Popular science abstract

Amorphous silicon oxycarbide-based protective coatings on steel for cladding materials in nuclear reactors

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Over-exploitation of fossil fuels and their shortage brought a profound economic and environmental crisis connected with the greenhouse effect and air pollution. Unfortunately, with Poland's climate and topography, the efficiency of solar, water and wind energy sources is insufficient. Nuclear reactors of the newest generation are the only alternative to fully replace or stop being dependent on fossil fuels. We have already made the historical step towards building our first nuclear power plant by signing relevant agreements. However, novel technologies require novel or modernized reliable materials that maintain their properties despite elongated exploitation time. The most broadly used for construction elements, metals and alloys, possess excellent mechanical properties and are easy to manufacture. Their resistance to hostile conditions (high temperature and irradiation) is adequate for current technologies, but novel ones set the bar higher.

Neutrons and ions affect the material creating point defects, which can spread like a cascade in the material, causing severe structural damage resulting in a gradual decline in properties and final deterioration of a construction element. There are a few ways to stop this radiation-caused destruction. We can implement oxide particles into the alloy (the so-called ODS - oxide dispersion strengthened alloys). This way, we create a metal/particle interface, which will stop defects from spreading. A more efficient way is to introduce the barrier between metal or alloy and the reactor's environment as a firm layer, which will protect the construction part. This project proposes a particular type of coatings which will be amorphous. It means they do not possess long-range order and no crystalline structure where the defects could spread. That should be accompanied with immunity to the high-temperature conditions of the reactor. The proposed material for the coating is silicon oxycarbide (SiOC). It is a hybrid material combining amorphous silica with the advantages of silicon carbide, such as suitable mechanical parameters, durability, and chemical and thermal stability. Moreover, SiOC has in its structure phase of separated graphite-like carbon.

The main aim of the proposed project is to develop amorphous protective coatings based on silicon oxycarbide (SiOC) for elevating the radiation tolerance and high-temperature stability of construction elements in nuclear reactors. Therefore, layers with varying carbon content and doped with iron ions will be deposited on austenitic steel. A thorough examination will show the material's behaviour under radiation and at high temperatures. Based on that, it will be possible to evaluate SiOC and SiFeOC applicability as protective coatings in nuclear reactors.

It is impossible to obtain silicon oxycarbide by melting it like conventional glasses. In this project, materials will be obtained a so-called polymer-derived ceramics (PDCs) by high-temperature decomposition of organosilicon polymers. This method allows modifying precursors (and hence ceramics) with various ions to enhance or add new properties, in this particular case – with iron.

As the proposed project's result, novel reliable protective coatings with well-defined properties for steel construction elements in nuclear reactors will be designed to enhance their efficiency and safety. Moreover, under PI's direction, the experimental base will be built for the proposed project and future challenges, offering a unique opportunity for interdisciplinary and comprehensive research from test tube to application.