied to the sample. Such bias not only allows us to eliminate space charge problems on the sample, but, more importantly, allows us to work with landing energies close to zero still using the e^- gun in an energy region where it is stable ($E_g > V_{bias} = 75$ eV) and focused onto a transverse cross-sectional area of known diameter (here around 1.5 mm).

The landing energy E_p is nothing but the energy of the electrons emitted by the gun (E_g) minus the negative applied sample bias voltage (V_{bias}) plus the difference between the e^- gun cathode and sample work (or electron affinity + energy gap) functions ($\Delta_W = W_s - W_G$).

So that:

$$E_p = E_g - V_{bias} - W_G + W_s = E_g - V_{bias} - \Delta_W$$

Here we refer all e^- energies to the Fermi Energy level E_F, which is the common and sample-independent reference for the entire system (see Fig. 1). With this energy reference, the minimum energy of a primary electron interacting and producing a measurable I_s, with an atomically clean polycrystalline Cu will be the Work Function (W_{Cu}) of such sample, which is known from literature to be 4.65 eV [24]. Scaling this spectrum (as well as all the others) in this way, eliminates systematic errors linked to the absolute estimate of V_{bias}, E_g and Wg. In other words, we set:

$$E_p\,(above\ E_F) = 4.65eV \ when \ E_g - V_{bias} - W_G = 0$$

This implies that, in all spectra measured, the measured E_p corresponding to the onset of electrons interacting with the solid, (that is when: $E_g - V_{bias} - W_G \sim W_S$) is an accurate measure of the surface work function W_s (for metals) and χ_s (for semiconductors and Insulators) of the new sample under analysis with respect to W_{Cu}.

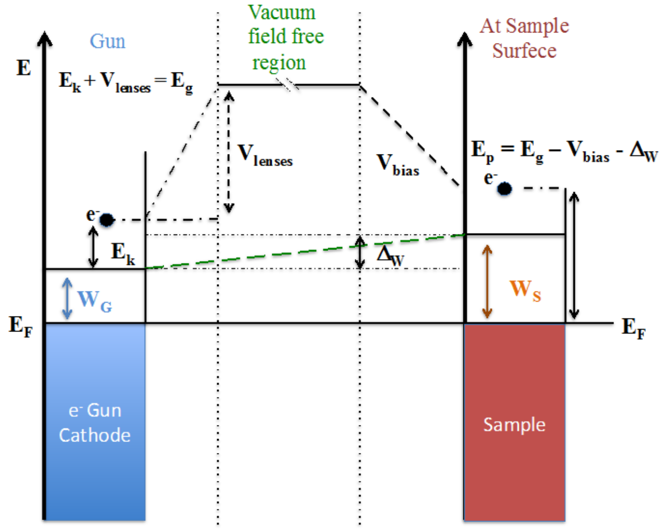

Fig. 1. Schematic of the energetic of our experimental set-up. The energy levels are aligned to the equilibrium Fermi level E_F. The symbols used are: W_G is the e^- gun Cathode Work Function; W_s is the sample Work Function (for metals) or $\chi_s + E_G$ (for semiconductors and Insulators, cases not shown here)); Δ_W is the difference between W_G and W_s (or $\chi_s + E_G$); E_k is the kinetic energy of the e^- just emitted from the cathode; V_{lenses} are the voltage potentials accelerating electrons emitted from the cathode; E_g is the Energy of the e^- emitted by the gun into Vacuum; V_{bias} is the retarding voltage applied to the sample; E_p is the landing energy (above E_F) of the electrons at the surface, as defined in the text.

For completeness, we mention here that in [6-9, 21, 22], as well as in most literature on SEY [1], the energy scale of the landing electrons was referenced to be zero at W_s (or $\chi_s + E_G$) without considering any variation of W_s (or $\chi_s + E_G$) for all samples and sample preparations. This would not significantly alter the conclusions of those papers, since it introduce only small energy offsets between different experiments. To be noticed that most if not all previous works on SEY did not pay any attention on the energy scale (which could actually affect the SEY maximum value called δ_{max} by only less than a few eV at most), and only recent theoretical studies [19, 23] and this paper do really necessitate the lengthy and very precise discussion here presented.

In conclusion, this analysis suggests that LE-SEY can be successfully used to measure Work functions and its variations upon surface treatment and condition.

B. *Measuring SEY*

Once the energetics is clear and settled, SEY ($\delta(E)$), is then defined as the ratio of the number of electrons leaving the sample surface ($I_{out}(E)$) to the number of incident electrons ($I_p(E)$) per unit area. $I_{out}(E)$ is the number of electrons emitted from the surface but also the balance between the current

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impinging on the sample, $I_p(E)$ minus the current flowing from the sample $I_s(E)$.

So that:

$$\delta(E) = I_{out}(E) / I_p(E) \qquad (3)$$

and:

$$I_{out}(E) = I_p(E) - I_s(E) \qquad (4)$$

then:

$$\delta(E) = (I_p(E) - I_s(E)) / I_p(E) = 1 – I_s(E) / I_p(E) \qquad (5)$$

The e^- gun emits electrons by means of thermionic emission and the beam emitted has then an energy broadening related to temperature at which the gun emitter works. In the laboratory we used two different e^- guns: one ELG-2, from Kimball Physics, which uses a standard Ta disc cathode and one SL1000, from Omicron, which uses a LaB_6 electron source. The expected width of the primary energy distribution at typical gun working current should be slightly different, since the Ta disk normally requires higher temperature than the LaB_6 to produce the needed e^- flux. The data here presented have been taken using the e^- gun from Kimball Physics i.e. with an expected slightly broader width but similar and consistent results are obtained with both sources. In general terms such thermal broadening, indicated by the beam Full Width Half Maximum ($FWHM_g$), can be assumed to be Gaussian in shape and is known to be ~ 0.5 – 1.0 eV, depending on the actual operating gun current. Such $FWHM_g$ will than enter in the energetics discussed above, introducing a Gaussian broadening to E_p. Actually, before extrapolating any conclusion from our data, we should indeed experimentally crosscheck that the experimental procedure used (biasing the sample force us to work in a non-completely field free region) will not affect such $FWHM_g$ value. There are two conceptually identical ways of scanning E_p in the desired energy range, that are obvious from Fig.1: one implies working with a fixed E_g and vary, by a computer controlled acquisition program, V_{bias} applied to the sample; the other necessitates to work with a fixed V_{bias} applied to the sample and using a computer controlled acquisition program to vary E_g. It is usually preferred to measure SEY at very low doses (i.e. I_p and I_s < than a few nA) to avoid surface modification by e^- bombardment (scrubbing) [1, 21]. Then a variable sample bias has to be avoided since its use not only would affect more significantly the electrostatic fields in the system, especially at higher E_p, but would also cause bigger leakage currents at increasing V_{bias} especially when trying to work at the lowest possible I_p. The use of a battery box to apply a fixed V_{bias} between 30 and 80 Volts, is then preferred and has shown its advantages eliminating such spurious effects and leak currents. The possibility of performing energy scans is offered by most of the e^- gun on the market so that the choice of a fixed V_{bias} and a variable E_g is an experimentally preferable solution which minimizes any potentially detrimental systematic errors. In our setup the SEY measurement is then performed by two subsequent operations: a) collect the sample e^- current $I_s(E_p)$ as a function of the intensity $I_p(E)$ and energy (E_p) of the primary electron beam, b) collect the e^- gun emitted current $I_p(E_g)$ by using an "ad hoc" designed Faraday cup described in [1].

To finally calculate $\delta(E)$ one needs to scale the energy E_g at which $I_p(E)$ is emitted by the e^- gun and measured with the Faraday cup, to the final landing energy E_p by considering the applied retarding voltage V_{bias} and Δ_W. The stability of $\delta(E)$ is guaranteed if a series of repeated measurements with the Faraday cup gives very similar $I_p(E)$: a few percent error bars are intrinsic to most of the SEY data and that are due to experimental uncertainties as well as to intrinsic differences from local chemical or morphological sample inhomogeneity.

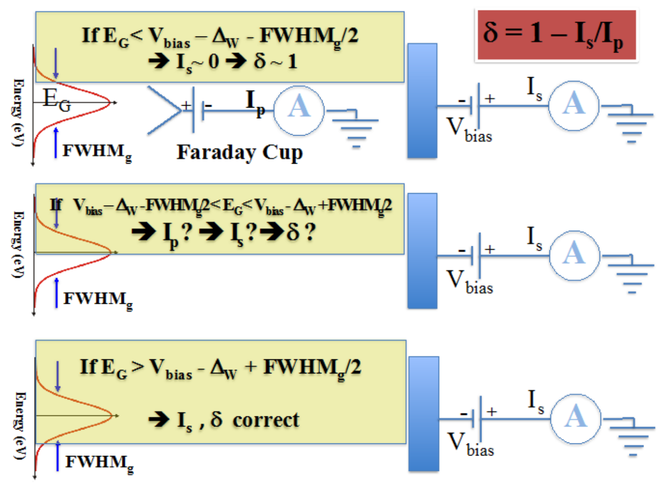

Fig. 2. Schematic of the experimental set-up at E_g close to V_{bias} to analyze potential artifacts of the measuring method. In figure we assume that the e^- beam is Gaussian in nature with a certain $FWHM_g$.

All SEY curves as a function of E_p are characterized by a maximum value (δ_{max}) reached in correspondence of a certain energy E_{max}. The δ_{max} values and SEY spectra have been extensively studied in recent years [1,6-9, 21, 22] and are not the topic of the present paper. Here we would ? like to validate the capability of our set-up to correctly measure LE-SEY, and to benchmark with it the experimental data reported in some of those references.

C. *Measuring LE-SEY*

In Fig. 2, we pictorially analyze the intrinsic difficulties in dealing with low energy landing energies $E_{p,}$ especially when they are comparable with $FWHM_g$.

Obviously, for energies $E_g < V_{bias} - \Delta_W - FWHM_g/2$, (see top panel in Fig. 2), even if the Faraday system will correctly measure a non-zero current $I_p(E)$, all electrons impinging on the surface will be electrostatically repelled (reflected) by the higher negative bias voltage, resulting in an I_s ~ 0, and, consequently, a value of $\delta(E)$ =1 will be obtained (see Fig. 2, top panel). What is not always correct is to assume it to be valid in absence of any V_{bias} and for all Δ_W values, since, obviously, E_p < 0 is unphysical. With this reasoning in mind, we plot all our measured SEY starting from 1 at $E_g < V_{bias} - \Delta_W - FWHM_g/2$. When all the electrons reach the surface without being repelled by the bias, ($E_g > V_{bias} - \Delta_W + FWHM_g/2$) then they will interact with the surface, and $\delta(E)$ is measured correctly (see bottom panel in Fig. 2).

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Due to the finite energy width $FWHM_g$ of the e^- gun beam when $V_{bias} - \Delta_W - FWHM_g/2 < E_g < V_{bias} - \Delta_W - FWHM_g/2$ only some of the electrons reach the surface (having an energy > $V_{bias} - \Delta_W$), while some other (having an energy < $V_{bias} - \Delta_W$) are repelled by the sample bias. It follows that the measured δ(E) is inaccurate, since the $I_p(E)$ used in (5) measures the total number of the e^- emitted by the gun, while $I_s(E)$ only refers to only those e^- reaching the surface with energy > $V_{bias} - \Delta_W$, which will be only a percentage of the ones emitted and measured by the Faraday cup. Their actual number does strongly depend on the shape of the energy distribution of the emitted beam.

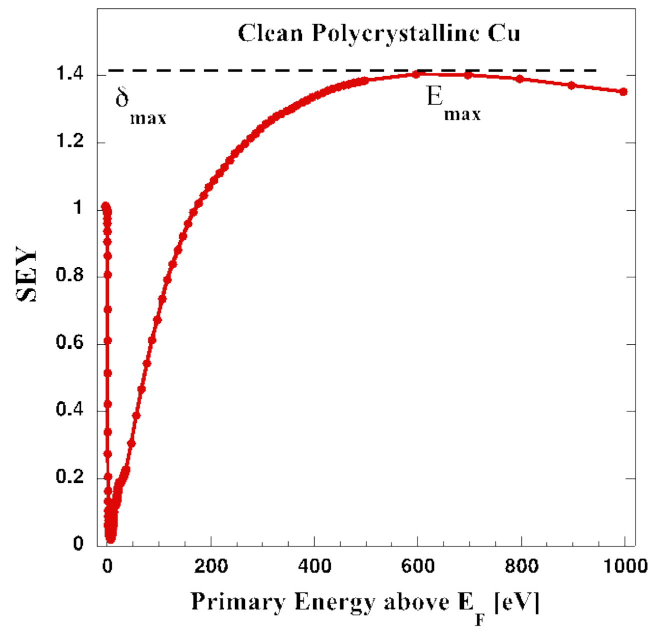

Fig. 3. SEY of a clean polycrystalline Cu in the energy region spanning from zero to 1000 eV above E_F.

In conclusion, the LE-SEY we measure should consist of three region: 1) at low energy ($E_p << V_{bias} - \Delta_W$), when all impinging electrons are repelled by the biased sample, δ(E) =1; 2) at high energy ($E_p >> V_{bias} - \Delta_W$), when all impinging electrons interact with the sample, δ(E) is measured correctly; 3) at $E_p \sim (V_{bias} - \Delta_W)$, when some of the impinging electrons are reflected and some interact with the sample, δ(E) cannot be accurately measured. The width of this region will measure the e^- gun line width if no other experimental artifacts are affecting our experimental set-up.

III. Experimental results

In this section we present the experimental results that allow us to confidently validate our experimental technique and compare the different literature results. To address such issue we compared an Oxygen-free high thermal conductivity (OFHC) Cu technical surface "as received" and after having been atomically cleaned by ion sputtering, as checked by XPS analysis. We mention that the geometry and all other experimental conditions were kept constant during the acquisition of the different set of data.

A. *Atomcally Clean Cu Sputtered samples*

The SEY measured on an OFHC polycrystalline Cu sample cleaned by ion sputtering is shown in Fig. 3. The clean surface was obtained after repeated Ar^+ sputtering cycles of 1h @1.5 KeV in an Ar pressure of $5x10^{-6}$ mbar.

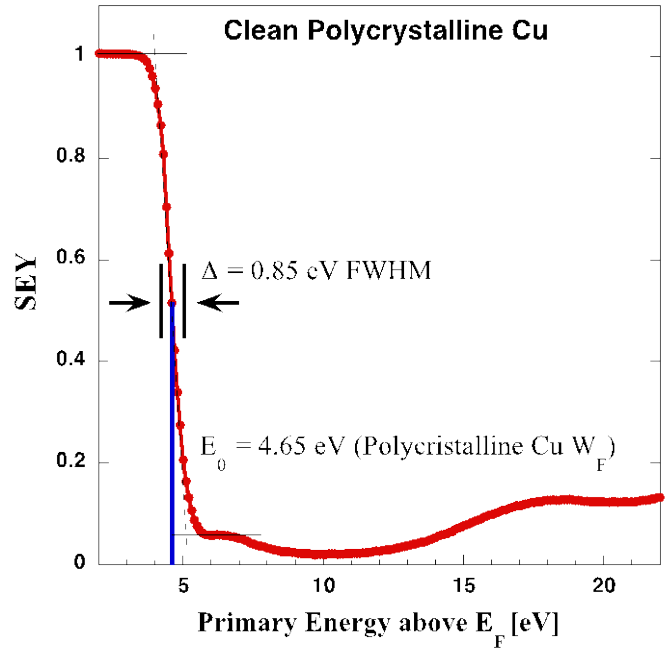

Fig. 4. LE-SEY of a clean polycrystalline Cu zooming in the energy region from 2 to 22 eV above E_F.

Surface cleanliness was determined by the absence of C and O signals in the XPS spectrum. The SEY curve is measured varying E_p between zero and 1000 eV.

The SEY reported in Fig. 3 shows that the clean polycrystalline Cu has a δ_{max} = 1.4 at around E_{max} = 640 eV, consistent with literature results [6, 22]. The curve shape is similar to the one of other clean metals [10, 13–16], with SEY values approaching zero when E_p decreases to zero. A magnification of the very low energy region, shown in Fig. 4, is indeed very instructive. As expected from Fig. 2 and from the discussion in section II.*C*, the LE-SEY starts at 1, then, very sharply ($FWHM_g$ = 0.85 eV) decreases to less than 0.1 and slowly increases to higher SEY values. As previously discussed, the threshold energy where such decrease takes place has been set at $E_p = W_{Cu}$ = 4.65 eV, being E_F our energy reference. The width of the transition region is measured to have a FWHM = 0.85 eV and is absolutely consistent with the expected thermal broadening deriving from the Ta disk of the Kimball gun. This data suggest that the energy region where our LE-SEY technique is blind, is less than one eV in width.

These data, taken within an unprecedented energy range, spanning over all the low energies of interest, are consistent with previously published data [10, 13 – 16], on atomically clean samples and with the calculations performed on clean Al [11, 12]. This suggests that clean metals do tend to have LE-SEY values approaching zero at landing electron energies approaching W_S (in our energy scale) and to have low LE-SEY values for this entire energy interval. Structures at ~ 2 and 14 eV above the W_{Cu} are clearly visible and can be ascribed to plasmon collective exitations occurring in the solid discussed and described elsewere [11, 12, 25].

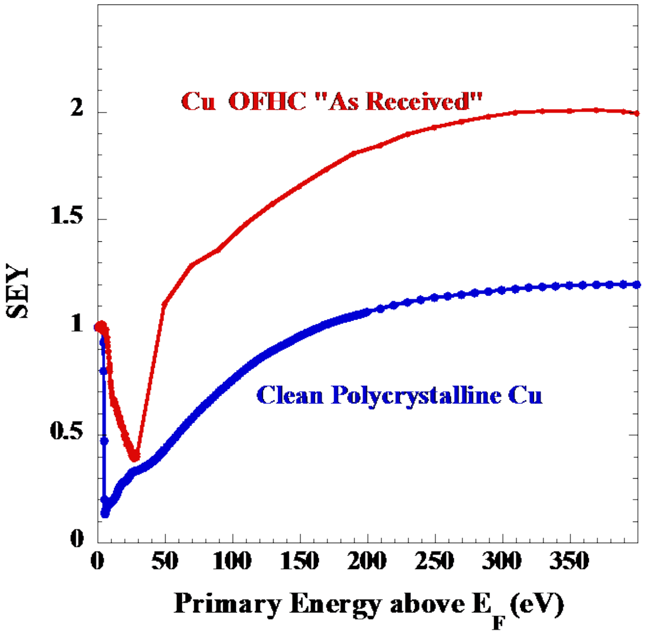

Fig. 5. Comparison between SEY of: a) Clean Polycrystalline Cu (blue curve) and b) "As received" OFHC Cu (red curve).

Moreover, and perhaps more importantly, the data confirm the capability of our system to measure with great accuracy LE-SEY values as low as 0.1 at impinging energies less than 1 eV above W_S (or χ_s). In our setup, a quasi-zero SEY can only be measured if we measure an $I_s(E)$ of the same sign and value of $I_p(E)$. As already discussed, such two quantities are measured independently and the fact that are of very similar values cannot be ascribed to any experimental artifacts. In case of clean polycrystalline Cu, we can clearly confine in less than the 1.0 eV any eventual physical effect bringing the e^- reflectivity to 1 at E_p close to W_S. This is the region where we are blind due to the intrinsic width of our e^- beam.

B. "As received" Cu samples

High resolution LE-SEY curves were measured on several as-received OFHC Cu samples before cleaning them by ion sputtering. The as-received samples were rinsed in ethanol and deionized water before being inserted into vacuum. We stress here that the 'as-received' and the clean Cu were actually the same sample, before and after sputtering, so that the difference in the measured signal cannot be ascribed to any difference in sample positioning or dimensions. The results are shown in Fig. 5 in the E_p region between 0 and 400 eV above E_F. The SEY of the "as received" Cu agrees well with literature results, showing a δ_{max} = 2.0 at E_{max} = 350 eV [1]. It is clear that the term "as received" does not correspond to a well defined surface composition and that 'as received" surfaces may significantly differ one from each other. Ancillary XPS analysis (shown in [21, 22]) identify a bit more quantitatively such surface. Typically, the Cu signal, which dominates the XPS spectrum of clean Cu, is hardly visible, and the spectrum is dominated by the broad O1s and C1s core levels.

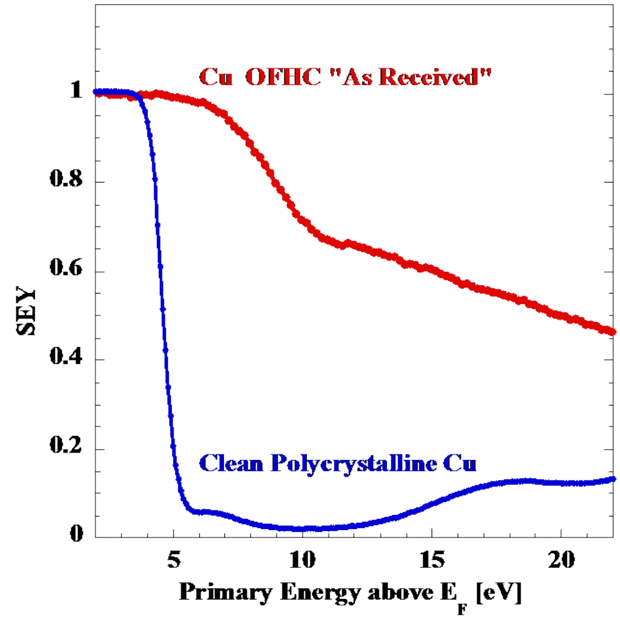

Fig. 6. Comparison between LE-SEY of: a) Clean Polycrystalline Cu (blue curve) and b) "As received" OFHC Cu (red curve).

Such spectra indicate the presence of different bonding configurations and different oxides and carbonaceous species in the contaminant layer which can be deduced to be as thick as 10-50 atomic layers.

The difference between the "as received" and the clean Cu sample is even more evident in their LE-SEY zoomed regions showed in Fig. 6. Clearly, the "as received" surface exhibits a work function (or χ_s) higher than W_{Cu}, which does not seem to have a very well defined value. The decrease of the LE-SEY value in the "blind region" of our apparatus is much reduced. The measured reduction from SEY=1 to its first flexus, is much wider (more than 4 eV in width) and cannot be ascribed to the experimental $FWHM_G$ broadening. This feature could be ascribed to the presence of disomogeneous areas with different work funcions (or χ_s) even if 4 eV is quite a significant value for such work function (or χ_s) variation. We ascribe this behavior to the enhanced ability of the "as received" surface to reflect low landing energy e^-. In fact the data clearly shows that, for this "as received" sample, the reflectivity at landing energy close to W_S (or χ_s) can be assumed to be close to unity, and that the SEY value in the entire LE region is always higher than 0.5 at variance with the clean Cu. This observation, toghether with the certified confidence that our experimental method is able to correctly measure LE-SEY up to Ep values less than 1 eV higher than the W_S (or χ_s), clearly indicates that the dramatic difference of the LE-SEY curves is due to the presence of the contaminant layer of the "as received" Cu. This observation clarifies the apparent discrepancy of literature data which can be simply ascribed to the different samples cleanliness, and actual composition and metallicity of the outermost layers, which significantly alter the reflectivity R_{el} at zero landing energies. We show here that SEY and, in particular, its LE part is very surface sensitive and it is strongly affected by the presence of a non metallic over layer onto a metal surface.

The detailed analysis of why such contaminant layer is so significantly modifying the capability of a surface to reflect low energy impinging e^- is outside the scope of the present work. Space charge or dipole formation in the quasi insulating over layer, as well as its significant difference in electronic properties from the ones of the clean metal substrates are, indeed, good candidates. Further studies are required to address in detail this issue, specially in presence of well defined and thick over layer on an otherwise clean metal surface. Also it may be interesting to confirm that most clean metals show the same low reflectivity behavior observed here for Cu and in ref. [21,22] and to analyze subtle differences that could be related to different metals electronic properties. Surface order and different reconstructions should also have effects on the measured data. Also, the SEY and LE-SEY evolution versus different gas adsorbates can give insight on the different electronic properties of chemically modified surfaces.

For technical surfaces, which are of interest here, we confirm the validity of the data presented in [1, 6-9] and again suggest that detailed studies must be performed to analyze the LE-SEY behavior of any technical surface of interest in the specific device under study.

C. Over the "blind region".

As discussed, our data show a "blind region" at landing energy close to W_S, where the energy width of the e^- beam prevents us to measure the actual number of electrons. In fact, as discussed in fig.2 (central panel), in this energy region the measure of I_p by means of the Faraday cup does not provide us the correct number of e^- reaching the surface with energy E_p (above E_F) > W_S (which will be called in the following I_p^*).

We can analyze the data in light of this discrepancy, and calculate the actual primary current Ip* by convolving the measured Ip (which is nearly flat and negative in the small LE region of interest) with the impinging e^- beam assumed to have a Gaussian profile with $FWHM_G$ = 0.85 eV and centered at 4.65 eV above E_F. Such analysis is presented in fig. 7, where we compare the measured SEY with the one obtained by using in (5) I_p^*. The inset of Fig. 7 shows I_p^* and I_p. As expected, I_p^* is zero when all electrons are repelled (as in Fig. 2 top panel); is negative and equal to I_p when all e^- interact with the surface (as in Fig. 2, bottom panel); and, in the intermediate region (as in Fig.2 central panel), is the convolution of a Gaussian with a step function, being exactly ½ of I_p at $E_p = W_S$. Some peculiarities have to be clarified to better understand the analysis of such corrected SEY. The first regards the region where I_p^* is zero. In this region, as from eq. (3) and (5), SEY is not a defined quantity and has not been plotted. The other aspect regards the energy scale of the x axis of Fig.7. Such x scale represents the centroid of the Gaussian beam of width $FWHM_g$ = 0.85 eV. This does not imply that we have SEY ~ zero at impinging energy less than W_S but that, when the centroid of the Gaussian e^- beam is below W_S there will still be some e^- of energy above W_S that will interact with the surface generating the measured I_s.

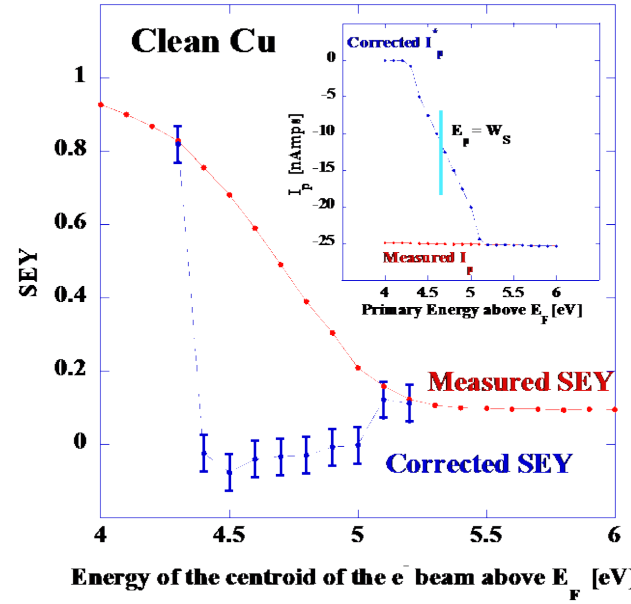

Fig. 7. Comparison between SEY data as obtained by dividing the measured Is with the measured I_p (red dots) with the one obtained by using the corrected I_p^* (blue dots) obtained by convoluting I_p with the Gaussian profile of the e^- beam of $FWHM_g$ = 0.85 eV.

With this in mind and within the error bar expected from the procedure, we see that we may extract significant information also from the so called "blind region". Just by assuming a given $FWHM_g$ the corrected I_p^* is, within the error bar, very close to the measured I_s, hence the SEY is close to zero also in the "blind region" suggesting that no Reflectivity rise is occurring for clean Cu even at energy less than 1 eV from W_S.

A similar analysis on the different "as received" surfaces, here not shown, confirms, on the other hand, the significant e^- reflectivity measured for such technical samples in the LE-SEY energy region.

With this we show that, the "blind region" can still be studied and reduced by analyzing the measured data in light of the finite width of the e^- beam and confirm, also in this region not directly accessible from the 'as measured' data, the same trend as discussed for the entire LE-SEY region.

IV. Conclusion

By setting the energy scale and analyzing in details the measuring technique used to study SEY and its LE-SEY, we validate our data to be free from experimental artifacts up to landing energies less than an eV above W_s (or χ_s). By doing so we clearly identify the tendency of clean metallic surfaces to have a LE-SEY tending to zero at landing energies close to W_S. On the other end, the technological counterparts of such metallic surfaces, i.e. the "as received" samples used in all technological relevant applications show a LE-SEY above 0.5 – 0.7 in the entire low energy region and show a tendency to have a high reflectivity (close to 1) at landing energy close to W_s(or χ_s), at variance with clean metalsurfaces. Clearly, since an "as received" technical surface is not at all a well defined structure, we suggest that detailed studies must be performed to analyze the LE-SEY behavior of any technical surface of interest in the specific device under study.

The analysis of SEY and LE-SEY, if shown (as done here) to be free from experimental artifacts, qualifies this technique as a powerful and simple analytical tool not only to extract δ_{max} and E_{max} but also sample work function (or electron affinity), work function changes and more subtle processes and parameters of relevance to basic as well as technology oriented surface and material science.

ACKNOWLEDGMENT

We wish to thank the DAΦNE-L technical team for continuous assistance during the experiments and Annalisa Romano for participating to the early phase of this research.

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