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# New "dry" plasma technology for nuclear materials processing

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New approach to solve a wide range of problems in various nuclear materials processing is discussed. One of them –irradiated reactor graphite decontamination with inert gas (argon) plasma sputtering and thermo-treatment with interdisciplinary synthesis of plasma physics, materials science and reactor physics. At present time wide search of effective technology to deactivate reactor graphite is very acute due to the large volumes of accumulated irradiated
graphite in the world (about 100 thousand tons) and the challenging problem of uranium-graphite reactors decommissioning period. Proposed high pressure short discharge technology has advantage compared with traditional radiochemistry in versatility (work with any kind of radionuclides, since ion etching process allows ones to sputter any atoms) and in the absence of the additional secondary radioactive wastes (as a buffer media is inert gas forming no chemical
compounds with radionuclides). It is known [1] that one of the possible contamination mechanisms of graphite masonry surfaces is the neutron activation of nitrogen atoms from the cooling gas mixture, as well as the process of intercalation of nitrogen migrating inside graphene-graphene layers of graphite.
This leads to the fact that the RBMK graphite masonry acquires significant activity due to the 14C isotope localized on and inside of the surface layers of micron depth. We experimentally studied sorption capacity of the surface for some fresh (before irradiation) reactor graphite samples and obtained that the 14C isotopes arising from nitrogen neutron activation may be localized under the
graphite surface of the 30 nm thickness. It is very suitable for plasma etching and provides problems for the other competitive technologies creating large volume of secondary radioactive wastes. Our estimates of operating parameters for the irradiated reactor graphite deactivation in an inert gas plasma were made for discharge current (0.001 - 1 A / cm2), voltage (300-1000V), inert gas pressure (0.01-1 atm.), gap between the treated graphite surface and the anode collector
(1-5mm). The reactor graphite temperature under treatment was in the range of 600-1800K [2], integrity of the treated graphite blocks remains and they are ready for a final burial, in comparison with competitive approaches.
Also proposed plasma technology is applicable for a fast deactivation of the internal of the nuclear power plants constructions during reload or repair periods, instead of radiochemical methods. Described plasma treatment provides removal and transfer of the surface contaminating radionuclides in highly concentrated form with the opportunity to extract selectively useful radioisotopes via proposed spatial differentiation of the sputtered atoms
condensation according to their individual evaporation temperatures.
Additionally, some modification of our technology can be used for a new scheme of spent nuclear fuel reprocessing with uranium deoxidation-oxidation reactions and fission fragments removal in plasma gas mixture with the following fuel sedimentation, adapted for the perspective new nuclear energetics and closed circulating fuel cycle. Technology is patented in collaboration of Intro-Micro LLC, Concern Rosenergoatom JSC and Rosatom [3] and is suitable for Fukushima NPPs accident dismantling efforts.

[1] Dunzik-Gougar M.L., Smith T.E. Removal of carbon-14 from irradiated graphite // Journal of Nuclear Materials / -2014 -V. 451 –P. 328–335
[2] A.S.Petrovskaya, A.Yu.Kladkov, S.V.Surov, A.B.Tsyganov «New Thermo-Plasma Technology for Selective 14C Isotope Extraction from Irradiated Reactor Graphite» AIP Conference Proceedings 2179, 020020 (2019)
[3] A.S.Petrovskaya, A.B.Tsyganov, M.R.Stakhiv "Method for deactivating a structural element of a nuclear reactor" Patent RU №2711292, International patent application PCT/RU2019/000816 (14.11.2019).

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