Coatings for nuclear fuel to prevent explosions in reactors

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Physicists from Tomsk Polytechnic University are creating protective titanium nitride-based coatings for shells of fuel elements (fuel rods) of nuclear reactors. Such shells can significantly reduce hydrogenation of containers holding nuclear fuel, extend their service life and prevent reactor explosions such as the Fukushima disaster.

"In reactors, nuclear fuel is placed in special 'tubes' made of zirconium alloys, forming fuel rods. In the fuel rods, a nuclear reaction takes place. As a result of radiolysis of the water coolant, and also as a result of interaction of water and zirconium under high temperatures, hydrogen is released. Hydrogen is able to accumulate in fuel rod shells causing degradation of their mechanical properties and eventual destruction," says one of the developers, an assistant at the Department of General Physics Egor Kashkarov.

According to the young scientist, the danger presented by the interaction of zirconium and water is that the higher the reactor temperature, the more hydrogen is released. For example, at the Fukushima-1 station in Japan, flooding of pumping equipment in the active zone caused the reactor to heat up over 1,200 °C, and a steam-zirconium reaction proceeded swiftly, releasing a large amount of hydrogen. The explosion of accumulated hydrogen resulted in one of the biggest radiation accidents in the world.

The scientific team from the TPU Department of General Physics is creating protective titanium nitride-based coatings to protect zirconium

fuel rods from water and hydrogen accumulation. "During tests, titanium nitride has proved itself with high hardness, wear resistance, heat resistance and inertia. We also found that it protects well from hydrogen penetration into the material, what is critical for nuclear energy. The coatings can reduce hydrogen penetration in zirconium alloy," says Egor Kashkarov.

The coatings on the zirconium substrate are applied using two technologies—magnetron sputtering and vacuum arc deposition. Both processes are carried out on a setup created at the university. The result is a thin film coating—no more than two microns thick.

"One of the applications of the elaborating titanium nitride coatings is next-generation reactors and thermal nuclear reactors where hydrogen-impermeable coatings are a pressing issue. In such future reactors, temperatures are supposed to increase up to 400-450 °C to improve fuel burn-up efficiency. Consequently, hydrogenation of fuel rods will be here much faster. Our coatings are able to prevent it," says the developer.

More information: E.B. Kashkarov et al, Hydrogenation behavior of Ti-implanted Zr-1Nb alloy with TiN films deposited using filtered vacuum arc and magnetron sputtering, *Applied Surface Science* (2017). DOI: 10.1016/j.apsusc.2017.04.035

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