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dr Elena Lagzdina
Center for Physical Sciences and Technology, Lithuania

Radiological and structural characterisation of RBMK-1500 reactor graphite and application of the ion implantation method to investigate irradiation damage in graphite matrix

Abstract:

Graphite is widely used as a moderator, reflector, and fuel matrix in various types of gas- and water-cooled nuclear reactors and is also designed to be used in generation IV reactors. Over 250,000 tons of irradiated graphite from nuclear reactors is temporarily stored in interim storage facilities at nuclear power plants worldwide, and each country individually decides how to handle this waste. The safe dismantling of the nuclear graphite by implementing the optimal radioactive waste management, provident utilization, storage or disposal technologies is one of the important problems at Ignalina Nuclear Power Plant (INPP) in Lithuania, which is under decommissioning for more than ten years: Unit 1 was shut down at the end of 2004, while Unit 2 at the end of 2009.

Graphite as a major structural component material of the RBMK-1500 nuclear reactor core is subjected to high levels of radiation, which affects both the physical and chemical properties of the material. 14C is a key long-lived radionuclide in the irradiated graphite, which is produced mainly from naturally abundant isotope 13C in the graphite matrix (inner contamination) or from 14N, which may be found as an impurity (inner contamination) and may incorporate in the material from the environment (more likely as surface contamination). The other radionuclides are also originated from impurities (e.g., 60Co) or due to contamination (e.g., 137Cs) process, but 14C is the limiting radionuclide when considering options of disposal in near-surface disposal facility or geological disposal facility. To evaluate the total activity of the spent graphite waste both experimental and theoretical methods (e.g., MCNP modelling) are used.

Recently the rapid analysis method for the 14C mass activity determination in small graphite samples of the 1-100 μg range was proposed. It is based on the graphite combustion and

subsequent CO_2 and 14C measurements by using the commercial elemental analyzer and the semiconductor detector, respectively. There is no need for sample weighing and detection procedure for a sample containing a higher 14C activity than 20 Bq takes approximately 10 minutes. This method could be implemented for the direct radioactive graphite waste characterization.

For the structural graphite characterization, the ion beam implantation can be applied as a substitute for neutron irradiation. The neutron interaction with graphite is via ionizations and recoils of carbon atoms, which adds up to displacement cascades. The same cascades can be obtained by impinging carbon ions in graphite, thus the ion implantation technique with corresponding conditions of the reactor (C^+ or N^+ ions, their energy, fluency, temperature and nitrogen environment) can be used as a substitute for neutron irradiation – the ion-induced defects in the lattice are equivalent to neutron-induced ones. The main advantages of this method are that samples are not activated, while the same displacement damage can be obtained in a much shorter time (a few to tens of hours instead of years in the reactor). Another advantage is the ability to control the experimental parameters to observe defect dynamics. In this work, we present the ion implantation experiments and subsequent structural analysis (SEM, Raman, SIMS) of both raw and irradiated graphite (nuclear grade and HOPG) samples.

Serdecznie zapraszamy
M. Dąbrowski, T. Kwiatkowski
http://www.phd4gen.pl

BIO:

Dr. Elena Lagzdina currently works as a research fellow at the Center for Physical Sciences and Technology, dept. of Nuclear research. During her PhD studies (2015-2020) at the Center for Physical Sciences and Technology, she investigated both radiological and structural properties of the RBMK-1500 reactor graphite. She actively participated in several national and international conferences and workshops. In 2019 she obtained a scholarship for an internship at the Institute of Nuclear physics of Lyon (IPNL), Lyon, France, which were extremely useful for her studies on irradiation damage in a graphite matrix. She has defended her doctoral dissertation in September 2020. By now she has 9 peer-reviewed publications in scientific journals (2 as a first author). Recently she is working on the HORIZON 2020 PREDIS project "Pre-disposal management of radioactive waste" on the metallic waste characterization.

Adres:
ul. A. Sołtana 7
05-400 Otwock

+48 22 273 10 01
+48 22 779 34 81
ncbj@ncbj.gov.pl

KRS: 0000171393
NIP: 532-010-01-25
www.ncbj.gov.pl