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PVD METALLIC AND CERAMIC COATINGS AFFECTING CORROSION PROTECTION OF STEEL CONTAINERS FOR NUCLEAR WASTE IN A DEEP GEOLOGICAL REPOSITORY

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- ❑ The search for suitable container/canister materials for the deep geological disposal of radioactive **high-level waste (HLW)** and **spent nuclear fuel (SNF)** has been in progress for the past 40-50 years. **Carbon steel**, **passive metals** and **ceramics** - under consideration.
- ❑ The corrosion of container materials can be attributed to the presence of bentonite and/or clay pore water, which will cause environmental pollution. This necessitates the implementation of protective coatings for the surface of the storage facility.
- ❑ **The objective of this study** is to determine the impact of thin nitride, oxide and metallic coatings, which are obtained by Physical Vapor Deposition (PVD) utilising cathodic arc evaporation (CAE), on the corrosion resistance of steel substrates.
- ❑ **Why PVD?** Major advantage of Physical Vapor Deposition - **the environmental friendliness of the process**.

❖ **Methodology**

❖ Ceramic (**TiO_2, CrN**) and metallic (**Cu, Cr, Ti**) coatings with a thickness of 30 μm were formed using unfiltered CAE in a Ukrainian industrial vacuum arc furnace "Bulat-6". Bias potentials U_b were varied in a range -25…-300 V. **Substrate** – carbon steel C45.

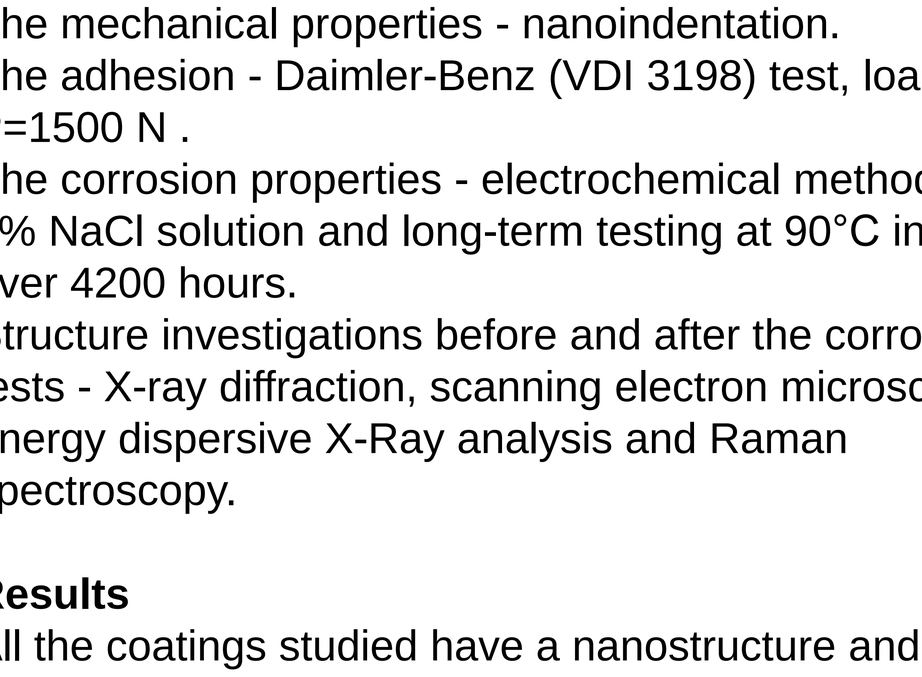
❖ The mechanical properties - nanoindentation.

❖ The adhesion - Daimler-Benz (VDI 3198) test, load: P=1500 N .

❖ The corrosion properties - electrochemical method in a 3% NaCl solution and long-term testing at 90°C in water over 4200 hours.

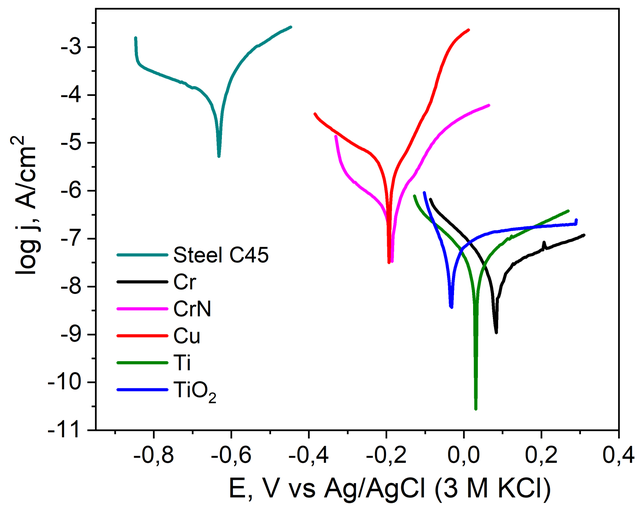
❖ Structure investigations before and after the corrosion tests - X-ray diffraction, scanning electron microscopy, energy dispersive X-Ray analysis and Raman spectroscopy.

- **Results**
- All the coatings studied have a nanostructure and high mechanical properties ($H_{ceramic}$ = 12…24 GPa; $H_{metallic}$ = 0.9…5 GPa).



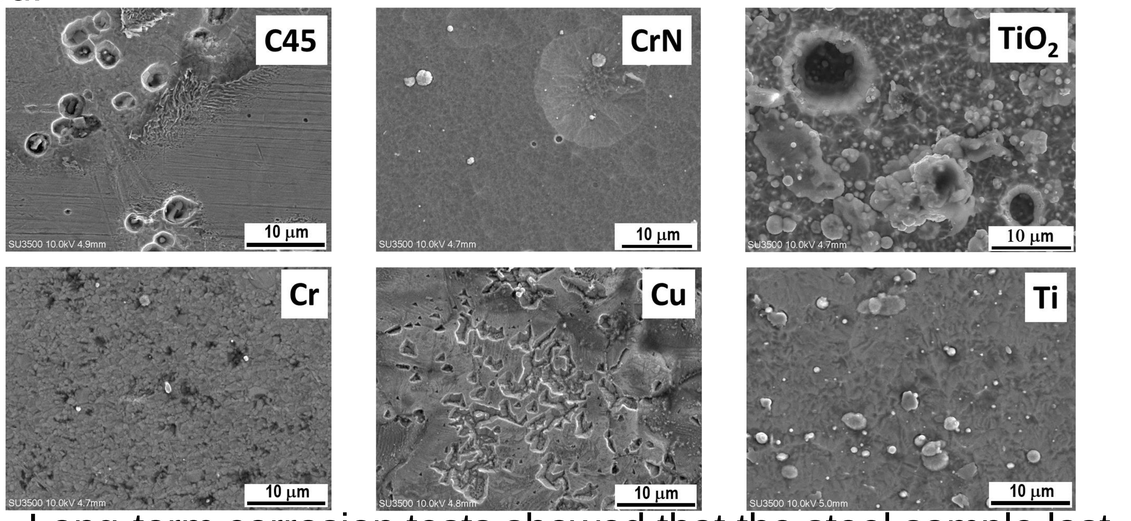
Coatings under study have high adhesion to the steel substrate (without cracking or delamination) at the level HF1-HF2 according to the VDI 3198 test scale.

- 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.

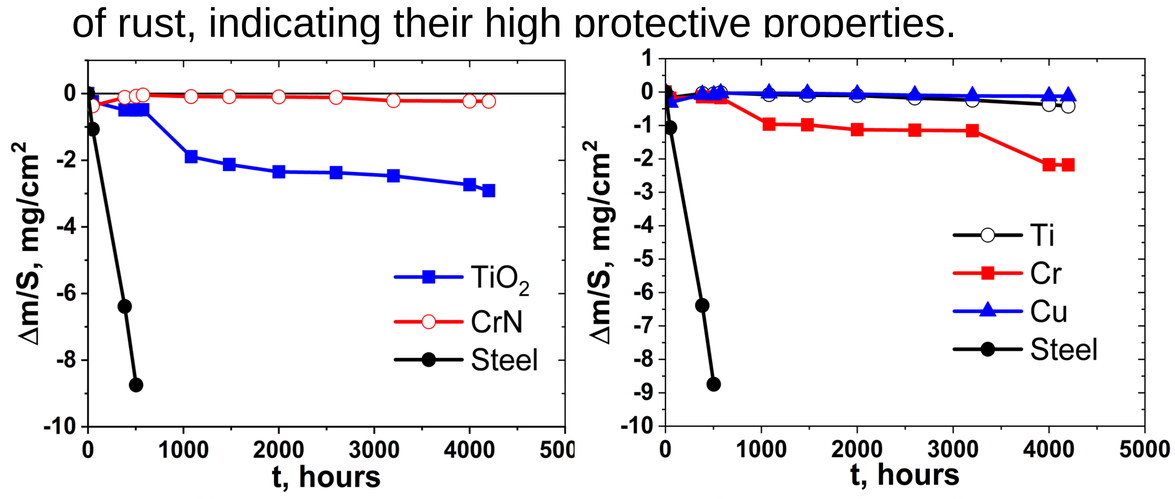


Tafel plots for steel substrate and substrate-coating systems in 3 wt% NaCl solution

The **C45** steel surface shows traces of pitting corrosion. No pits on the **Ti, Cr** and **CrN** coatings were observed. For **TiO_2** coating, the appearance of pits may be attributed to the loss of macroparticles of cathode material, but such craters do not penetrate the steel substrate, so 30 μm coatings provide a relatively high level of protection against corrosion of steel substrates. Pits on the surface of the **Cu** coating are likely a consequence of the oxidation of Cu to Cu^{2+} during the potentiodynamic testing, which resulted in a dissolution of the Cu.



- 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.

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