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Experimental study of the effect of the temperature on the electron emission yield of silver surface

M. Belhaj[(1)], S. Dadouch[(1)] , J. Puech[(2)]

[(1)] DPHY, ONERA, Université de Toulouse F-31055
2, avenue Edouard Belin - BP 74025 - 31055 Toulouse, France
mohamed.belhaj @onera.fr; sarah.dadouch@onera.fr

[(2)] CNES Toulouse
18 Av. Edouard Belin, 31400 Toulouse, France
Jerome.puech@cnes.fr

INTRODUCTION

The increase in temperature leads to an increase of the vibrations of the material's lattice and thus to a greater probability of electron-phonon interaction [1]. Therefore, in principle, it is expected that the increase in the temperature leads to decrease of the total electron emission yield (TEEY). However, in metals, the most main energy loss processes is the electron-electron interaction [2]. Therefore, it is anticipated that the TEEY of metals to be insensitive between -200°C to and 200°C to the temperature variations. Despite this well-established assertion, the effect of the temperature on the TEEY is still being intensively discussed in the multipactor community [3]. The TEEY is the ratio of the total number of electrons emitted from the material (backscattered and secondary) over the number of incident electrons.
We have investigated the effect of temperature variation on the TEEY of silver sample. We clearly show that there is no impact of the temperature variation in the temperature range under ultra-high vacuum conditions (10^{-10} mbar- 10^{-9} mbar). Only very slight decrease of the TEEY was observed after exposing the sample to 200°C. We show that this variation is only due to hydrocarbon contamination desorption from the surface and not to an intrinsic effect of the temperature. However, when the experiments were conducted at high vacuum conditions of about 10^{-7} – 10^{-6} mbar, representative of commonly multipactor ground test vacuum chamber, the surface adsorption of residual gas of H_20 at low temperatures affects the TEEY and hence most likely the multipactor power threshold.

EXPERIMENTAL SETUP

TEEY measurements as well as XPS analyses were performed in UHV facility (**typically 10^{-10} mbar**), spatially designed for TEEY characterisations. The analyses chamber is equipped with:
- Three electrons Kimball Physics electrons guns allowing the electron irradiation from 1 eV to 30 keV;
- Aspect SIGMA hemispherical electron energy analyser equipped with large dynamic 128 micro channel plates (MCP);
- Focus –FDG150 ion source;
- Thermostatically controlled sample holder (-180° to 450°C)

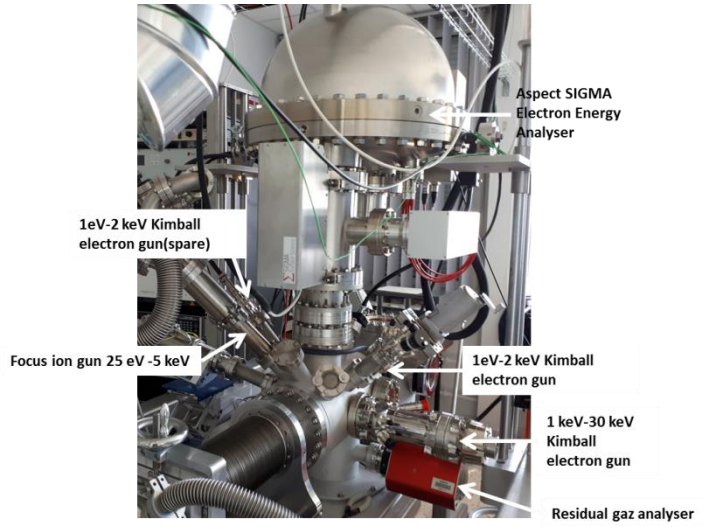


Fig. 1. ALCHIMIE; TEEY and surface analyses facility located at ONERA

A second used facility, is a high vacuum (**HV**,**10^{-7} mbar)** facility: PHEDRE.

PHEDRE is equipped with:

- Two electrons Kimball Physics gun allowing the electron irradiation from 1 eV to 30 keV.
- VUV source
- Electron collector detector
- Thermostatically controlled sample holder (-180° to 450°C)
- Electrostatic Kelvin probe

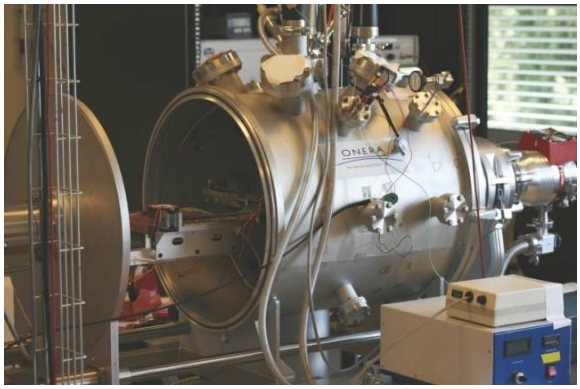


Fig. 2. PHEDRE; TEEY and charging effects facility located at ONERA

EXPERIMENTAL

The sample is silver plate aluminium typically used in RF hardware's. The sample was stored under ambient atmosphere with uncontrolled humidity during more than two years before this study.
The standard TEEY measurement procedure, compliant with the ECSS- multipaction [3] for conductive samples was applied. The sample is irradiated in short pulse mode (few ms) in order to prevent the electron induced surface modification phenomenon (conditioning effect). The TEEY was deduced from the measurement of the sample current (I_S) and the incident electron current (I_0) using the following expression:

$TEEY=(I_0-I_S)/I_0$

During the sample current measurement the sample holder was negatively biased in order to prevent the recollection of the emitted electrons by the sample surface. In ALCHMIE, the vacuum level during the measurements was in the range of 10^{-10} mbar at low and room temperatures and in the range of 10^{-9} mbar at high temperatures. In PHEDRE, the vacuum level during the measurements was in the range of 10^{-7} mbar at low and room temperatures and in the range of 10^{-6} mbar at high temperatures.

The TEEY and the surface composition were monitored after 8 steps of temperature variation.

Step 1: Room temperature, 25°C, on as received sample
Step 2: 200°C during 2H before measurement
Step 3: 100°C during 1H before measurement
Step 4: 25°C during 1H before measurement
Step 5: -50°C during 2H before measurement
Step 6: -100°C during 2H before measurement
Step 7: -150°C during 2H before measurement
Step 8: 200°C during 2H before measurement

Note that during all the measurement procedure the sample was kept under UHV in ALCHIMIE and HV in PHEDRE.

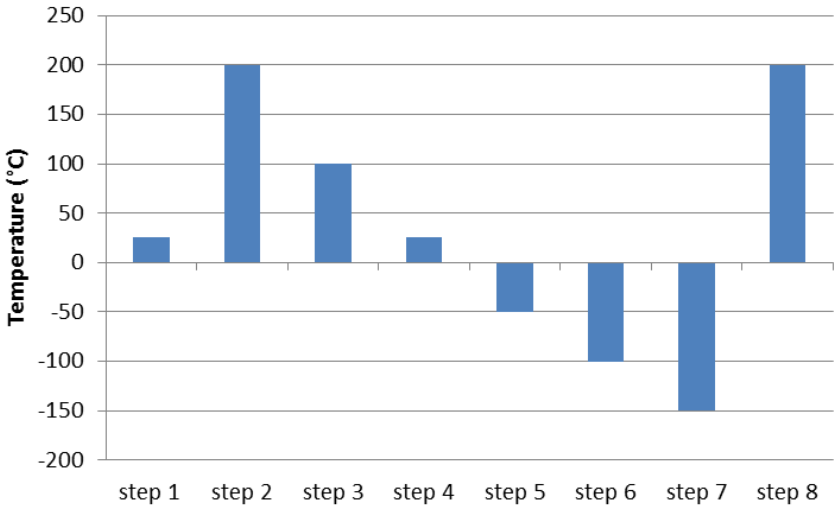


Fig 3. Temperature variation protocol

RESULTS

Ultra-high vacuum condition: 10^{-10} mbar to 10^{-9} mbar

The TEEY measured after the 8 steps in ALCHIMIE under UHV are shown in the Fig.4. We observed only a very small lowering of $TEEY_{max}$ (maximum of the TEEY) when the temperature is increased from the 25°C to 200°C (from 2.30 to 2.27). The EEY decreases again during the temperature relaxation from 200° to 25°C (from 2.27 to 2.10, see Figure 5). This decrease is attributed to the carbon content molecules desorption from the surface. The desorption "amplitude" increases as well as with the heating and the applied heating time. Under vacuum the temperature relaxation time from 200°C to 25°C is relatively long (more than 10 hours), as the consequence, the most change on the TEEY (lowering) was observed after this step. Note that, no significant change was observed on the first crossover energy, E_{C1}.

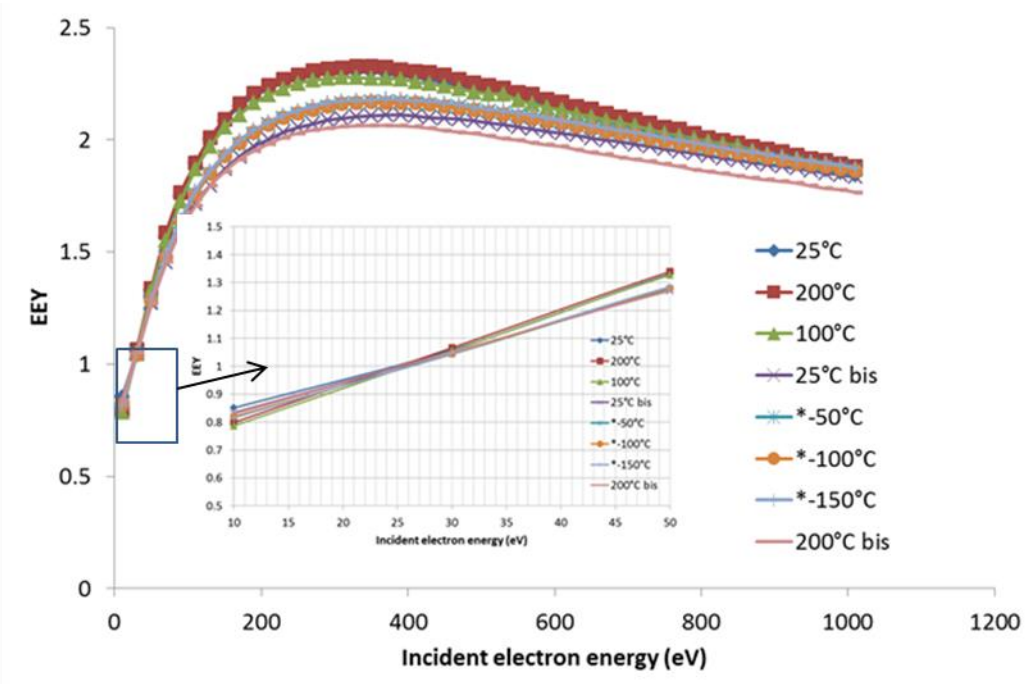


Fig.4. TEEY measured at normal electron incidence as function of the temperature under UHV.

When the temperature being negative (step 5), we observed an extremely moderate increase of the TEEY ($TEEY_{MAX}$ increases from 2.10 to 2.15).

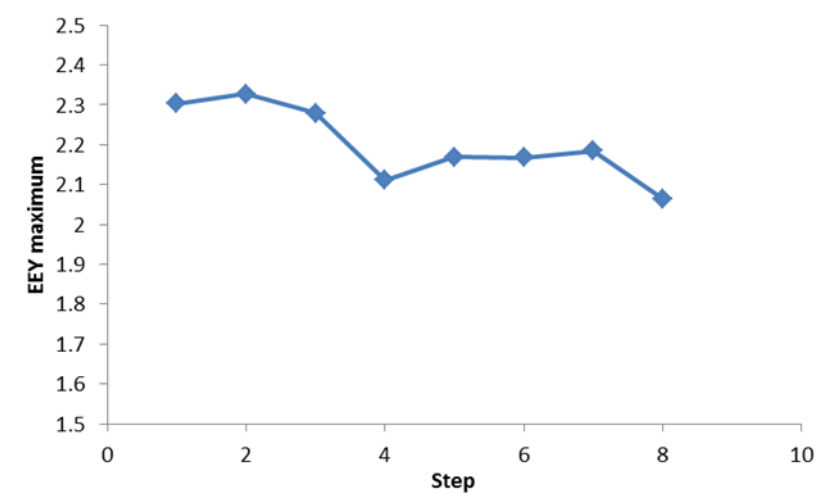


Fig.5. TEEY measured at normal electron incidence as function of the temperature under UHV.

The XPS in situ analyses during the temperature lowering procedure show that the oxygen concentration was stable even the temperature was set to -150°C. This result attests that there is no significant accumulation of ice (H_2O) at the surface. During the heating the carbon content decreases and the silver content increases due to the contaminant desorption.

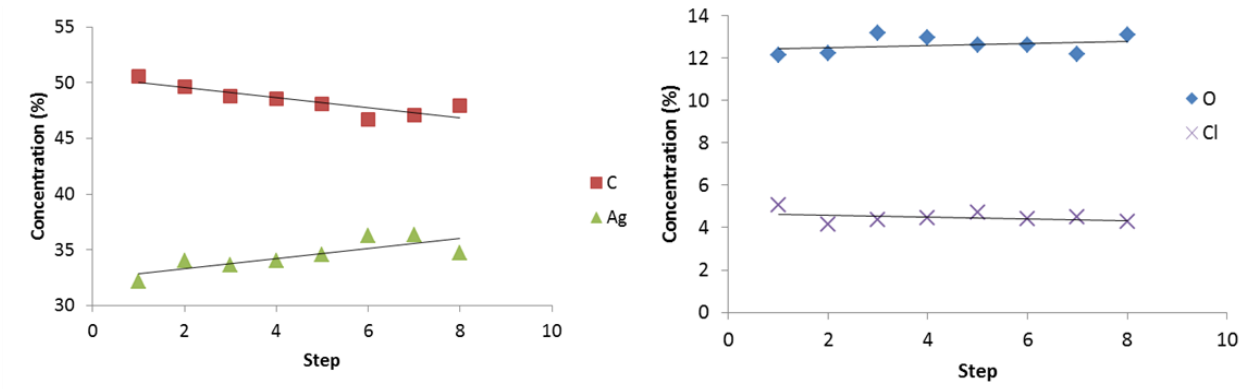


Fig.5. In situ XPS analyses under UHV

All the measured $TEEY_{max}$ at various temperatures are plotted as function of the carbon concentration in the Fig.6. The result show that the mean effect of temperature is the variation of contaminant concentration (carbon content molecules) that affect the indirectly the TEEY. It should be also mentioned that in our UHV ground conditions, in any cases (high or low temperature) the measured TEEY are lower than that of measured at room temperature of the as received sample.

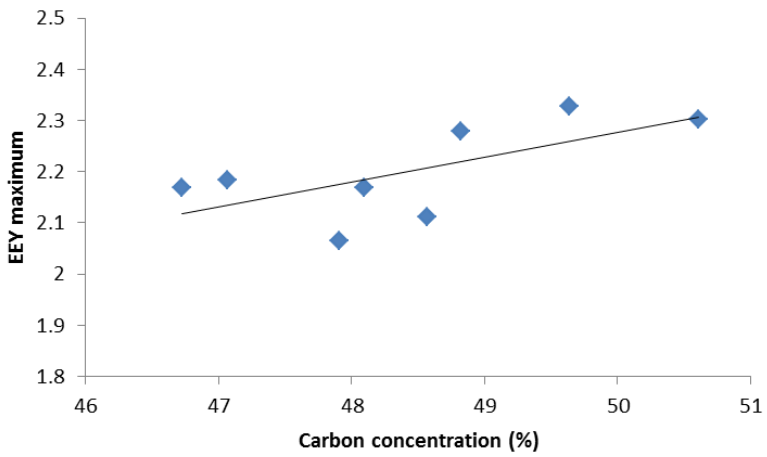


Fig.6. TEEY as function of carbon concentration under UHV

High vacuum condition: 10^{-7} mbar to 10^{-6} mbar

The TEEY measured as functions of the temperature under HV are shown in the Fig.7. In contrast with the TEEY measured in ALCHIMIE under UHV, we observed a huge change on the results as function of the temperature, notably when the temperature being negative. Indeed, as soon as the temperature becomes negative, the TEEY increases suddenly. Note also that a local minimum appears for negative temperatures around 900 eV. This local minimum is the typical and unambiguous signature of an electric charging effect [4].

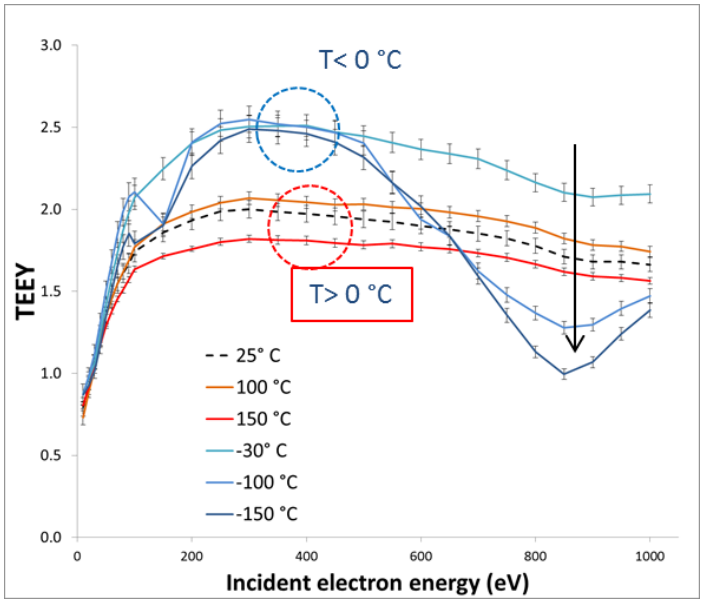


Fig.7. TEEY as function of the temperature measured under HV conditions

The Fig. 8 shows a comparison between the evolutions of the TEEY maximum as function of the temperature for both measurements conditions HV and UHV. If at under UHV conditions, the $TEEY_{max}$ is relatively stable, under UH condition the $TEEY_{max}$ increases suddenly when the temperature becomes negative (< 0°C). It is well known that H_2O is the dominant molecules that remains in the residual gas of vacuum chambers (expect may be that equipped with cryogenic-pumps). If as we have shown with XPS analyses under UHV, there is no significant accumulation of H_2O at the surface at negatives temperatures, most probably, a few nm layer of H_2O was accumulated at the surface under HV conditions (PHEDRE). As the TEEY is extremely sensitive to the surface composition, this leads to huge change on the

results. The accumulated H_2O is an electrical insulting layer, which explains the signature of charging effect observed in the shape of the TEEY at negative temperature (see Fig.7., the local minimum at 900 eV).

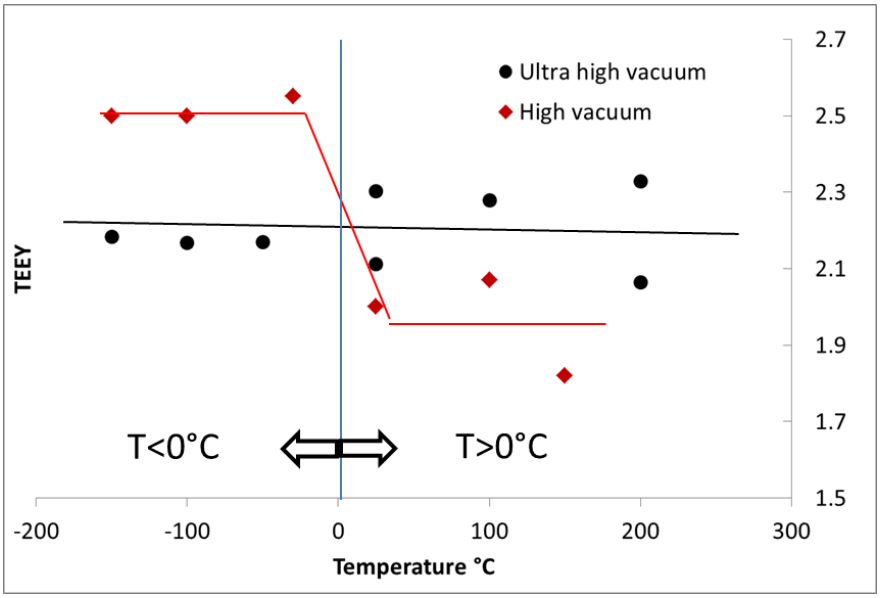


Fig.8. $TEEY_{max}$ as function of the temperature for both vacuum conditions UHV and H.

CONCLUSION

The present results show that as it was expected for metals there is no intrinsic effect of the temperature on the TEEY of silver plate aluminum under ultra-high vacuum conditions (10^{-10} mbar). A very moderate variation in $TEEY_{max}$ was observed along the experiment time (few days). The surface analyses by XPS show clearly that this variation is related to the carbon content molecules desorption during the temperature rising stage. The XPS analyses show also that there no H_2O accumulation on the surface under the applied UHV conditions and at low temperatures (< 0°C). However, we observed a huge change on the TEEY at low temperature when the experiments were conducted under HV conditions (10^{-7} mbar), that we attributed to the H_2O accumulation on the surface

It should be mentioned that multipactor tests are usually performed under relatively poor vacuum conditions [3] (10^{-5} to 10^{-6} mbar). Under this condition, at negative temperatures, most likely a H_20 layer is formed on the surfaces of the RF hardware's under test. As the consequence, the TEEY will be more representative of the accumulated H_2O then that of the original surface. The measured $TEEY_{max}$ at low temperatures on silver under HV condition is much higher than that of measured under UHV condition (2.78 vs 2.15)

Refereeing to the present analyses, the results of multipactor tests on metallic surfaces at low temperature (<0°) obtained under HV conditions are questionable and in particular from the point of view of the space environment representativeness. Most likely is that the multipactor power threshold measured at negative temperature in the ground test conditions (HV) differs from that of real inflight condition (UHV)

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REFERENCES

[1] J. Llacer and E. L. Garwin, "Electron-Phonon Interaction in Alkali Halides. I. The Transport of Secondary Electrons with Energies between 0.25 and 7.5 eV", Journal of Applied Physics 40, 2766-2775 (1969)

[2] Jacques Cazaux , "Some considerations on the secondary electron emission, δ, from $e-$ irradiated insulators", Journal of Applied Physics 85, 1137-1147 (1999)

[3] J. Hillairet, M. Goniche, N. Fil, M. Belhaj, and J. Puech, , in proceeding of MULCOPIM Workshop, 2017, Noordwijk, Netherlands
[4] C. Rigoudy, K. Makasheva, M. Belhaj, S. Dadouch, G. Teyssedre, and L. Boudou, "Atypical secondary electron emission yield curves of very thin SiO2 layers: Experiments and modeling", Journal of Applied Physics 130, 135305 (2021)

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