NUCLEAAR

A. Marcelli (Resp. Naz.), S. Macis (Ass.), S.J. Rezvani (Ass.), S. Lupi (Ass.), G. Della Ventura (Ass.), I.P. De Padova (Ass.), and B. Spataro (Ass.)

I. SUMMARY

NUCLEAAR is one of the projects of the Research and Development (R&D) section of the INFN Vth Committee, which addresses the scientific and technological challenges required to pushing forward the research frontiers on accelerators. The R&D is oriented to technological and industrial applications of accelerators, future colliders and next generation of accelerators after LHC, which is a relevant issue under discussion in the European Particle Physics Strategy Form. In this context the aim of the NUCLEAAR project is the investigation of novel coatings to improve the performance of copper cavities. Actually, in order to design more powerful and compact accelerators, it is necessary to enhance the electromagnetic fields at which accelerating devices operate. The present copper-based technology is limited by breakdown phenomena that unavoidably damage the surface of RF cavities operating for long time at electrical gradients greater than 100-200 MV/m. Additional information on the NUCLEAAR experiment is available on the LNF website at the URL: http://w3.lnf.infn.it/ricerca/ricerca-tecnologica/nucleaar/.

II. ACTIVITY

Overcoming the problems of the pandemic that slowed down almost all experimental activities, in 2020 the program of the NUCLEAAR experiment has been reoriented focusing on the:

- Assembly of an improved HV chamber for the evaporation of materials;
- Improvement of the annealing setup inside the HV chamber;
- The optical setup for non-linear THz spectroscopy experiments.

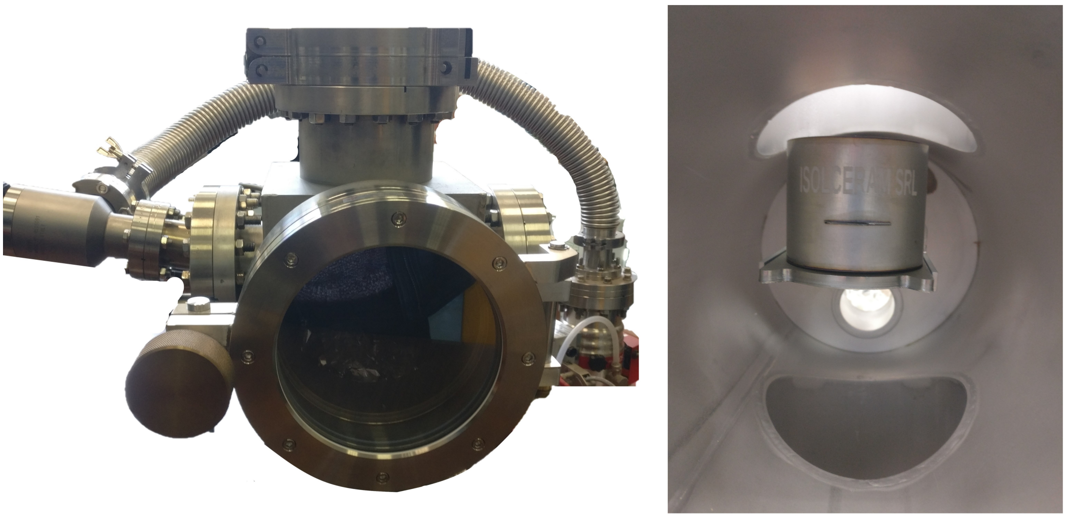

FIG. 1 : (left) Photo of the HV evaporation chamber: in the upper part is now located the sample holder while in the bottom of the HV chamber is located the crucible to be filled with powders; (right) the sample annealing system with the new SiC heater. This system is more stable in temperature and may reach about 800°C).

For the preparation of new copper substrate coated with MoO_3 and to make possible in 2021 the evaporation of longer substrates (up to 10 cm) we improved the evaporation setup of the existing HV chamber, the vacuum pumping system and the annealing system. In Fig. 1 (left) a photograph of the evaporation chamber installed at the LNF and assembled thanks to the cooperation with the Roma Tor Vergata University. In the right panel of Fig. 1 the photograph of the new high-temperature annealing setup. This layout based on a SiC heating element, molybdenum shields and a new setup allows achieving a stable temperature up to 800°C. It allows heating the powders inside the crucible minimizing the heating of the walls of the HV chamber. The evaporation system has been tested and some flat copper substrates were evaporated. The new system is able to deposit materials at a higher evaporation rate reaching a MoO_3 thickness up to $2\mu m$. With this new setup, the annealing procedure can be performed after the evaporation with a better control of both mechanical properties and morphology of the evaporated films.

A. THz spectroscopy measures and high electric field irradiations performed with high intensity radiation

As shown in Figure 2, applications of thousands of THz pulses using the ISIR Free Electron Laser at Osaka, may seriously damage a copper surface [Fig. 2 - left image] as demonstrated by a set of angular resolved experiments inducing controlled breakdowns with a high electric field gradient generated by THz pulses (4 GV/m) [1,2]. At variance, a MoO_3 coating is able to protect the copper surface from both damage and oxidation [2]. To understand the response mechanism of MoO_3 films and the resistance to damage observed during the Free Electron Laser tests performed at ISIR with THz radiation we plan new experiments in the THz range both at Osaka and at the Teralab laboratory of the Sapienza university.

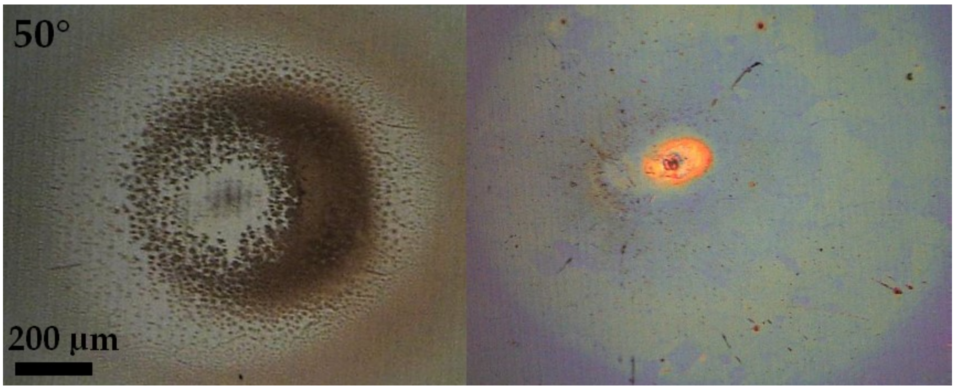

FIG. 2 : (left) Optical microscope mage of the damaged area on a copper substrate. The effect is the result of the irradiation of 5000 THz pulses radiation on the copper surface at the incident angle of 50°; (right) this image shows the reduced damage on a MoO_3 coating deposited on the copper surface. Using the same layout and experimental conditions, the oxide was able to prevent oxidation and minimized the damage induced by THz pulses.

To this purpose a new reflection configuration for optical reflectivity at THz wavelengths has been made available using the THz Pulsed System (TPS) showed in Figure 3.

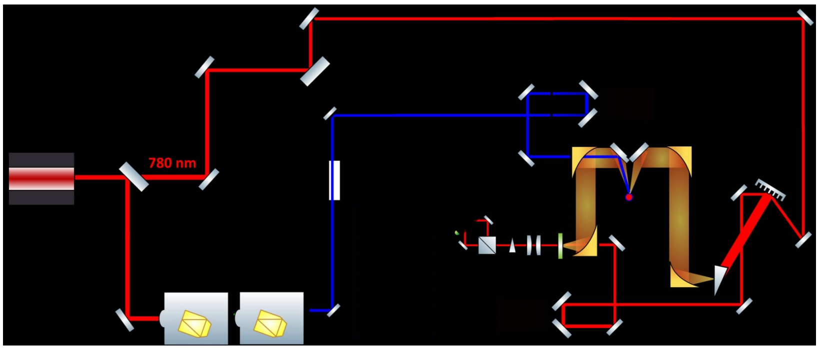

FIG. 3 : Layout of the THz Pulsed system based on the THz- Time Domain Spectroscopy (TDS) available at the the Teralab laboratory at Sapienza university [3,4]. The layout allows working in the reflection configuration with a laser system working at 780 nm generated by a broadband THz beam in the range 0.1-6.5 THz. This setup is able to perform non-linear THz spectroscopy generating an electric field up to 0.3 GV/m on the sample surface.

This optical layout uses the broadband THz radiation generated by organic crystals (Dstms and $LiNbO_2$) in the range 0.1-6.5 THz. With 800 fs pulse duration this layout is able to perform also non-linear THz spectroscopy and pump-probe experiments in a wide frequency range. Damage tests at high electric fields will be carried out with this setup on copper and other metallic substrates covered by films of transition metal oxides. The high electric field (up to 300 MV/m) coupled with an angular resolved spectroscopy characterization of the surfaces will allow to clarify the dynamic of damage of both metallic surfaces and films coated on copper samples. The optical setup has been completed and the first tests were successful.

III. ACKNOWLEDGEMENTS

We acknowledge the Ministero degli affari esteri e della cooperazione internazionale for support, within the framework of the Italian-Chinese collaborative research in 3D graphene and the project "Spettroscopia THz lineare, non lineare e risolta in tempo con sorgenti di radiazione di ultima generazione" coordinated by S. Lupi. We also acknowledge Akinori Irizawa and the Osaka University for providing beamtime at the ISIR facility. Also we acknowledge Ivan Davoli, Massimiliano Lucci, Annalisa D'Arco and Luca Tomarchio for their support.

IV. PUBLICATIONS

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