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NEUTRON ACTIVATION ANALYSIS OF 3C-SiC NANOPARTICLES UNDER THE NEUTRON FLUX

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Abstract: Silicon carbide (3C-SiC) nanoparticles have been irradiated by neutron flux ($2x10^{13}$ n/cm^{2}s) at the nuclear research reactor. After neutron irradiation, the radioisotopes of active elements in the 3C-SiC nanoparticles were studied. The identification of isotopes which significantly increased the activity of the samples as a result of neutron radiation was carried out. The methodology of neutron activation analysis of 3C-SiC nanoparticle has been studied.

Key words: nano 3C-SiC, nanomaterial, radioactivity, neutron activation analysis, neutron irradiation

1. Introduction

Over the past decade, silicon carbide and its various composites have been widely studied by the researchers in the world [1-14]. SiC with attractive physical and chemical resistance has a wide range of applications in extrinsic environments [15-19]. The change of the bandwidth in the 2.4eV – 3.2eV ranges has led to a wide use of SiC as a semiconductor in electronic systems [20-27]. In the general approach, SiC is a covalent bonded semiconductor. In terms of structure, each Si atom is covalently bonded to four carbon atoms and vice versa. Si and C atoms in SiC have combined in different modifications and have led to the formation of more than 200 polytypes. The most common of these are cubic (3C-SiC) and hexagonal (4H-SiC and 6H-SiC) polytypes. In this study, nanocrystalline 3C-SiC were used, in which the bandgaps was 2.2eV at room temperature.

The activity of the samples used in the experiment reached approximately 3GBq as a result of the neutron irradiation effect on the mixture radioisotopes. In this case, until the activity of samples decreases (approximately after 500 hours), it is impossible to carry out other experiments. Simultaneously, it is important to note "cooling time" on the other scientific researches [28-35]. At the present work, active isotopes and they standard decreasing table has been given.

2. Experimental

At the present work, research object is silicon carbide nanoparticles, which is has special surface area (SSA) of 120 m^2/g, the particle size of 18nm and the density of 0.03g/cm^3 (true density 3.216 g/cm^3) (US Research Nanomaterials, Inc., TX, USA). Samples irradiated by neutron flux ($2x10^{13}$ n/cm^{2}s) in the central canal (canal A1) of the TRIGA Mark II light water pool type research reactor at full power (250kVt) in the Reactor Center of Institute Jozef Stefan (IJS) in Ljubljana, Slovenia. It is important to note that, if the reactor is working at full power then neutron flux parameter as followed: $5.107x10^{12}$ n/cm^{2}s (1±0.0008, E_n < 625eV) for thermal neutrons, $6.502x10^{12}$ n/cm^{2}s (1±0.0008, E_n ~ 625eV ÷ 0.1MeV) for epithermal neutrons, $7.585x10^{12}$ n/cm^{2}s (1±0.0007, E_n > 0.1 MeV) for fast neutrons and finally, the flux is $1.920x10^{13}$ n/cm^{2}s (1±0.0005) for all neutrons in the central canal [36-43].

Absorption dose value of studied samples which were powder and tablet was determined according to the geometric measures, radiation intensity, radiation periods, the density of neutron flux effect and energetic spectrums of neutrons. The neutron flux value for the samples in the form of tablet changes between $1,3338x10^{17}$ ÷ $2,6676x10^{18}$ neutron/tablet intervals. The radionuclides

formed in nano SiC after mutual influence of neutron were analyzed in "Ortec HPGe detectors (Coaxial, Low and Well-Type)" and "Canberra coaxial HPGe detector" spectrometers. Radioactivity, isotope composition and mixed elements concentration of irradiated samples were determined according to [44-47] methodics.

3. Results and Discussion

At the present work, the activity of mixture elements in the 3C-SiC nanoparticle has been studied under the neutron irradiation. If we accept the initial number of these radioactive nucleus as N, the number of nucleus decreases according to the following conformity as a result of radioactive decay:

$$\frac{dN}{dt} = -\lambda N \tag{1}$$

here, λ is decay constant. We can get the following equality by simplifying the equation (1):

$$\ln N = -\lambda t + C \tag{2}$$

If we accept the number of radioactive isotopes as N_0 at the start ($t=t_0$), we can write equation (2) like the following:

$$\begin{aligned} &\ln N = -\lambda t + \ln N_0 \\ &\ln\left(\frac{N}{N_0}\right) = -\lambda t \\ &N = N_0 \exp(-\lambda t) \end{aligned} \tag{3}$$

The last equation is exponential radioactive decay equation. Half-life period (half-life $t_{1/2}$) can be calculated following equations:

$$\begin{aligned} &\frac{N}{N_0} = 0.5 = \exp\left(-\lambda t_{1/2}\right) \\ &t_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda} \end{aligned} \tag{4}$$

Identification of radioactive isotopes was studied according to gamma spectroscopy method. Ray intensity γ appropriate to nuclear transmutation in gamma spectrum is different depending on radiation period and decay constants.

At the present work, clearly, described the analysis procedure of gamma-spectrum to the determination of the amount of activity. The acquisition of sample gamma spectrum has been described in Fig 1. Via the spectroscopy, it is possible to identify the radionuclides produced and their amounts of radioactivity in order to derive the target elements from which they have been produced and their masses in the activated sample. The spectrum analysis starts with the determination of the location of the (centroids of the) peaks. Secondly, the peaks are fitted to obtain their precise positions and net peak areas.

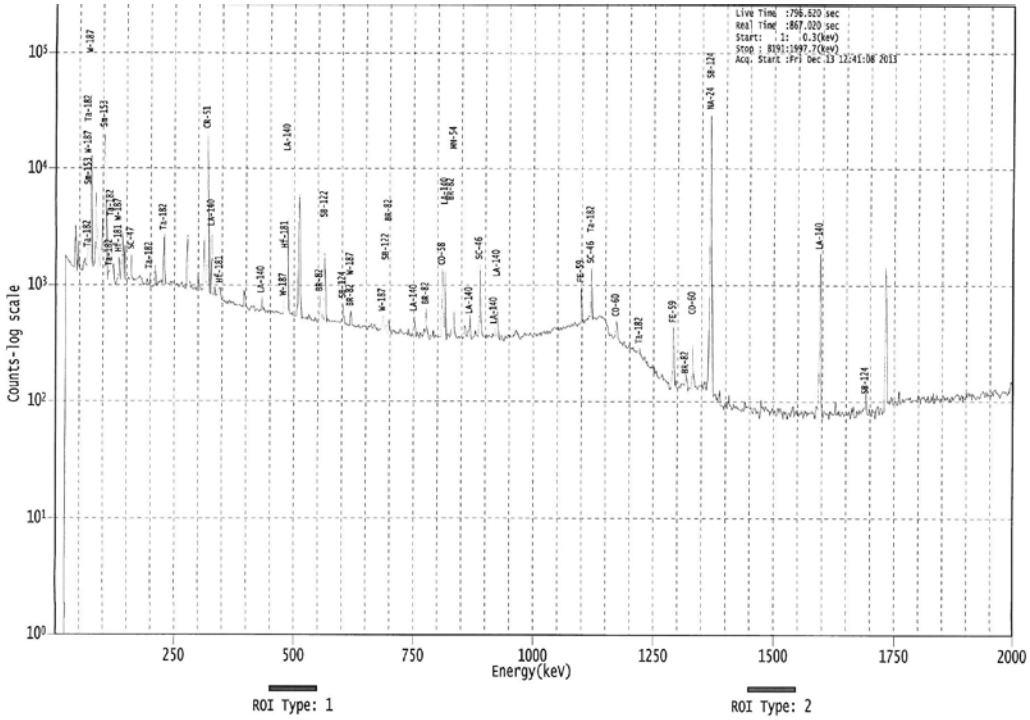

Fig 1. Gamma spectrum of nanoparticles after the neutron irradiation.

The determination of concentrations of elements is conducted according to the activities in appropriate energetic interval. The reaction rate (R) of the neutrons in each nucleus is defined as below [44-47]:

$$R = \int_0^\infty \sigma(v)\phi'(v)dv = \int_0^\infty \sigma(E)\phi'(E)dE = \int_0^\infty n'(v)v\sigma(v)dv \qquad (5)$$

σ(v) is effective cross-section (cm^2) if the neutron velocity is v, σ(E) is effective cross-section (cm^2) if the neutron energy is E (eV), $\phi'(v)$is neutron flux (cm^{-3}) whose velocity is v, $n'(v)$is neutron density (cm^{-4}) whose velicity is v, $\phi'(E)$is neutron flux ($cm^{-2}\ s^{-1}\ eV^{-1}$) whose energy is E. Radioactivity of 3C-SiC nanoparticle has been giving at the table for low and high half-life elements (Table 1).

***Table 1a**. Radioactivity of various elements in the 3C-SiC nanoparticles (for high half-life elements)*

Time (hour)	Radioactivity (kBq)									Radioactivity (MBq)	
	Ca 41	***Cr 51***	***Fe 59***	***Hf 181***	***Mn 54***	***Ni 59***	***Sn 121***	***Sr 89***	***Zr 93***	***Cu 64***	***Na 24***
0	0.273	14.8943	0.160034	0.326954	0.023668	0.351	1.126551	0.967156	0.075	163.419	108.2264
5	0.273	14.81813	0.15952	0.325848	0.023657	0.351	0.990842	0.964452	0.075	124.3904	85.89935
24	0.273	14.53224	0.157581	0.32168	0.023616	0.351	0.608371	0.954247	0.075	44.09882	35.7014
48	0.273	14.17899	0.155166	0.316492	0.023563	0.351	0.328539	0.94151	0.075	11.90012	11.77707
72	0.273	13.83432	0.152787	0.311387	0.023511	0.351	0.177421	0.928943	0.075	3.211262	3.884984
96	0.273	13.49803	0.150446	0.306364	0.023459	0.351	0.095812	0.916544	0.075	0.866563	1.281567
120	0.273	13.16991	0.14814	0.301422	0.023407	0.351	0.051742	0.90431	0.075	0.233843	0.422759
144	0.273	12.84977	0.145869	0.29656	0.023355	0.351	0.027942	0.89224	0.075	0.063103	0.139459
168	0.273	12.53741	0.143633	0.291777	0.023304	0.351	0.01509	0.880331	0.075	0.017028	0.046004
192	0.273	12.23265	0.141432	0.28707	0.023252	0.351	0.008149	0.868581	0.075	0.004595	0.015176
216	0.273	11.93529	0.139264	0.28244	0.023201	0.351	0.004401	0.856987	0.075	0.00124	0.005006
240	0.2729999	11.64516	0.137129	0.277884	0.023149	0.351	0.002376	0.845549	0.075	0.000335	0.001651
264	0.2729999	11.36209	0.135027	0.273402	0.023098	0.351	0.001283	0.834263	0.075	9.03E-05	0.000545
288	0.2729999	11.08589	0.132958	0.268992	0.023047	0.351	0.000693	0.823127	0.075	2.44E-05	0.00018
312	0.2729999	10.81641	0.13092	0.264653	0.022996	0.351	0.000374	0.81214	0.075	6.58E-06	5.93E-05
336	0.2729999	10.55348	0.128913	0.260384	0.022945	0.351	0.000202	0.8013	0.075	1.77E-06	1.96E-05
360	0.2729999	10.29694	0.126937	0.256184	0.022894	0.351	0.000109	0.790605	0.075	4.79E-07	6.45E-06
384	0.2729999	10.04664	0.124992	0.252052	0.022844	0.351	5.89E-05	0.780052	0.075	1.29E-07	2.13E-06
408	0.2729999	9.802421	0.123076	0.247986	0.022793	0.351	3.18E-05	0.769641	0.075	3.49E-08	7.02E-07
432	0.2729999	9.564139	0.121189	0.243986	0.022743	0.351	1.72E-05	0.759368	0.075	9.41E-09	2.32E-07
456	0.2729999	9.33165	0.119332	0.240051	0.022692	0.351	9.28E-06	0.749232	0.075	2.54E-09	7.64E-08
480	0.2729999	9.104812	0.117503	0.236179	0.022642	0.351	5.01E-06	0.739232	0.075	6.85E-10	2.52E-08
504	0.2729999	8.883488	0.115702	0.232369	0.022592	0.351	2.71E-06	0.729365	0.075	1.85E-10	8.31E-09

***Table 1b**. Radioactivity of various elements in the 3C-SiC nanoparticles (for low half-life elements)*

Time (hour)	Radioactivity (kBq)			Radioactivity (MBq)		Radioactivity (GBq)	
	Ba 139	***Mo 99***	***Ti 51***	***Mg 27***	***V 52***	***Al 28***	***Cl 38***
0	5.79E-01	7.71E-01	6.98E+00	5.36E+01	1.51E+01	1.43E+00	3.04E+00
0.1	5.51E-01	7.24E-01	3.36E+00	3.48E+01	4.95E+00	2.20E-01	2.72E+00
0.5	4.51E-01	5.62E-01	1.82E-01	6.15E+00	5.65E-02	1.23E-04	1.74E+00
0.8	3.88E-01	4.65E-01	2.04E-02	1.68E+00	1.97E-03	4.45E-07	1.24E+00
1.1	3.33E-01	3.85E-01	2.28E-03	4.57E-01	6.90E-05	1.61E-09	8.89E-01
1.4	2.87E-01	3.19E-01	2.56E-04	1.25E-01	2.41E-06	5.84E-12	6.36E-01
1.7	2.47E-01	2.64E-01	2.86E-05	3.40E-02	8.43E-08	2.12E-14	4.54E-01
2	2.12E-01	2.19E-01	3.21E-06	9.26E-03	2.94E-09	7.67E-17	3.25E-01
2.3	1.82E-01	1.81E-01	3.59E-07	2.52E-03	1.03E-10	2.78E-19	2.32E-01
2.6	1.57E-01	1.50E-01	4.03E-08	6.88E-04	3.60E-12	1.01E-21	1.66E-01
2.9	1.35E-01	1.24E-01	4.51E-09	1.88E-04	1.26E-13	3.65E-24	1.19E-01
3.2	1.16E-01	1.03E-01	5.06E-10	5.11E-05	4.39E-15	1.32E-26	8.50E-02
3.5	9.98E-02	8.49E-02	5.66E-11	1.39E-05	1.53E-16	4.80E-29	6.08E-02
3.8	8.59E-02	7.03E-02	6.35E-12	3.80E-06	5.36E-18	1.74E-31	4.34E-02
4.1	7.39E-02	5.82E-02	7.11E-13	1.04E-06	1.87E-19	6.30E-34	3.11E-02
4.4	6.35E-02	4.82E-02	7.97E-14	2.83E-07	6.55E-21	2.28E-36	2.22E-02
4.7	5.46E-02	3.99E-02	8.93E-15	7.70E-08	2.29E-22	8.28E-39	1.59E-02
5	4.70E-02	3.30E-02	1.00E-15	2.10E-08	8.00E-24	3.00E-41	1.14E-02

Nuclear transmutations are defined according to the number of nuclear fissions. Initially, the number of active nucleus ($N(t_i, t_d)$) can be calculated following equation [44-47]:

$$N(t_i, t_d, t_m) = \frac{RN_0}{\lambda}(1-\exp[-\lambda t_i])\exp[-\lambda t_d] \tag{6}$$

The number of nuclear fissions during the measurement can be defined according to the following equation:

$$\Delta N(t_i, t_d, t_m) = \frac{RN_0}{\lambda}(1-\exp[-\lambda t_i])\exp[-\lambda t_d](1-\exp[-\lambda t_m]) \tag{7}$$

Here, t_d is decay or waiting time (the time between the end of irradiation and the beginning of measurement), t_i is end of the irradiation time, t_m is measurement time. According to the existed peaks in the spectrum we can write activation formula like the above:

$$N_p = \Delta N \gamma \varepsilon = \varphi_{th}\sigma_{eff}\frac{N_{av}m_x\theta}{M_a}(1-\exp[-\lambda t_i])\exp[-\lambda t_d](1-\exp[-\lambda t_m])I\varepsilon \tag{8}$$

Here, N_p is total number in gamma peak (E_γ), N_{av} is Avogadro's number, θ is isotopic abundance of target isotopes, m_x is mass of irradiated element in grams, M_a is atomic mass (g mol^{-1}), I is the gamma-ray abundance and ε is total energy detected in detector. Simply, element quantity can be calculated from the net peak area according to the following equation:

$$m_x = N_p \cdot \frac{M_a}{N_{av}\theta} \cdot \frac{\lambda}{\varphi_{th}\sigma_{eff} I\varepsilon(1-\exp[-\lambda t_i])\exp[-\lambda t_d](1-\exp[-\lambda t_m])} \tag{9}$$

Calculations are a bit complicated in k_0 comparator method [32].

4. Conclusions

Radioisotopes generated in the nanocrystalline 3C-SiC particles after neutron irradiation and it were studied. It was found out that initial activity and half life of mixed elements in the sample differed from each other significantly. The dependence of the radioactivity of isotopes on observation time were studied. Long half life isotopes were found in the nano SiC samples and it

was suggested to consider them in the explanation of physical properties of nanocrystalline 3C-SiC particles after irradiation.

References

1. Roland Nagy, Matthias Widmann, Matthias Niethammer, Durga B. R. Dasari, Ilja Gerhardt, Öney O. Soykal, Marina Radulaski, Takeshi Ohshima, Jelena Vučković, Nguyen Tien Son, Ivan G. Ivanov, Sophia E. Economou, Cristian Bonato, Sang-Yun Lee, and Jörg Wrachtrup "Quantum Properties of Dichroic Silicon Vacancies in Silicon Carbide" Phys. Rev. Applied 9, 034022, 2018
2. Greg Calusine, Alberto Politi, and David D. Awschalom "Cavity-Enhanced Measurements of Defect Spins in Silicon Carbide" Phys. Rev. Applied 6, 014019, 2016
3. Najmeh Delavari, Mahmoud Jafari "Electronic and optical properties of hydrogenated silicon carbide nanosheets: A DFT study" Solid State Communications 275, 1-7, 2018
4. Kierstin Daviau and Kanani K. M. Lee "Decomposition of silicon carbide at high pressures and temperatures" Phys. Rev. B 96, 174102, 2017
5. Abram L. Falk, Paul V. Klimov, Viktor Ivády, Krisztián Szász, David J. Christle, William F. Koehl, Ádám Gali, and David D. Awschalom "Optical Polarization of Nuclear Spins in Silicon Carbide" Phys. Rev. Lett. 114, 247603, 2015
6. Hsun-Chi Li, Wei-Sheng Chen "Recovery of silicon carbide from waste silicon slurry by using flotation" Energy Procedia 136, 53-59, 2017
7. Sara Toth, Peter Nemeth, Peter Racz et al. "Silicon carbide nanocrystals produced by femtosecond laser pulses" Diamond and Related Materials 81, 96-102, 2018
8. Bo Peng, Yuming Zhang, Yutian Wang, Hui Guo, Lei Yuan, and Renxu Jia "Ferromagnetism observed in silicon-carbide-derived carbon" Phys. Rev. B 97, 054401, 2018
9. I.Vivaldo, M.Moreno, A.Torres et al. "A comparative study of amorphous silicon carbide and silicon rich oxide for light emission applications" Journal of Luminescence 190, 215-220, 2017
10. K.Kefif, Y.Bouizem, A.Belfedal, J.D.Sib, D.Benlakehal, L.Chahed "Hydrogen related crystallization in silicon carbide thin films" Optik - International Journal for Light and Electron Optics 154, 459-466, 2018
11. Junfeng Wang, Yu Zhou, Xiaoming Zhang, Fucai Liu, Yan Li, Ke Li, Zheng Liu, Guanzhong Wang, and Weibo Gao "Efficient Generation of an Array of Single Silicon-Vacancy Defects in Silicon Carbide" Phys. Rev. Applied 7, 064021, 2017
12. Yu Zhou, Junfeng Wang, Xiaoming Zhang, Ke Li, Jianming Cai, and Weibo Gao "Self-Protected Thermometry with Infrared Photons and Defect Spins in Silicon Carbide" Phys. Rev. Applied 8, 044015, 2017
13. M. Sedighi, V. B. Svetovoy, and G. Palasantzas "Casimir force measurements from silicon carbide surfaces" Phys. Rev. B 93, 085434, 2016
14. Andrey A.Stepashkin, Dilyus I.Chukov, Sergey D.Kaloshkin et al. "Carbonized elastomer based composites filled with carbon fillers and silicon carbide" Materials Letters 215, 288-291, 2018
15. Robert W.Flammang, John G.Seidel, Frank H.Ruddy "Fast neutron detection with silicon carbide semiconductor radiation detectors" Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 579,1, 177-179, 2007
16. L.L.Snead, T.Nozawa, M.Ferraris et al. "Silicon carbide composites as fusion power reactor structural materials" Journal of Nuclear Materials 417,1–3, 330-339, 2011
17. P.Z.Takacz, T.L.Hursman, J.T.Williams "Application of silicon carbide to synchrotron radiation mirrors" Nuclear Instruments and Methods in Physics Research 222, 1–2, 133-145, 1984

18. T.Nozawa, T.Hinoki, A.Hasegawa et al. "Recent advances and issues in development of silicon carbide composites for fusion applications" Journal of Nuclear Materials 386–388, 622-627, 2009
19. Yutai Katoh, Lance L.Snead, Izabela Szlufarska, William J.Weber "Radiation effects in SiC for nuclear structural applications" Current Opinion in Solid State and Materials Science 16, 3, 143-152, 2012
20. Kai Wei, Kaiyu Wang, Xiangmeng Cheng et al. "Structural and thermal analysis of integrated thermal protection systems with C/SiC composite cellular core sandwich panels" Applied Thermal Engineering 131, 209-220, 2018
21. Bejoy N.Pushpakaran, Anitha Sarah Subburaj, Stephen B.Bayne, John Mookken "Impact of silicon carbide semiconductor technology in Photovoltaic Energy System" Renewable and Sustainable Energy Reviews 55, 971-989, 2016
22. Peipei Wang, Hejun Li , Jia Sun, Ruimei Yuan, Longxin Zhang, Yulei Zhang, Tao Li "The effect of HfB2 content on the oxidation and thermal shock resistance of SiC coating" Surface and Coatings Technology 339, 124-131, 2018
23. M.Perani, D.Cavalcoli, M.Canino et al. "Electrical properties of silicon carbide/silicon rich carbide multilayers for photovoltaic applications" Solar Energy Materials and Solar Cells 135, 29-34, 2015
24. José Sánchez-González, Angel L.Ortiz, Fernando Guiberteau, Carmen Pascual "Complex impedance spectroscopy study of a liquid-phase-sintered α-SiC ceramic" Journal of the European Ceramic Society 27, 13–15, 3935-3939, 2007
25. Hui Deng, Nian Liu, Katsuyoshi Endo, Kazuya Yamamura "Atomic-scale finishing of carbon face of single crystal SiC by combination of thermal oxidation pretreatment and slurry polishing" Applied Surface Science 434, 40-48, 2018
26. I.Vivaldo, M.Moreno, A.Torres et al. "A comparative study of amorphous silicon carbide and silicon rich oxide for light emission applications" Journal of Luminescence 190, 215-220, 2017
27. Gabriela Huminic, Angel Huminic, Claudiu Fleaca, Florian Dumitrache, Ion Morjan "Thermo-physical properties of water based SiC nanofluids for heat transfer applications" International Communications in Heat and Mass Transfer 84, 94–101, 2017
28. Elchin M. Huseynov "Electrical impedance spectroscopy of neutron-irradiated nanocrystalline silicon carbide (3C-SiC)" Applied Physics A, 124:19, 2018
29. Elchin M. Huseynov "Neutron irradiation, amorphous transformation and agglomeration effects on the permittivity of nanocrystalline silicon carbide (3C-SiC)" NANO 13/3, 1830002, 2018
30. Elchin M.Huseynov "Current-voltage characteristics of neutron irradiated nanocrystalline silicon carbide (3CSiC)" Physica B: Condensed Matter 544, 23-27, 2018
31. Elchin M. Huseynov "Neutron irradiation effects on the temperature dependencies of electrical conductivity of silicon carbide (3C-SiC) nanoparticles" Silicon 10/3, 995–1001, 2018
32. Elchin Huseynov, Anze Jazbec "Trace elements study of high purity nanocrystalline silicon carbide (3C-SiC) using k_0-INAA method" Physica B: Condensed Matter 517, 30–34, 2017
33. Elchin M. Huseynov "Permittivity-frequency dependencies study of neutron-irradiated nanocrystalline silicon carbide (3C-SiC)" NANO 12, No. 6, 1750068, 2017
34. Elchin M. Huseynov "Investigation of the agglomeration and amorphous transformation effects of neutron irradiation on the nanocrystalline silicon carbide (3C-SiC) using TEM and SEM methods" Physica B: Condensed Matter 510, 99–103, 2017
35. Elchin Huseynov "Neutron irradiation and frequency effects on the electrical conductivity of nanocrystalline silicon carbide (3C-SiC)" Physics Letters A 380/38, 3086-3091, 2016
36. Tanja Goričanec, Gašper Žerovnik, Loïc Barbot, Damien Fourmentel, Christophe Destouches, Anže Jazbec, Luka Snoj "Evaluation of neutron flux and fission rate distributions inside the JSI TRIGA Mark II reactor using multiple in-core fission chambers" Annals of Nuclear Energy 111, 407-440, 2018

37. Luka Snoj, Gasper Zerovnik, Andrej Trkov, “Computational analysis of irradiation facilities at the JSI TRIGA reactor”, Applied Radiation and Isotopes 70, 483–488, 2012
38. K.Ambrožič, G.Žerovnik, L.Snoj "Computational analysis of the dose rates at JSI TRIGA reactor irradiation facilities" Applied Radiation and Isotopes 130,140-152, 2017
39. P. Filliatre, C. Jammes, L. Barbot, D. Fourmentel, B. Geslot, I. Lengar, A. Jazbec, L. Snoj, G. Žerovnik "Experimental assessment of the kinetic parameters of the JSI TRIGA reactor" Annals of Nuclear Energy 83, 236–245, 2015
40. Zerovnik, G et al. “Validation of the neutron and gamma fields in the JSI TRIGA reactor using in-core fission and ionization chambers” Applied Radiation and Isotopes, 96, 27-35, 2015
41. Henry R., Tiselj I., Snoj L. “Analysis of JSI TRIGA MARK II reactor physical parameters calculated with TRIPOLI and MCNP” Applied Radiation and Isotopes, 97, 140-148, 2015
42. Tanja Kaiba, Gasper Zerovnik, Anze Jazbec, Ziga Stancar, Loic Barbot, Damien Fourmentel, Luka Snoj "Validation of neutron flux redistribution factors in JSI TRIGA reactor due to control rod movements" Applied Radiation and Isotopes 104, 34–42, 2015
43. Kolsek A., Radulovic V., Trkov A., Snoj L. “Using TRIGA Mark II research reactor for irradiation with thermal neutrons” Nuclear Engineering and Design, 283, 155–161, 2015
44. Steinnes E. "Some Neutron Activation Methods for the Determination of Minor and Trace Elements in Rocks" 3 editions published, Kjeller, Norway (1972)
45. Marcelis de Bruin "Instrumental neutron activation analysis - a routine method" Delftse Universitaire Pers, 1983
46. Hans Mommsen "The importance of a reliable grouping – Neutron activation analysis (NAA) data of Mycenaean pottery sherds re-evaluated with the Bonn filter method" University, Germany, Journal of Archaeological Science 39, 3 (2012) 704–707
47. Lylia Hamidatou, Hocine Slamene, Tarik Akhal and Boussaad Zouranen "Concepts, Instrumentation and Techniques of Neutron Activation Analysis" Imaging and Radioanalytical Techniques in Interdisciplinary Research - Fundamentals and Cutting Edge Applications, Faycal Kharfi (Ed.), InTech, DOI: 10.5772/53686, 2013

НЕЙТРОННО-АКТИВАЦИОННЫЙ АНАЛИЗ НАНОЧАСТИЦ 3C-SiC ПОД НЕЙТРОННЫМ ПОТОКОМ

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Резюме: Наночастицы карбида кремния (3C-SiC) были облучены потоком нейтронов ($2x10^{13}$ н/см^{2}с) в ядерном исследовательском реакторе. После облучения нейтронами изучались радиоизотопы активных элементов в наночастицах 3C-SiC. Была проведена идентификация изотопов, которые значительно увеличили активность образцов в результате нейтронного излучения. Изучена методология нейтронно-активационного анализа наночастиц 3C-SiC.

Ключевые слова: нано-3C-SiC, наноматериал, радиоактивность, нейтронно-активационный анализ, нейтронное облучение

NEYTRON SELININ TƏSIRI ALTINDA 3C-SiC NANOHISSƏCIKLƏRININ NEYTRON AKTIVLƏŞMƏ ANALIZLƏRI

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Xülasə: Silisium karbid (3C-SiC) nanohissəcikləri neytron seli ilə ($2x10^{13}$ n/sm^{2}san) tədqiqat nüvə reaktorunda şüalandırılmışdır. Neytronlarla şüalanmadan sonra 3C-SiC nanohissəciklərində aktiv elementlərin radioizotopları öyrənilmişdir. Neytronlarla şüalanmanın təsiri nəticəsində nümunənin aktivliyini artıran izotoplar təyin edilmişdir. 3C-SiC nanohissəciklərində neytron aktivləşmə analizlərinin metologiyası analiz edilmişdir.

Açar sözlər: nano 3C-SiC, nanomaterial, radioaktivlik, neytron aktivasiya təhlili, neytron irradiasiyası