PVD metallic and ceramic coatings affecting corrosion protection of steel containers for nuclear waste in a deep geological repository

H.YU. ROSTOVA[1,2*], A.S. KUPRIN[2], S.YU. SAYENKO[2], I.V. KOLODIY[2], M. SAWCZAK[1], J. RYL[3], K. TRZCINSKI[4]

[1] The Szewalski Institute of Fluid-Flow Machinery of Polish Academy of Sciences, 80-231 Gdansk, Poland
[2] National Science Center Kharkiv Institute of Physics and Technology, 61108 Kharkiv, Ukraine
[3] Faculty of Applied Physics and Mathematics, Gdansk University of Technology, 80-233 Gdansk, Poland
[4] Faculty of Chemistry, Gdansk University of Technology, 80-233 Gdansk, Poland

** Corresponding author email: H.Yu.Rostova: hrostova@imp.gda.pl; A.S. Kuprin: kuprin@kipt.kharkov.ua, S.Yu. Sayenko: sayenko@kipt.kharkov.ua, I.V. Kolodiy giao@ukr.net, M. Sawczak mireks@imp.gda.pl, J. Ryl jacryl@pg.edu.pl, K. Trzciński kontrzci@pg.edu.pl*

Research into candidate container/canister materials for the deep geological disposal of radioactive high-level waste (HLW) and spent nuclear fuel (SNF) has been ongoing for the past 40-50 years. Options range from carbon steel with a corrosion resistant barrier to passive metals and ceramics. The primary requirement of a coating applied to carbon steel (or cast iron) canisters for HLW/SNF disposal is to prevent access of bentonite and/or clay pore water to the substrate by cracking or leaching for a period of a few hundred to a few (tens of thousands) of years, depending on the design of the geological disposal facility. Major advantage of Physical Vapor Deposition (PVD) coatings over electrochemical deposition is the environmental friendliness of the process. The aim of this study is to determine the influence of thin nitride, oxide and metallic PVD coatings using cathodic arc evaporation (CAE) on the corrosion resistance of steel substrates. A series of ceramic (TiO_2, CrN) and metallic (Cu, Cr, Ti) coatings with a thickness of 30 μm were formed using unfiltered CAE. The structure of the coatings before and after the corrosion tests was investigated by X-ray diffraction, scanning electron microscopy, energy dispersive X-Ray analysis and Raman spectroscopy. The mechanical properties of the coatings were determined by nanoindentation. The adhesion of the coatings to the C45 steel substrate was determined using the Daimler-Benz 1500N load test. The corrosion properties of the coatings on steel substrates were investigated by the electrochemical method in a 3% NaCl solution. A thermostatically controlled oven was used to perform long-term corrosion tests in water (90°C) over 4200 hours on steel samples with coatings. All the coatings studied have a nanostructure, high mechanical properties and high adhesion to the steel substrate without cracking or delamination. According to electrochemical studies, the coatings have very low porosity (0.01%) and significantly lower corrosion current levels (from 2 for Cu to 4 orders of magnitude for Ti and Cr) than the steel substrate. Long-term corrosion tests showed that the steel sample lost a lot of weight and dissolved to form rust, whereas the CrN, Ti and Cu coatings showed no weight change and no traces of rust, indicating their high protective properties. The studies have shown that steel container for HLW/SNF disposal can be protected from corrosion in water up to 90 °C using PVD ceramic and metallic coatings.

Acknowledgements
The research was supported by the funding from the European Union's Horizon 2020 research and innovation programme 2014-2018 under grant agreement N°847593 EURAD (work package ConCorD).

072_abstract