RBS analysis and ion implantation of the multilayer WC/WS_2 nanostructures

I. Burducea, A. Mateescu, G. Mateescu, C. Ionescu, L. Craciun, P. Mereuta, M. Straticiuc

Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH), 30 Reactorului St., Magurele. Bucharest 077125, Romania

Experiment Responsible: dr. Ion Burducea, bion@nipnne.ro

The need for new materials with tunable properties and better surface performance is continuously increasing. Prolonging the lifetime of different industrial machinery parts is an important goal from economical point of view. Tribological properties are essential for many industrial applications starting from military, automotive up to space industries [1]. Ion implantation represents a doping process in which a beam of accelerated ions is directed onto the sample surface. In this process the impurity is introduced due to its high kinetic energy and geometric changes are below 0.1 µm [2].

Ion implantation has been successfully used in industry on a large scale but also for basic research [3]. The effect of Nb ion implantation by changing the microstructure and mechanical properties of Mo was investigated by F. V. Makarov *et al*. Their studies demonstrated that the presence of Nb trace amounts in molybdenum results in reducing the surface defect layer, in decreasing the rate of grain growth, in a considerable decrease of the amount of internal structure defects, interstitial alloy phases and, as a result, in reducing the brittleness of the metal. The operation life of molybdenum modified by Nb used in the reductive sintering of uranium dioxide demonstrated a 30-60% increase [4].

Nb implantation with proper ion fluences can significantly improve the corrosion resistance and the electric conductivity of SS316L in the simulated PEMFC environments [5]. For Ti-Al alloys, isothermal studies with exposure times up to 200 hours and cyclic-oxidation tests up to 800 hours revealed a negligible effect for the low implantation dose, while a remarkable decrease in the oxidation rates was observed for the material implanted with 10^{17} Nb ions/cm^2. The improvement in the oxidation resistance appeared to be similar to that obtained by alloying of the intermetallic with a few atomic percent Nb [6]. It has been also reported that Nb^+ ion implantation on high-purity Zr created β phase with bcc structure. The relative presence of bcc β phase appeared to be dependent on the Nb^+ fluence. At the highest Nb^+ implantation dose, significant presence of subsurface residual shear stress (τ_{13}) was noted. Molecular dynamics simulations, considering only momentum transfer revealed the presence of microscopic residual shear strains. With the increase in Nb bombardment the displacement per atom increased, but the shear strain dropped [7].Surface modification of WC-Co alloy implanted with nitrogen was also investigated. It was concluded that hardness and wear resistance increased after nitrogen implantation by a factor of 2, respectively by 1.3. The microhardness and wear resistance did not increase directly proportionally with the implanted dose, but there was an optimum value at a dose of $5x10^{17}$ N^+/cm^2 [8].

The purpose of this work is to continue the investigations of the complex tribological coatings started some time ago and now applying the acquired knowledge for binary composition from compound materials and with a structure of monolayer or multilayer-type, from the following compound materials: *WS_2 and WC* using WS_2, and WC sputtering targets.
For obtaining the monolayer-type structures the DC standard magnetron sputtering deposition method will be used and for obtaining the monolayer-type structures the DC reactive magnetron sputtering deposition method will be used, with simultaneous working of 2 guns/magnetron devices.

The multilayer type structure of: WS_2/WC will be obtained by successively deposition of the component materials by DC reactive magnetron sputtering deposition method by using the Multifunctional Sputtering Deposition Plant, existent in the Hadronic Physics Department of the “Horia Hulubei” National Institute for Physics and Nuclear Engineering *(IFIN-HH)*.

We will use He beam with the energy between 2 to 4.5 MeV. Thickness and stoichiometry of the films will be evaluated using RBS. Ion implantation will be performed using Nb ions in order to increase the material hardness. AFM, SEM and tribological measurements will also be performed. We will perform the RBS experiments in the IBA beam line and for the implantation we will use the IIB beam line, at the 3 MV Tandetron [9].

We request **7 days** of beam time taking account the large amount of samples to be taken into consideration and also the fact that RBS analysis must be performed before and after the analysis to measure the oxygen content in the films using the narrow resonance of the He beam at 3.038 MeV.

Results from previous beam time: 2 ISI papers, another one submitted to NIM B:

1. A.O. Mateescu, G. Mateescu, L.S. Craciun, C. Ionescu, I. Burducea,
   Morphological and compositional investigations of the tribological coatings with quaternary & pentanary composition, obtained from WC, TiB_2 and Ti by DC standard & reactive magnetron sputtering
   Journal of Optoelectronics and Advanced Materials 17(11–12) (2015) 1767–1771.
2. V. Jinga, A.O. Mateescu, D. Cristea, G. Mateescu, I. Burducea, C. Ionescu, L.S. Craciun, I. Ghiuta, C. Samoila, D. Ursutiu, D. Munteanu,
   Compositional, morphological and mechanical investigations of monolayer type coatings obtained by standard and reactive magnetron sputtering from Ti, TiB_2 and WC
   Applied Surface Science 358 (2015) 579–585.
3. Another paper submitted to NIM B, I. Burducea *et al.*

References

[1] J. Jagielski, A. Piatkowska, Z. Rymuza, Z. Kusznierewicz, D. Treheux, D. Boutard, L.Thomé, G. Gawlik,
Micromechanical measurements of ion-beam treated steel
Wear 238 (2000) 48–55.

[2] C.A. Straede,
Practical applications of ion implantation for tribological modification of surfaces
Wear **130** (1989) 113–122.

[3] F. V. Makarov, V. V. Guzeev, V. P. Pishchulin, A. Y. A. Svarovskiy and T. I. Guzeeva,
Effect of High-Dose Ion Implantation of Niobium on Changing the Mechanical Properties and Structure of Molybdenum Used at the Stage of Sintering Nuclear Fuel from Uranium Dioxide
Chemistry for Sustainable Development 19, (2011) 503-508.

[4] K. Feng, Z. Li, X. Cai, P.K. Chu,
Corrosion behavior and electrical conductivity of niobium implanted 316L stainless steel used as bipolar plates in polymer electrolyte membrane fuel cells
Surface & Coatings Technology 205 (2010) 85-91.

[5] M.F. Stroosnijder, N. Zheng, W.J. Quadakkers, R. Hofman, A. Gil and F. Lanza,
The effect of niobium ion implantation on the oxidation behavior of aγ-TiAl-based intermetallic
Oxidation of Metals, 46 1-2 (1996) 19-35.

[6] A.K. Revelly, H.W. Becker, B. Vishwanadh, K.V. Mani Krishna, R. Tewari, D. Srivastava, G.K. Dey, I. Samajdar & A.S. Panwar,

High-purity Zirconium under Niobium ion implantation: possibility of a dynamic precipitation?
Philosophical Magazine 95 33 (2015) 3727-3744.

[7] W.D. Shi, X.Y. Wen, J.H. Liu, C.S. Ren, Z.H. Long, G.B.Zhang, Z.X. Gong, Y.N. Wang and T Zhang,
Study of surface modification of WC-Co alloy by nitrogen implantation
Nuclear Instruments and Methods in Physics Research B 80/81 (1993) 229-232.

[8] E. Riedo, J. Chevrier, F. Comin, H. Brune,
Nanotribology of carbon based thin films: the influence of film structure and surface morphology
Surface Science 477 (2001) 25-34.

[9] I. Burducea, M. Straticiuc, D.G. Ghita, D.V. Mosu, C.I. Calinescu, N.C. Podaru, D.J.W. Mous, I. Ursu, N.V. Zamfir,
A new ion beam facility based on a 3 MV Tandetron™ at IFIN-HH, Romania
Nuclear Instruments and Methods in Physics Research B **359**, 12–19 (2015).