XVI International School and Symposium
on Synchrotron Radiation in Natural Science
Poland, 25-30 May 2025

Surface analysis of TiO_2 and Ti nanolayers modified with highly charged Xe^{q+} ions using synchrotron radiation based XRR and GIXRF methods

R. Stachura[1,2]*, D. Banaś[1,3], P. Jagodziński[1,2], A. Kubala-Kukuś[1,3], I. Stabrawa[1,3], K. Szary[1,3], M. Pajek[1], G. Aquilanti[4], I. Božičević Mihalić[4,5], Md. A. Alam[6] and M.K. Tiwari[6]

[1]*Institute of Physics, Jan Kochanowski University, 25-406 Kielce, Poland*
[2]*Central Office of Measures, 00-139 Warszawa, Poland*
[3]*Holycross Cancer Center, 25-734 Kielce, Poland*
[4]*Elettra - Sincrotrone Trieste, 34149 Basovizza, Trieste, Italy*
[5]*Rudjer Boskovic Institute, 10000 Zagreb, Croatia*
[6]*Raja Ramanna Centre for Advanced Technology, Indore 452013, India*

*e-mail: regina.stachura@ujk.edu.pl

Due to their unique physical and chemical properties, nanolayers currently play a key role in various technological applications, including electronics, optics, biomedical coatings and energy storage devices [1-2]. Irradiation of nanolayers with highly charged ions (HCl) induces changes in the morphology, density and chemical composition, affecting the electronic, optical and mechanical properties of the nanolayers. By controlling HCI parameters such as fluence, ion charge state and energy, various modifications can be induced, allowing for the improvement of a surface properties such as adhesion, conductivity and corrosion resistance. Therefore, understanding the processes occurring during the interaction of HCI with surfaces is essential for the development of new materials with improved properties [3-4].

The main objective of this work was to analyse titanium dioxide (TiO2) and titanium (Ti) nanolayers deposited on Si substrate, unmodified and irradiated with low-energy, highly charged Xe^{q+} ions (q = 25, 30, 35), and to determine the effect of irradiation on their surface morphology. The nanolayers were irradiated at the Kielce EBIS facility (Jan Kochanowski University, Kielce, Poland) [5].

The analysis of non-modified and irradiated nanolayers was performed by X-ray reflectometry (XRR) and grazing incidence X-ray fluorescence (GIXRF) methods using synchrotron radiation excitation at Elettra Synchrotron XRF beamline. XRR method allowed the determination of nanolayer properties such as density, thickness, and roughness. Thanks to the low-angle GIXRF technique it was possible to characterize the depth distribution of a O, Si and Ti in the nanolayers [6]. In this work the results of measurements obtained using XRR and GIXRF techniques will be presented and compared with theoretical predictions. The analyses performed showed significant differences in the surface morphology of nanolayers depending on the ion charge state.

Acknowledgements: This work was co-financed by the Minister of Science under the "Regional Excellence Initiative" program (project no.: RID/SP/0015/2024/01). The facility functioning is supported by Polish Ministry of Education and Science (project 28/489259/SPUB/SP/2021).

References

1. N. Kumar et. al., Processing of Polymer-based Nanocomposites, Springer Publishing (2018) 15-55.
2. J. Barth et. al., Nature 437 (2005) 671– 679.
3. H. Gnaser, Low-Energy Ion Irradiation of Solid Surfaces, Springer Berlin Heidelberg (1999) 7-82.
4. R. A. Wilhelm et. al., Progress in Surface Science 90 (2015) 377-395.
5. D. Banaś et. al., Nucl. Instrum. Meth. Phys. Res. B 354 (2015) 125-128.
6. R. Klockenkämper et. al., Total-Reflection X-Ray Fluorescence Analysis and Related Methods, John Wiley & Sons Inc. (2014)