Nanocrystalline diamond layers protecting Zr fuel cladding surface in nuclear reactors against high temperature corrosion

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To satisfy the demands for safety operations in water-cooled nuclear power reactors and to extend the campaign of nuclear fuel it's necessary to decrease high temperature surface corrosion of standard elements - zirconium nuclear fuel claddings (Fig.1). At reactors working temperature (300°C/572°F) Zr surface strongly reacts with water steam. During this reaction zirconium oxidizes and strongly explosive hydrogen gas is released, which partly diffuses into the zirconium material and destroys it. Facing up to the problem, a protective layers for Zr alloys were developed. The nanocrystalline diamond (NCD) films are grown in microwave plasma enhanced linear antenna chemical vapor reactor on Zr alloy surface (Fig.2). Surface oxidation of NCD covered Zr tubes after 90 days in 400°C hot steam reactor was 20-30% reduced comparing to original non-protected Zr tubes [1,2]. This diamond layers can serve as a passive element of nuclear safety. NCD films significantly lengthen an operational life-time of the fuel road in the vessel and consequently the nuclear fuel consumption. They could protect the UO_2 pellets before leakage of nuclear fuel into the environment during accident of nuclear power station (e.g. Fukushima 2011).

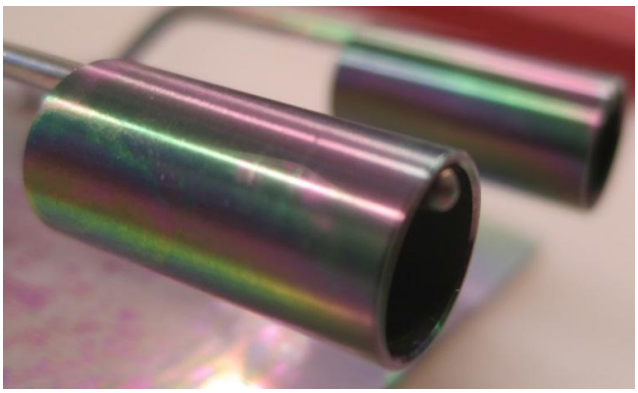

Figure 1: Fuel rod from Zirconium alloys protected by nanocrystalline diamond layer

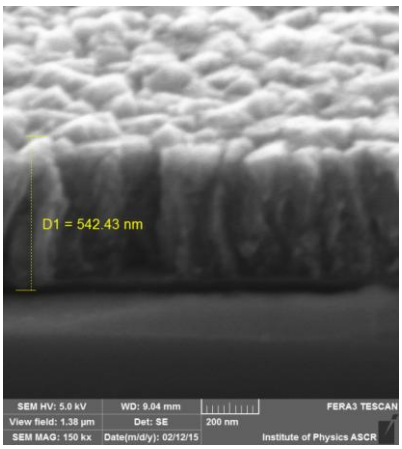

Figure 2: SEM images of NCD-coated Zircaloy

References

[1] I. Kratochvilova et al., Applied Surface Science **359**, 621–628 (2015).
[2] P. Ashcheulov et al., Recent Patents on Nanotechnology **10**, 59-65 (2016).

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