GAMMA SPECTROSCOPIC ANALYSIS OF IRRADIATED Fe-Ni-Nb-B ALLOY

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Received 13 May 2013; accepted 16 May 2013

1. Introduction

Influence of neutron radiation on amorphous and nanocrystalline $(Fe_{1-x}\ Ni_x)_{81}\ Nb_7\ B_{12}$ (x = 0, 0.25, 0.5, 0.75) alloys were analyzed using several methods at our department. Samples were irradiated in TRIGA reactor in Vienna to fluence 10^{16} cm^{-2} and 10^{17} cm^{-2}. This paper is focused on gamma spectroscopic analyze of activation of those samples. Samples were analyzed one year after irradiation.

2. Method and measurement

Gamma ray spectra collection was realized using 30% HPGe detector placed in low background chamber. Analysis was made using Genie 2000 Spectroscopy software. Efficiency calibration for those measurements was calculated using LabSOCS software. Mathematical calibration does not take into account cascade peak summation effect, therefore was necessary include in to activity calculation a correction according to peak to total calibration [1].

3. Results and discussion

According to samples composition (Fe, Ni, Nb, B) were in results expected products of activation of those elements (^{58}Co, ^{60}Co, …) and wasn't expected any significant difference between amorphous and nanocrystalline samples. Figure 1. shows the measured gamma ray spectra of nanocrystalline sample $(Fe_{0.75}\ Ni_{0.25})_{81}\ Nb_7\ B_{12}$ irradiated to fluence 10^{17} cm^{-2}.colected for 2 hours.

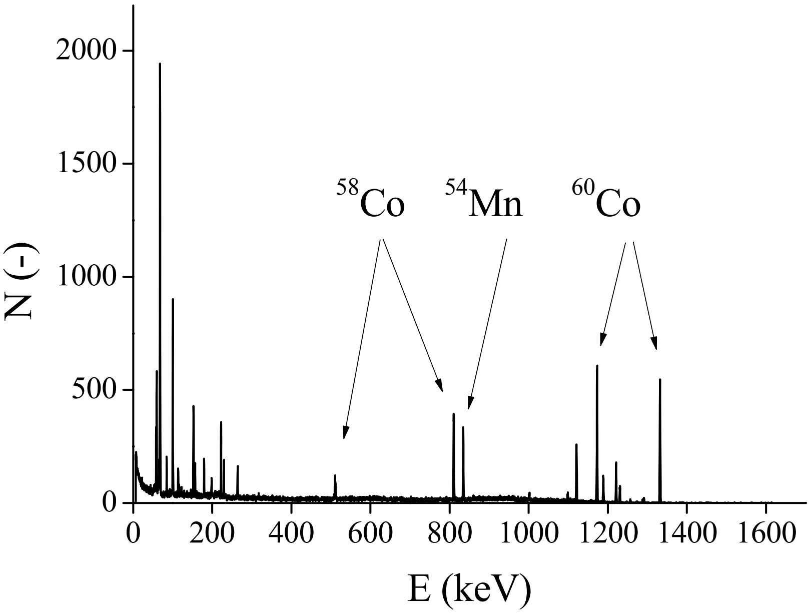

Fig.1: *Gamma ray spectra sample $(Fe_{0.75}\ Ni_{0.25})_{81}\ Nb_7\ B_{12}$*

In the spectra can be seen the peaks from ^{58}Co, ^{54}Mn, ^{60}Co, marked by arrows and the rest of significant peaks is corresponding to ^{182}Ta. Those four isotopes are the most significant activation products in all measured samples. Except those isotopes was also identified ^{59}Fe, ^{57}Co, ^{94}Nb in several samples, but the activities was below MDA.

Tables 1. – 4. shows calculated activity A [Bq] and its uncertainty u_A [Bq] of the most significant activation products for all samples.

Tab. 1. *Activity of main nuclides in amorphous samples irradiated to fluence 10^{16} cm^{-2}.*

Sample	$Fe_{81} Nb_7 B_{12}$		$(Fe_{0.75} Ni_{0.25})_{81} Nb_7 B_{12}$		$(Fe_{0.5} Ni_{0.5})_{81} Nb_7 B_{12}$		$(Fe_{0.25} Ni_{0.75})_{81} Nb_7 B_{12}$	
Isotope	A [Bq]	u_A [Bq]	A [Bq]	u_A [Bq]	A [Bq]	u_A [Bq]	A [Bq]	u_A [Bq]
^{54}Mn	15.84	0.85	14.77	1.09	6.77	0.76	6.01	9.70E-01
^{58}Co	-	-	288.16	16.78	346.75	18.83	873.83	4.17E+01
^{60}Co	3.60	0.14	16.07	0.55	18.39	0.71	48.75	1.44E+00
^{182}Ta	220.99	4.21	171.66	4.04	95.46	2.73	201.51	4.98E+00

Tab. 2. *Activity of main nuclides in nanocrystalline samples irradiated to fluence 10^{16} cm^{-2}.*

Sample	$Fe_{81} Nb_7 B_{12}$		$(Fe_{0.75} Ni_{0.25})_{81} Nb_7 B_{12}$		$(Fe_{0.5} Ni_{0.5})_{81} Nb_7 B_{12}$		$(Fe_{0.25} Ni_{0.75})_{81} Nb_7 B_{12}$	
Isotope	A [Bq]	u_A [Bq]	A [Bq]	u_A [Bq]	A [Bq]	u_A [Bq]	A [Bq]	u_A [Bq]
^{54}Mn	15.73	0.84	11.03	0.80	6.74	0.39	3.53	5.92E-01
^{58}Co	-	-	230.90	11.72	382.93	17.76	678.58	2.93E+01
^{60}Co	4.72	0.16	11.87	0.39	20.05	0.60	34.43	1.01E+00
^{182}Ta	245.35	4.50	119.14	2.63	111.33	2.36	152.89	3.05E+00

Tab. 3. *Activity of main nuclides in amorphous samples irradiated to fluence 10^{17} cm^{-2}.*

Sample	$Fe_{81} Nb_7 B_{12}$		$(Fe_{0.75} Ni_{0.25})_{81} Nb_7 B_{12}$		$(Fe_{0.5} Ni_{0.5})_{81} Nb_7 B_{12}$		$(Fe_{0.25} Ni_{0.75})_{81} Nb_7 B_{12}$	
Isotope	A [Bq]	u_A [Bq]	A [Bq]	u_A [Bq]	A [Bq]	u_A [Bq]	A [Bq]	u_A [Bq]
^{54}Mn	133.46	8.58	155.49	10.60	49.97	5.32	54.40	4.63E+00
^{58}Co	-	-	2811.69	156.61	2674.51	142.10	8028.01	3.32E+02
^{60}Co	32.09	1.19	197.40	6.27	85.66	3.12	507.59	1.48E+01
^{182}Ta	2158.89	2.19E+02	2060.67	40.44	786.71	18.64	2129.46	3.51E+01

Tab. 4. *Activity of main nuclides in nanocrystalline samples irradiated to fluence 10^{16} cm^{-2}.*

Sample	$Fe_{81} Nb_7 B_{12}$		$(Fe_{0.75} Ni_{0.25})_{81} Nb_7 B_{12}$		$(Fe_{0.5} Ni_{0.5})_{81} Nb_7 B_{12}$		$(Fe_{0.25} Ni_{0.75})_{81} Nb_7 B_{12}$	
Isotope	A [Bq]	u_A [Bq]	A [Bq]	u_A [Bq]	A [Bq]	u_A [Bq]	A [Bq]	u_A [Bq]
^{54}Mn	100.79	6.43	105.40	7.54	45.88	5.22	13.84	5.03E+00
^{58}Co	-	-	1834.23	112.20	2676.04	136.41	3628.89	1.79E+02
^{60}Co	24.09	1.03	131.13	4.13	151.61	4.57	237.82	7.03E+00
^{182}Ta	1556.17	31.69	1325.29	28.06	764.32	18.96	919.34	2.11E+01

The main difference between samples, except amorphous or nanocrystalline structure is in Fe to Ni ratio. Therefore was compared the activity of those elements according to this ratio. This comparison is showed at figure 2. - 5.

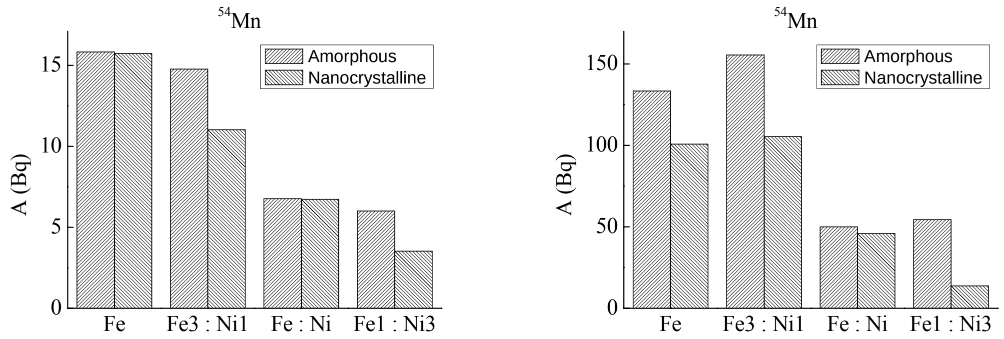

Fig.2: *Activity of ^{54}Mn in samples irradiated to fluence 10^{16} cm^{-2} on the left and 10^{17} cm^{-2} on the right side.*

First compared isotope is ^{54}Mn. It was most probably produced from ^{54}Fe(n,p)^{54}Mn reaction. At figure 2can be seen the decrees of its activity with the decreasing percentage of iron in the sample.

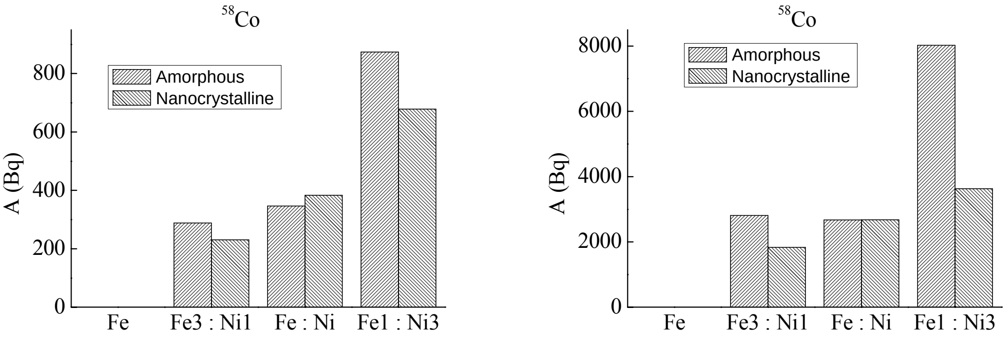

Fig.3: *Activity of ^{58}Co in samples irradiated to fluence 10^{16} cm^{-2} on the left and 10^{17} cm^{-2} on the right side.*

Second isotope is ^{58}Co. It was most probably produced from ^{58}Ni(n,p)^{58}Co reaction. At figure 3 can be seen the increase of its activity with the increasing percentage of nickel in the sample and also absence of this isotope in samples without nickel.

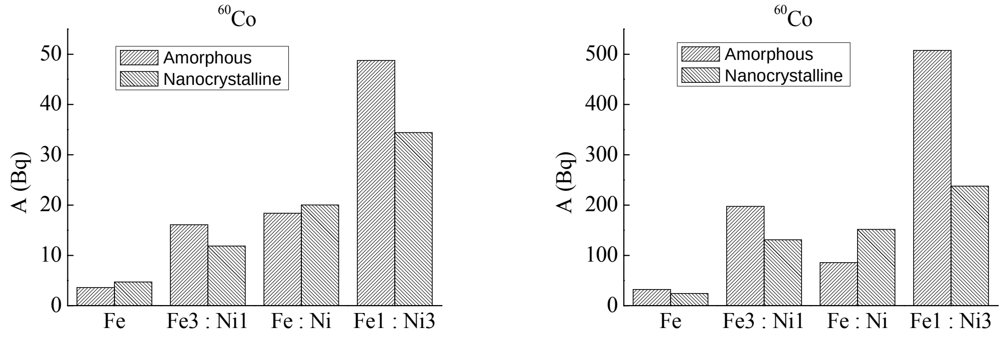

Fig.4: *Activity of ^{60}Co in samples irradiated to fluence 10^{16} cm^{-2} on the left and 10^{17} cm^{-2} on the right side.*

Third compared isotope is ^{60}Co. It was produced from ^{59}Co(n,γ) ^{60}Co or ^{60}Ni(n,p) ^{60}Co reaction. ^{59}Co is a stable isotope of cobalt. In samples could be as an impurity, because it often occurs in iron and nickel ore [2]. At figure 2. can be seen the increase of its activity with the increasing percentage of nickel in the sample, but some ^{60}Co was found also in sample without nickel.

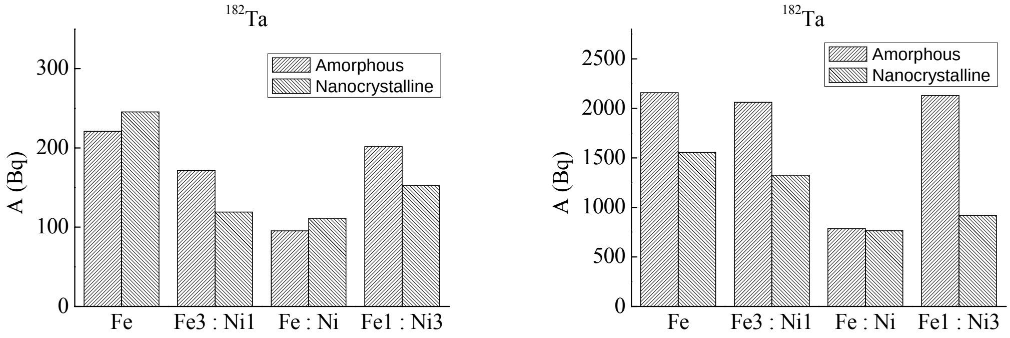

Fig.5: *Activity of ^{182}Ta in samples irradiated to fluence 10^{16} cm^{-2} on the left and 10^{17} cm^{-2} on the right side*

The last compared isotope is ^{182}Ta. It was produced from ^{181}Ta(n,γ) ^{182}Ta reaction. ^{181}Ta is a stable isotope of tantalum and it occurs in Niobium ore. At figure 5. is not any obvious correlation between activity of ^{182}Ta and Fe to Ni ratio.

Systematic differences between activities in amorphous and nanocrystalline samples were not observed. Small difference could be explained by little differences in dimensions of samples. The calculated activities of samples irradiated to fluence 10^{17} cm^{-2} was about an order of magnitude higher than the samples irradiated to fluence 10^{16} cm^{-2}.

4. Conclusion

In the measured spectra was identified the peaks from ^{58}Co, ^{54}Mn, ^{60}Co and ^{182}Ta. Those four isotopes are the most significant activation products in all measured samples. Increase of activity of ^{58}Co, ^{60}Co and decrees of its activity of ^{54}Mn with the increasing percentage of nickel in the sample was registered. Systematic differences between activities in amorphous and nanocrystalline samples were not observed.

Acknowledgement

This work was financially supported by grant of Scientific Grant Agency of the Ministry of Education of Slovak Republic and the Slovak Academy of Sciences No. VEGA-1/0204/13.

References:

[1] Canberra Industries: Model S574 LabSOCS Calibration Software, Meriden_USA.
[2] D. A. Atwood: Radionuclides in the Environment, John Wiley & Sons Ltd, Lexington_USA (2010).