TEMPLATE SYNTHESIS AND STUDY OF Co-Ni CORE/CARBON SHELL NANOPARTICLES

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ABSTRACT

Co-Ni core/carbon-based shell nanoparticles are synthesized at room temperature by the help of a template technique, using a carbon-containing support through a chemical reduction with 0.2 M $NaBH_4$ in a mixture of aqueous solutions of 0.1 M $CoCl_2.6H_2O$ and 0.1 M $NiCl_2.6H_2O$ at a ratio Co:Ni=1:1. As a support of fluorinated graphite (CF) in the presence of β-cyclodextrine (β-CDx), or respectively N-Methyl-2-pyrrolidone (NMP) and N-acetyl-D-glucosamine (NAG), is used during the reduction process. Both Scanning electron microscopy (SEM) and Energy dispersitive spectroscopy (EDS) analyses are carried out to determine the morphology and surface elemental composition. The SEM images show that the synthesized core/shell nanoparticles are too small, but definitely spherical in shape. The particles are spheroidal assemblies, because of magnetic interaction forces. It is observed that the nanoparticles are deposited among the graphite grains and surrounded with the β-CDx, NMP and NAG molecules, respectively. The ratio Co:Ni = 1:1, set in the reaction solution, is exactly reproduced in the Co-Ni nanoparticles. The prepared hybrid core/shell nanoparticles are also investigated with X-ray diffraction (XRD) and Infrared spectroscopy with Fourier transformation (FTIR) in the mid-Infrared region (4000–400 cm^{-1}). XRD analysis proves the formation of amorphous Co-Ni nanoparticles. FTIR spectra establish the existence of different chemical bonds such as O-H, C-O, C-H, C-N, B-O, B-H, Co-O, Ni-O in the corresponding atom groups situated on the nanoparticle surface.

Keywords: *Co-Ni core/shell nanoparticles, borohydride reduction, template synthesis, support, graphite, β-cyclodextrine, N-Methyl-2-pyrrolidone, N-acetyl-D-glucosamine, SEM, EDS, XRD, FTIR.*

INTRODUCTION

Nanoparticles based on magnetic elements such as Fe, Ni, Co and their chemical compounds, are characterized by functional properties that are usually important for biomedical applications [1-8]. By modifying their surface to obtain new functional properties and biocompatibility, the magnetic nanoparticles can be manipulated when subjected to an external magnetic field. This is used in e biomedicine for transport and drug delivery and other smart disease targeting treatments, as well as for immobilizing and separating of biological quantities. The magnetic nanoprticles are very attractive for biomedicine as diagnostic tools (biosensing) of cancer tumors and targeting treatment in cancer diseases and HIV infection, for therapeutics of tumor cells (hyperthermia), in vivo drug delivery, as contrast agents and enhancers of the signal from magnetic resonance imaging examinations [1 - 3].

The size, shape and composition of the magnetic nanoparticles determine the possibility for different biochemical applications. In order to apply magnetic nanoparticles in various potential fields, it is very important to control their size and shape, and to keep their thermal and chemical stability by surface modification. The modification generally plays a key role for the properties and applications of the magnetic nanoparticles in bio-solutions or tissue environments around the tumor cells [5].

The properties of nanoparticles depend on the method of their synthesis. It is very important to obtain magnetic nanoparticles with a very narrow distribution by size. A possible method to create new magnetic nanoparticles with a low dispersion, suitable for biomedical applications is the preparation of self-assembled magnetic nanoparticles of Co, Co-Ni, or these particles encapsulated in organic shell material [1, 4]. As one important class of transition metal alloys, Co-Ni alloys have high mechanical strength, good wear resistance, anticorrosive performance, thermal conductivity, thermal stability, electrical conductivity, electrocatalytic activity, and specific magnetic properties. So, these alloys should be good high-temperature catalysts and specific magnetic materials that can be applied in many devices and areas [3].

The magnetic structure of the surface layer usually is greatly different from that in the body of the nanoparticles, so the magnetic interactions in the surface layer can have a notable effect on their magnetic properties [4]. The understanding of the interaction between the surfactant and the nanoparticles is essential for their synthesis and application. Oleic acid is a commonly used surfactant to stabilize the magnetic nanoparticles synthesized by the traditional co-precipitation methods. To prevent the nanoparticles from external influence, graphite carbon layers that also give functional properties to the nanoparticles are used. Nowadays, many different methods for synthesis of nanoparticles, such as template-assisted electrochemical deposition, mechanical alloying, leaching technique, sol-gel routes, thermal decomposition of organometallic precursors, polyol reduction, electroless deposition under an external magnetic field, reduction of metal salts by a strong reducing agent, arc-discharge, magnetron and ion beam sputtering, laser irradiation, catalytic carbonization and CVD techniques are well-known [3, 5 - 7].

Transition metal nanostructures, especially those of Co, Ni that have attracted considerable attention from scientists and engineers due to their unique magnetic, electrical, optical, and catalytic properties and their extensive technological and biomedical applications, have determined the aims of this work. Firstly, by a borohydride reduction applying a template technique with a support, to synthesize nanoparticles with magnetic Co-Ni core and covered with a carbon-based shell. Secondly, to investigate the morphology, elemental and phase composition of the synthesized core/shell nanoparticles. Thirdly, to study their nanosurface state and the creation of chemical bonds between the surfactant used and the nanoparticles.

EXPERIMENTAL

„Template" synthesis of Co-Ni core/carbon shell nanoparticles

Intermetallic Co-Ni core/carbon shell nanoparticles have been synthesized by a borohydride reduction method with 0.2 M $NaBH_4$ in a mixture of aqueous solutions of the respective cobalt and nickel chloride salts (0.1 M $CoCl_2.6H_2O$ and 0.1 M $NiCl_2.6H_2O$) at a ratio Co:Ni = 1:1, using a template technique with carbon-containing support. To reach the ratio chosen according the phase diagram of the binary Co-Ni system, 25 ml 0,1 M $CoCl_2.6H_2O$ and 25 ml 0,1M $NiCl_2.6H_2O$ have been used. In order to carry the reduction process fully, the quantity of the reducing agent, stabilized with NaOH, was 50 ml 0.2 M $NaBH_4$, i.e. approximately equal to the sum of the quantities of the reaction solutions. Citric acid, $C_6H_8O_7$ in a quantity of 0,44 g/100 ml, was used as a complex forming agent.

The synthesis was carried out in a double-wall cell, ensuring consecutive introduction of the initial solutions and continuous mechanical stirring with a magnetic stirrer. The experiments were performed at room temperature and atmospheric pressure. The reduction process was carried out for 2 minutes. After the finishing of the reduction process, the powder samples obtained were filtrated, washed with distilled water and alcohol, and dried in a vacuum oven for 24 hours at 100°C.

As a support a fluorinated graphite (CF) in the presence of β-cyclodextrine (β-CDx) or organic solvent such as N-methyl-2-pyrrolidone (NMP) or N-acetyl-D-glucosamine (NAG) was used. In this way the carbon-based nanocomposites are obtained in-situ. The used quantities of CF and β-CDx, as well as MNP or NAG were 0,363 g/100 ml, respectively. In this case the ratio CF/β-CDx (respectively MNP or NAG)/Co-Ni nanoparticles is: 20 % CF: 20 % β-CDx (MNP or NAG): 60% Co-Ni nanoparticles.

INVESTIGATING TECHNIQUES

The morphology of the synthesized Co-Ni core/carbon shell nanoparticles was investigated with Scan-

ning electron microscopy (SEM). The SEM images were made with a JEOL JSM 6400F (Japan) SEM microscope at accelerating voltage of 20 kV in three regimes: secondary electron image (SEI image), a back reflex electron composition image (BEC image), and a split/shadow image, the so-called "combined regime" (SPI image). The SEI images give information for the surface of the investigated sample, while the BEC images – for its chemical composition. The dark regions of the BEC images characterize the existence of atoms with a smaller atom number, while the light region brings information for existence of atoms with higher atom numbers. The elemental dispersitive analysis (EDS) was made with the same SEM microscope, using its appliance for Energy-dispersive X-ray spectroscopy. The phase composition of the investigated samples was determined by X-ray diffracrion (XRD). The XRD patterns of all samples were collected within the 2θ range from 10^o to 95^o, with a constant step 0.03^o and counting time 1 s/step on a Philips PW 1050 diffractometer, using CuKα radiation.

The intermetallic Co-Ni core/carbon shell nanoparticles were also characterized by Infrared spectroscopy with Fourier transformation on an EQUINOX 55 (Bruker) FTIR spectrophotometer in mid- IR region of the spectrum in the interval from 4000 to 400 cm^{-1}. The FTIR spectra of the Co-Ni nanoparticles, synthesized through chemical reduction with $NaBH_4$ in a mixture of water solutions of the corresponding metal salts, using a support of graphite in the presence of β-CDx, respectively MNP and MAG, were taken.

RESULTS AND DISCUSSION

Investigation of the morphology and elemental composition of Co-Ni nanoparticles, obtained at a ratio

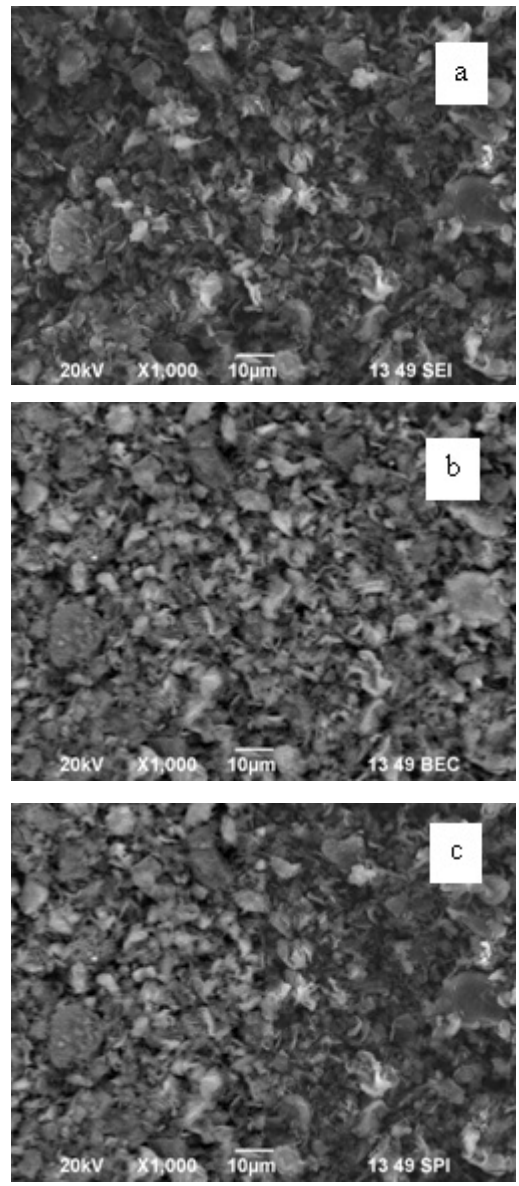
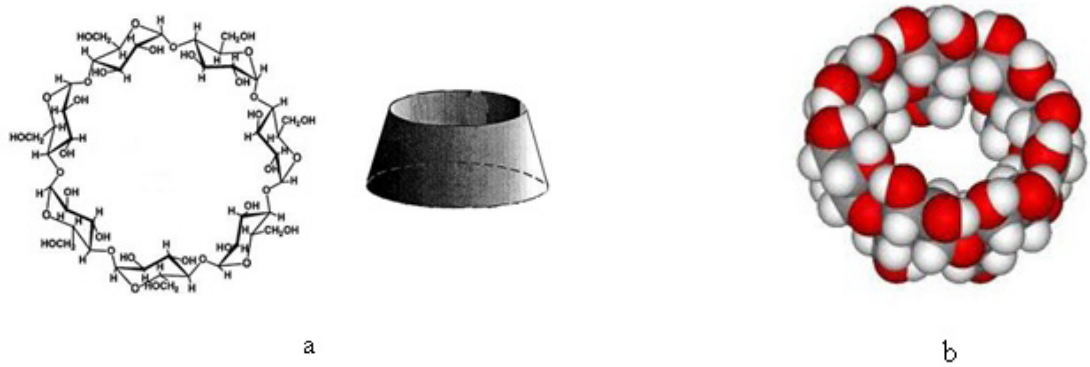


Fig. 1. SEM images of the graphite used as a support for the template synthesis of Co-Ni nanoparticles at a magnification x 1000: a- BEC image, b- SEI image, c- SPI image.



a b

Fig. 2. Graphic formula and stereo image of the β-cyclodextrine hydrate.

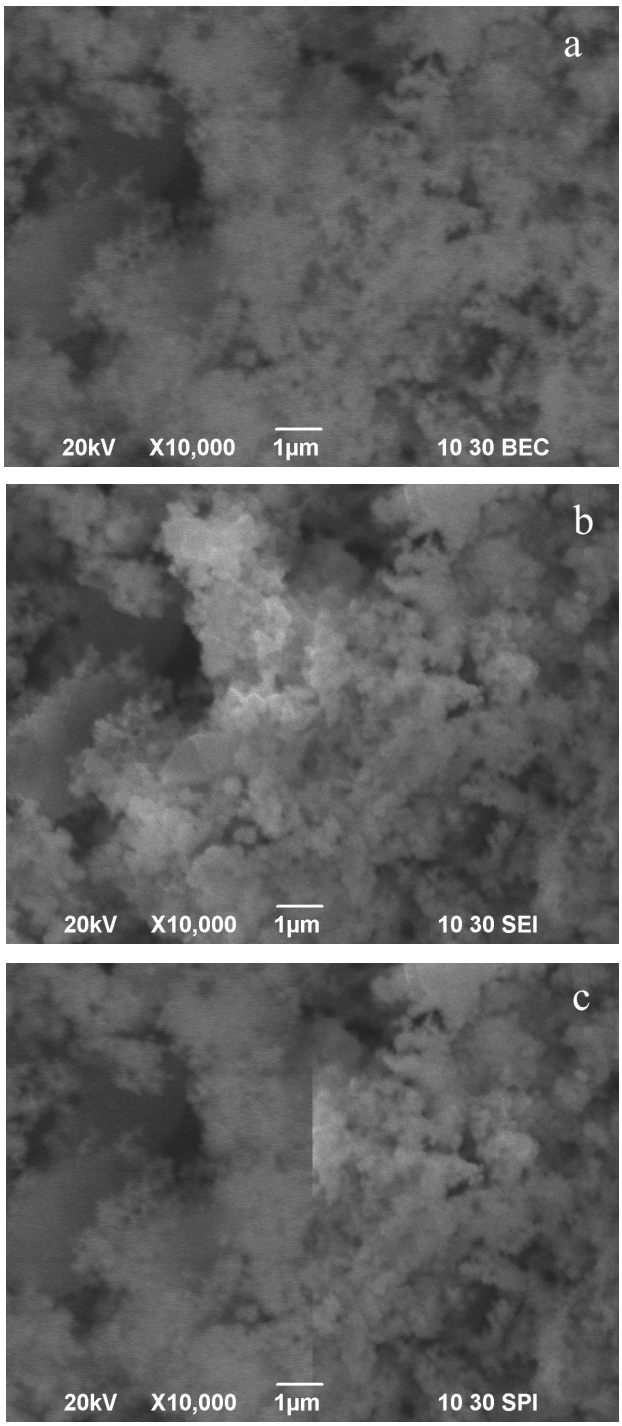


Fig. 3. SEM images of Co-Ni nanoparticles at a magnification x 10,000: a-BEC image, b-SEI image, c-SPI image.

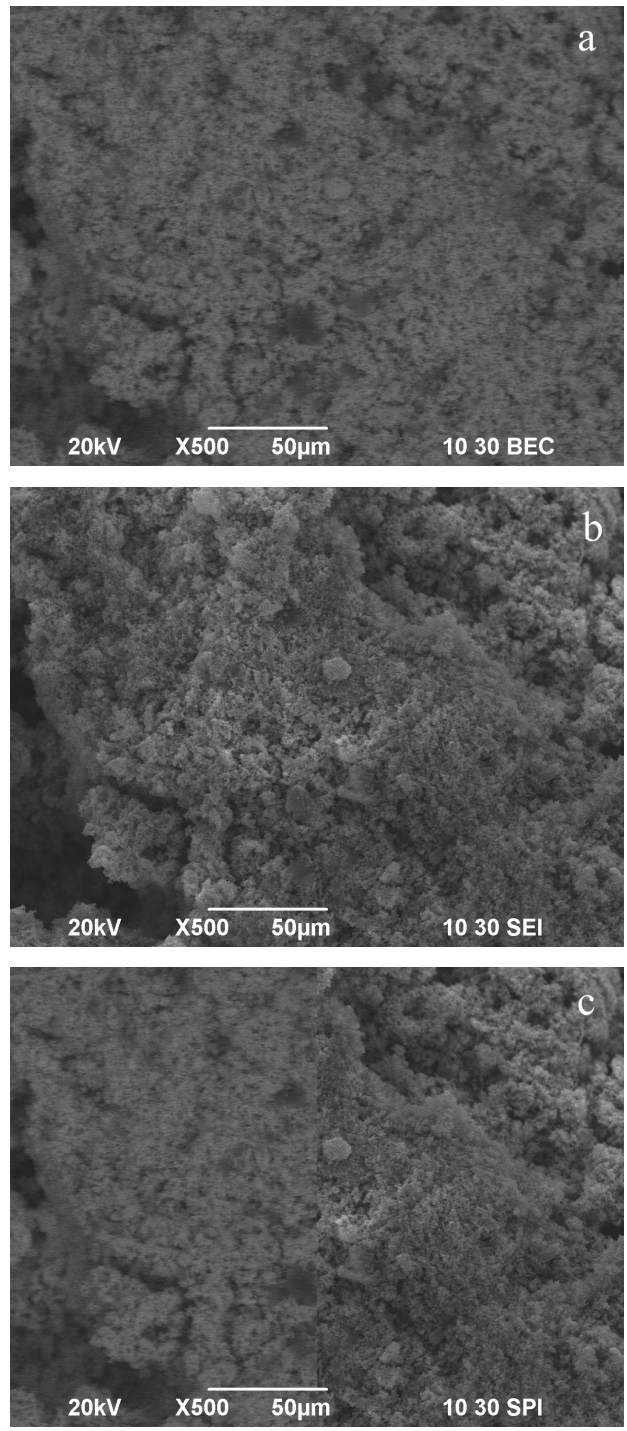


Fig. 4. SEM images of Co-Ni nanoparticles at a magnification x 500: a-BEC image, b-SEI image, c-SPI image.

Co: Ni = 1:1 with a fluorinated graphite (CF) support in the presence of β-cyclodextrine (β-CDx). Results from SEM/EDS analyses.

Fig. 1 presents SEM images of the graphite, used as a support for the synthesis of the Co-Ni nanoparticles.

The graphic formula and the stereo image of the β-cyclodextrine hydrate used during the template synthesis of Co-Ni nanoparticles, are shown in Fig. 2.

SEM images of the morphology of Co-Ni nanoparticles, obtained at a ratio Co: Ni = 1:1 using a support of fluorinated graphite (CF) in the presence of β-cyclodextrine (β-CDx), are given in Figs. 3 and 4.

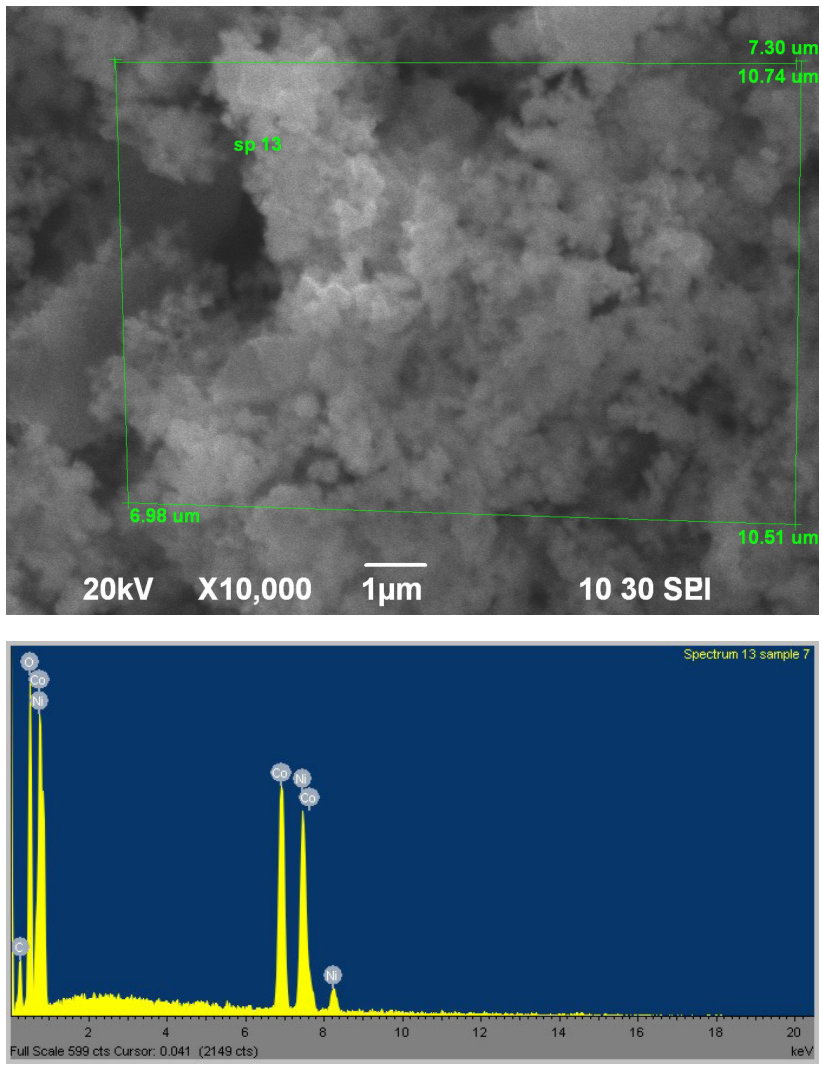


Fig. 5. Results from the EDS analysis: a-SEM image at a magnification x 10,000 of Co-Ni nanoparticles synthesized with a graphite support in the presence of β-CDx, respectively the sp13 point where EDS analysis is carried out is indicated, b-EDS spectrum of Co-Ni nanoparticles in the sp13 point shown in the SEM image left (b).

The images are made at different magnification in three regimes: BEC, SEI and SPI images, respectively.

The SEM images show that the synthesized Co-Ni core/carbon-based shell nanoparticles are too small, but definitely spherical in shape. The particles represent spheroidal assemblies, because of the magnetic interaction forces. It is observed that the nanoparticles are deposited among the graphite grains and surrounded

Table 1. Data for the elemental composition in sp13 point.

Element	App Conc.	Intensity Corrn.	Wt. %	Wt. % Sigma	At. %
C K	0.60	0.4310	10.70	1.03	25.29
O K	3.64	1.1435	24.46	0.72	43.41
Co K	3.84	0.8977	32.78	0.73	15.79
Ni K	3.89	0.9300	32.07	0.75	15.51
Totals			100.00		

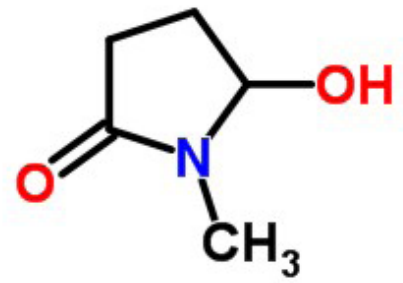


Fig. 6. Graphic formula of N-Methyl-2-Pyrrolidone (NMP).

with the β-CDx molecules.

In Fig. 5a, presenting a SEM image of the morphology of the Co-Ni nanoparticles synthesized with graphite support in the presence of β-CDx, at magnification x10 000, the drawn area indicates the sp^{13} point where the EDS analysis was carried out. The EDS spectrum of the element (Co, Ni, C, O) distribution on the nanoparticle surface in the sp^{13} point is shown in Fig. 5b. The elemental composition (mass or atomic %) of the

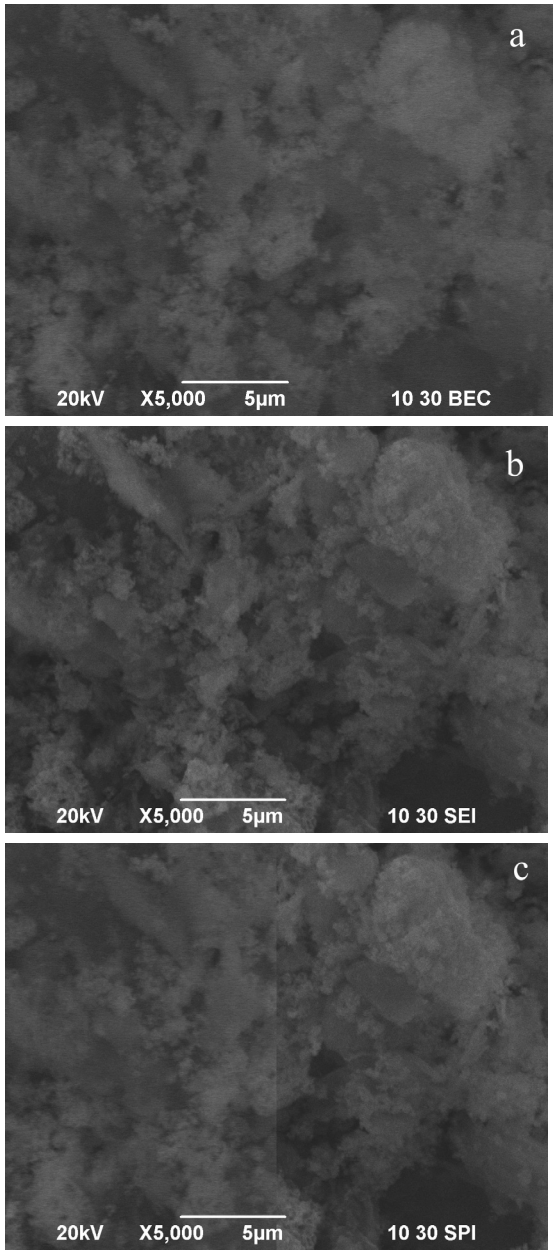


Fig. 7. SEM images at a magnification x 5 000 of Co-Ni nanoparticles synthesized with a graphite support in the presence of NMP: a-BEC image, b-SEI image, and c-SPI image.

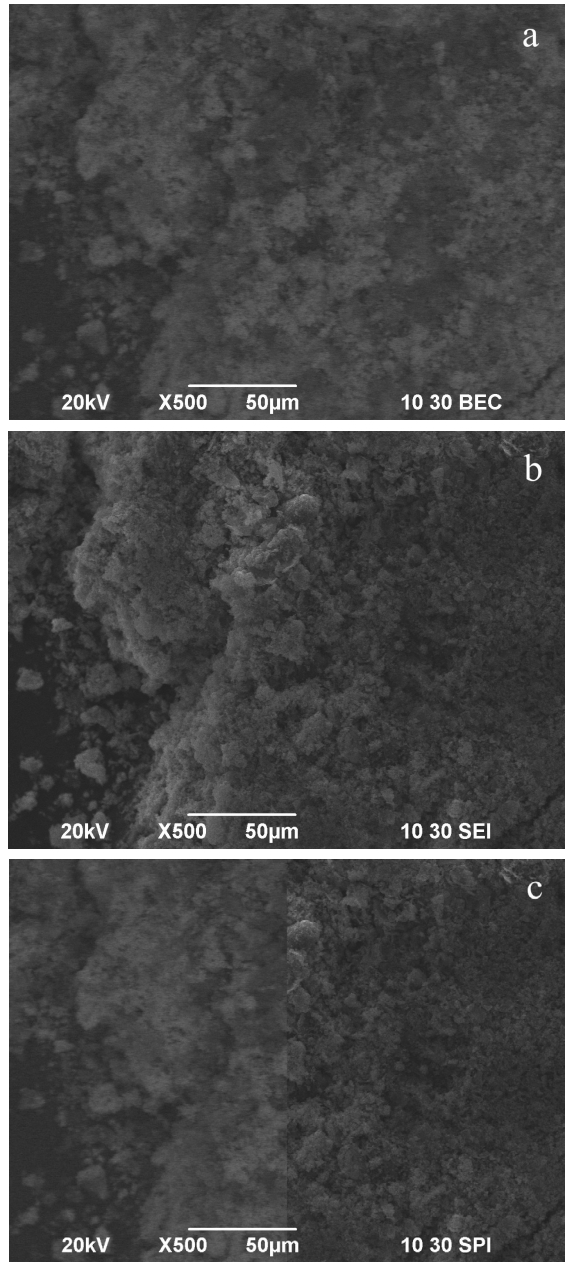


Fig. 8. SEM images at a magnification x 500 of Co-Ni nanoparticles synthesized with a graphite support in the presence of NMP: a-BEC image, b-SEI image, c-SPI image.

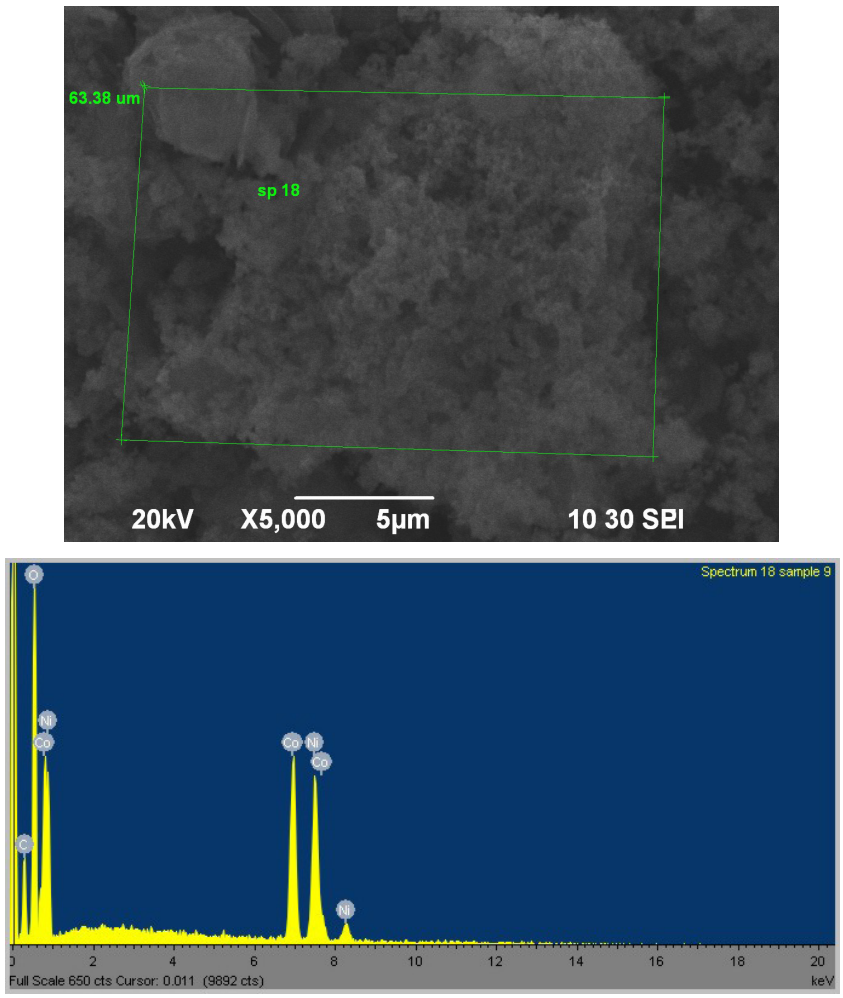


Fig. 9. Results from the EDS analysis: a-SEM image at a magnification x 5000 of Co-Ni nanoparticles synthesized with a graphite support in the presence of NMP, respectively the sp18 point where EDS analysis is carried out is indicated, b-EDS spectrum of Co-Ni nanoparticles in the sp18 point shown in the SEM image left.

investigated sample in the same point is given in Table 1.

On the basis of the EDS results, it can be concluded that the ratio Co: Ni = 1:1, set up in the initial solutions, is exactly kept for the synthesized Co-Ni nanoparticles, when the graphite is used as a support in the presence of β-cyclodextrine.

2. Investigation of the morphology and elemental composition of Co-Ni nanoparticles, synthesized at a ratio Co: Ni=1:1 with a fluorinated graphite (CF) support, in the presence of N-Methyl-2-Pyrolidone (NMP). Results from SEM/EDS analyses

The formula of N-Methyl-2-Pyrrolidone (NMP), used in the synthesis of Co-Ni nanoparticles is shown in Fig. 6, while the SEM images at different magnification

Table 2. Data for the elemental composition in sp18 point.

Element	App Conc.	Intensity Corrn.	Wt. %	Wt. % Sigma	At. %
C K	1.11	0.4810	17.09	1.03	33.72
O K	4.29	1.0434	30.47	0.78	45.14
Co K	3.08	0.8708	26.22	0.66	10.55
Ni K	3.19	0.9010	26.23	0.69	10.59
Totals			100.00		

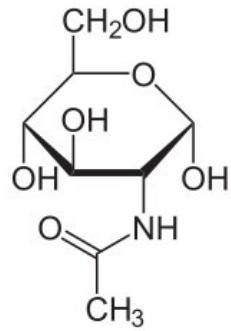


Fig. 10. Graphic formula of N-acetyl-D-glucosamine (NAG).

of the synthesized Co-Ni nanoparticles with a graphite support in the presence of NMP, are presented in Figs. 7 and 8.

The morphology of the Co-Ni core/carbon shell nanoparticles, synthesized with a graphite support in the presence of NMP, is similar to that obtained, when the graphite support is used in the reduction process in the presence of β-cyclodextrine. Assemblies from particles because of magnetic interaction forces could be also observed.

In Fig. 9a, presenting, at magnification x5 000, the SEM image of the morphology of the Co-Ni nanoparticles, synthesized with graphite support in the presence of NMP, the drawn area indicates the sp^{18} point, where the EDS analysis is carried out. The EDS spectrum for element (Co, Ni, C, F, O) distribution on the nanoparticle surface in the point sp^{18} is shown in Fig. 9b, while the elemental composition (mass and atomic %) of the investigated sample in the same point, is given in Table 2.

From the EDS results it can be deduced that the ratio Co:Ni = 1:1 set up in the initial solutions, is also kept for the Co-Ni nanoparticles when the graphite support is used in the presence of N-Methyl-2-Pyrolidone (NMP).

Investigation of the morphology and elemental composition of Co-Ni nanoparticles, synthesized at a ratio Co:Ni = 1:1 with a fluorinated graphite (CF) support, in the presence of N-acetyl-D-glucosamine (NAG). Results from SEM/EDS analyses.

The formula of N-acetyl-D-glucosamine (NAG), used in the synthesis of Co-Ni nanoparticles, is shown in Fig. 10, while the SEM images of the Co-Ni nanoparticles synthesized with a graphite support, in the presence of NAG are presented in Figs. 11 and 12 at different magnifications.

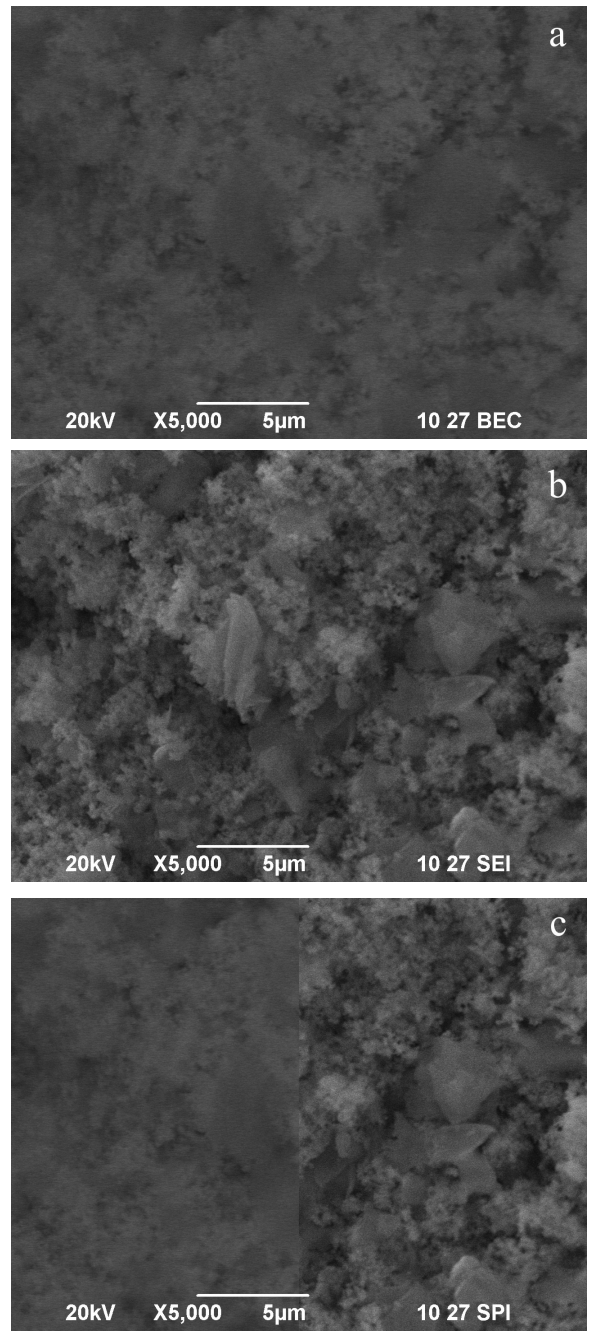


Fig. 11. SEM images at a magnification x 5 000 of Co-Ni nanoparticles synthesized with the graphite support in the presence of N-acetyl-D-glucosamine (NAG): a-BEC image, b-SEI image, and c-SPI image.

In the three cases, using of the graphite support in the presence of β-CDx, NMP и NAG, the morphology of the synthesized intermetallic Co-Ni core/carbon shell nanoparticles is typical for the alloyed materials. Aggregates of small particles spherical or irregular in shape due to their magnetic interaction, are observed.

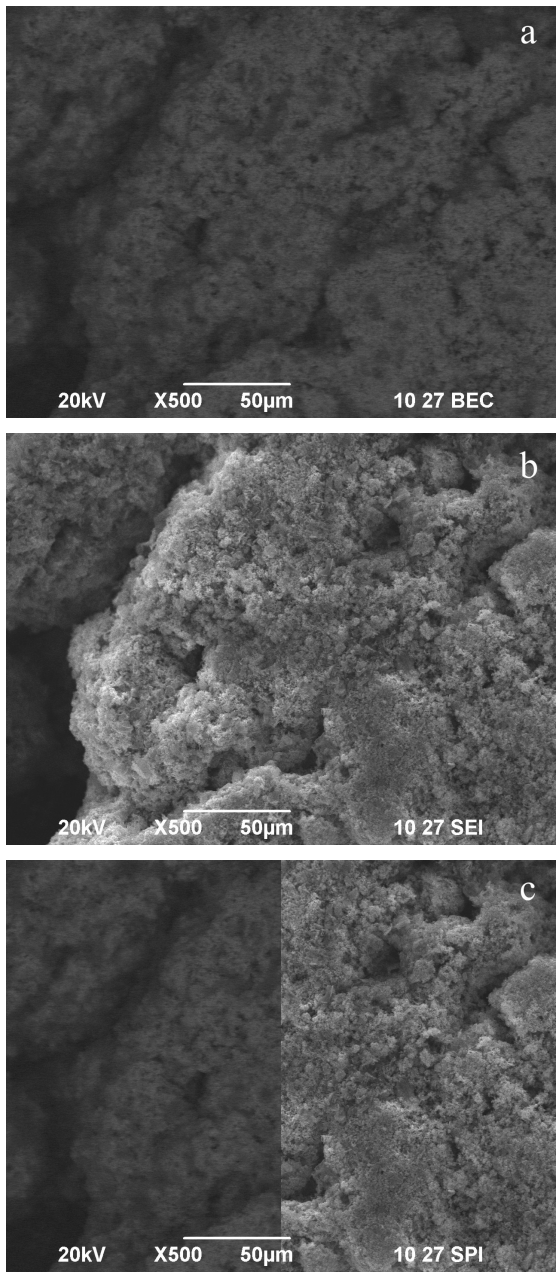


Fig. 12. SEM images at a magnification x 500 of Co-Ni nanoparticles synthesized with the graphite support in the presence of N-acetyl-D-glucosamine (NAG): a-BEC image, b-SEI image, c-SPI image.

In Fig. 13a, presenting at magnification x5 000 the morphology SEM image of Co-Ni nanoparticles, synthesized with a graphite support in the presence of NAG, the drawn area also indicates the sp[12] point, where EDS analysis was carried out. The EDS spectrum for element (Co, Ni, C, F, O) distribution in the point sp[12] on the nanoparticle surface, is shown in Fig. 9b, while

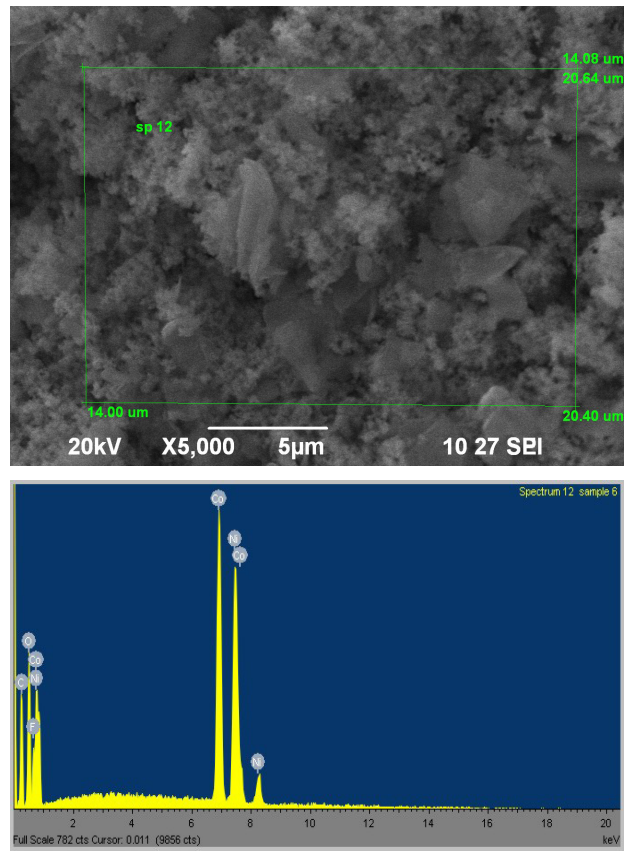


Fig. 13. Results from the EDS analysis: a-SEM image at a magnification x 5000 of Co-Ni nanoparticles synthesized with a graphite support in the presence of NAG, respectivly the sp12 point where EDS analysis is carried out is indicated, b-EDS spectrum of Co-Ni nanoparticles in the sp12 point shown in the SEM image left.

the elemental composition (mass and atomic %) of the investigated sample in the same point, is given in Table 3.

On the basis of the EDS results it can be seen that the ratio Co: Ni=1:1 set up in the initial solutions is also kept for the Co-Ni nanoparticles when the graphite support is used in the presence of N-acetyl-D-glucosamine (NAG).

Investigation of the phase composition of Co-Ni nanoparticles, synthesized at a ratio Co: Ni=1:1. Results from XRD analysis.

The XRD patterns of the investigated samples are presented in Figs. 14 - 16. The XRD analysis proved the formation of amorphous phases of Co and Ni, as well as Co_2B, Co_3B, NiB_2, $3Ni(OH)_2.2H_2O$ phases. The graphite phase is also observed.

FTIR spectroscopy investigations of Co-Ni nanoparticles, synthesized at a ratio Co: Ni = 1:1. Results from FTIR analysis.

Table 3. Data for the elemental composition in sp12 point.

Element	App	Intensity	Wt. %	Wt. %	At. %
	Conc.	Corrn.		Sigma	
C K	2.13	0.4410	20.69	0.79	46.85
O K	2.43	0.9048	11.52	0.45	19.57
F K	0.24	0.4495	2.31	0.40	3.30
Co K	6.93	0.8963	33.09	0.57	15.27
Ni K	7.03	0.9285	32.40	0.59	15.01
Totals			100.00		

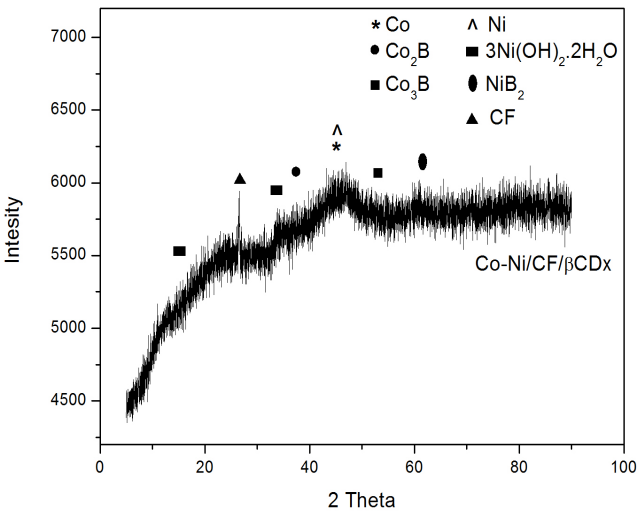


Fig. 14. XRD pattern of Co-Ni nanoparticles synthesized at a ratio Co:Ni = 1:1 with a graphite support (CF) in the presence of β-cyclodextrine (β-CDx).

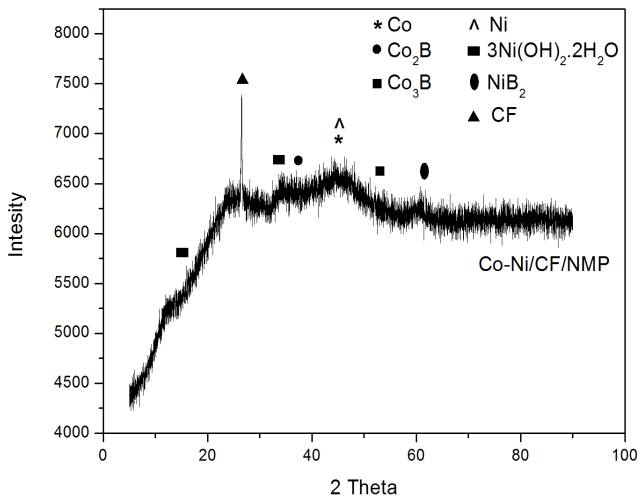


Fig. 15. XRD pattern of Co-Ni nanoparticles synthesized at a ratio Co:Ni = 1:1 with a graphite support (CF) in the presence of NMP.

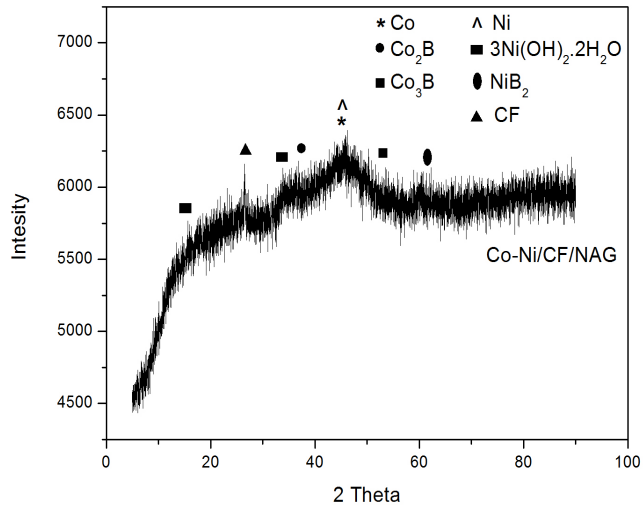


Fig. 16. XRD pattern of Co-Ni nanoparticles synthesized at a ratio Co:Ni = 1:1 with a graphite support (CF) in the presence of NAG.

The study of the synthesized Co-Ni nanoparticles with FTIR spectroscopy is carried out to identify the chemical bonds and atom groups, formed on the nanoparticles' surface. FTIR spectra of the graphite used as a support for the template synthesis of the Co-Ni nanoparticles and respectively - of the NMP and β-CDx used in the synthesis are presented in Figs. 17 - 19.

The FTIR spectra given in Figs. 17 - 19 demonstrate the typical bands of absorption of graphite (2932, 2346, 1211 cm^{-1}), NMP (3000, 1500-1000 cm^{-1}) and β-CDx (3392, 2927, 1029, 577 cm^{-1}) [8-13].

The FTIR spectra of the Co-Ni nanoparticles obtained at a ratio Co: Ni=1: 1 and synthesized with graphite support in the presence of β-CDx, NMP and NAG, respectively, are shown in Figs. 20 - 22, while the experimental data for the bands of absorption and the type of the bond vibrations in the formed atom groups

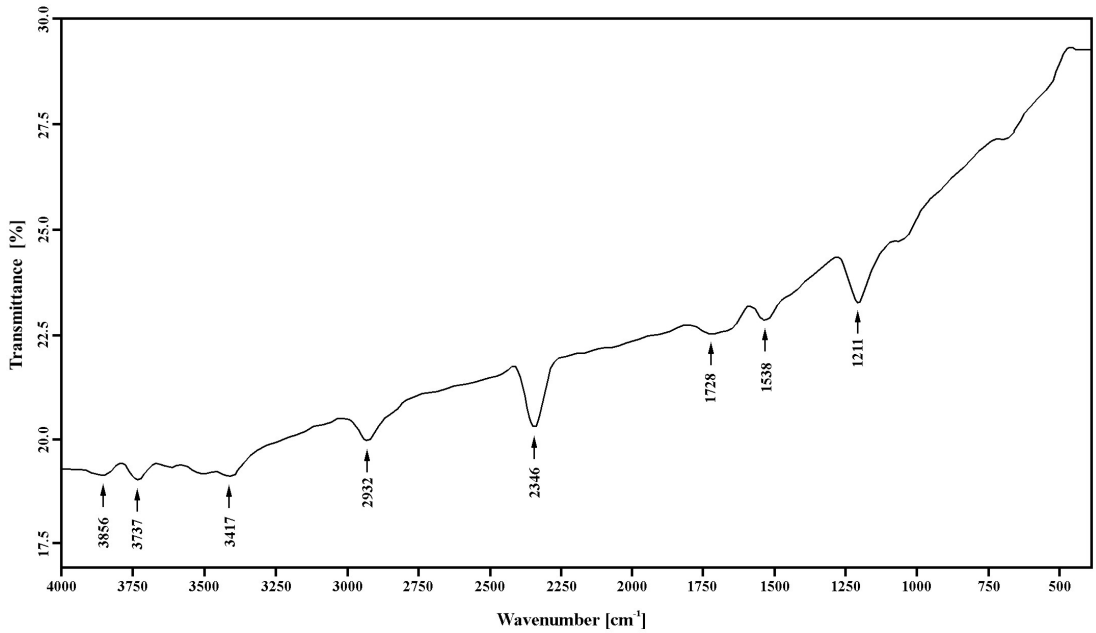


Fig. 17. FTIR spectrum of a graphite (experimental data).

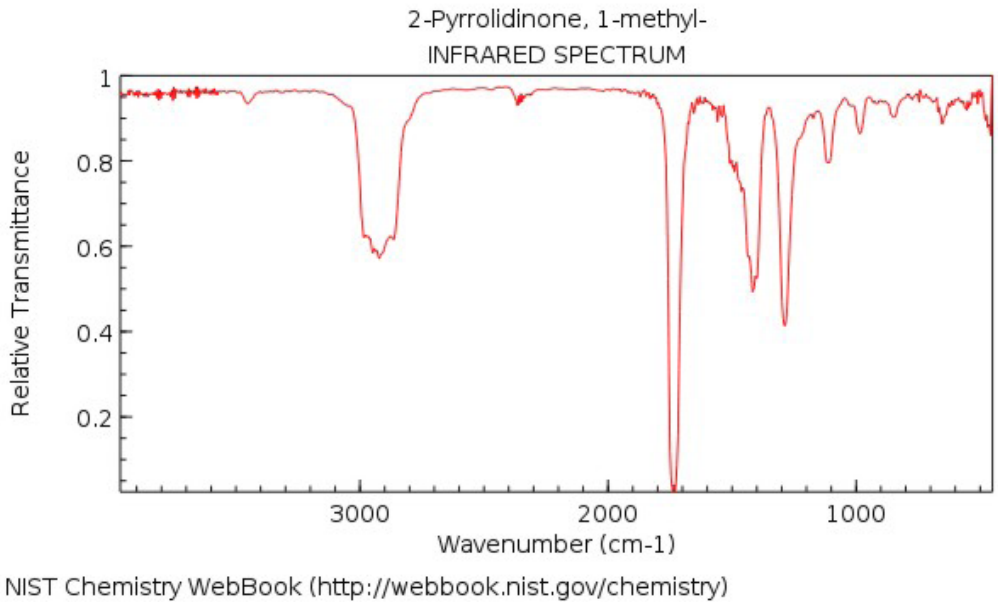


Fig. 18. FTIR spectrum of NMP [13].

at the corresponding wavenumber (cm^{-1}), are given in Table 4.

The FIRT spectrum presented in Fig. 20 exhibits some broad bands with peaks at 3564, 3303 and 3011 cm^{-1} and a sharper band with a peak at 2360 cm^{-1}. These bands correspond to the symmetrical stretching vibrations of O-H bonds in C-OH and CH_2-OH groups and adsorbed H_2O molecules. The band with a peak at 2687 cm^{-1} could be assigned to stretching vibrations of C-H bonds in CH_2-OH groups, characteristic for the polysaccharide structure of β-CDx. The bands, observed at 1416 cm^{-1} and 1030 cm^{-1}, are due to the asymmetric stretching vibrations of B-O bonds in BO_3 and BO_4 groups respectively, while the band with a peak at 688 cm^{-1} reveals bending vibrations of B-O bonds in a BO_3 group. These BO_3 and BO_4 groups are formed as a result of the borohydride reduction process with $NaBH_4$, used for the wet synthesis of the Co-Ni nanoparticle in aqueous medium.

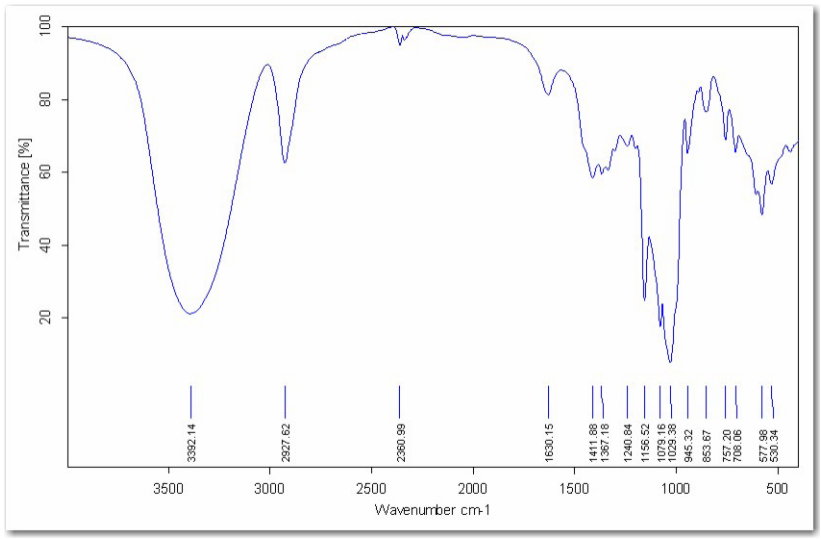


Fig. 19. FTIR spectrum of β-CDx[13].

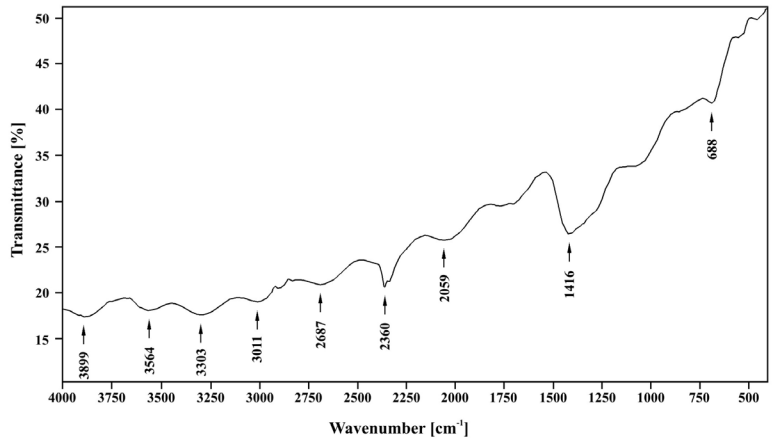


Fig. 20. FTIR spectrum of Co-Ni nanoparticles synthesized at a ratio Co:Ni = 1:1 with a graphite support in the presence of β-CDx.

On the FTIR spectrum, shown in Fig. 21, a broad band with a peak at 3523 cm^{-1} and a narrow band with a peak at 2360 cm^{-1} are observed. These can be assigned to symmetrical stretching vibration of O-H bonds in C-OH groups and H_2O molecules. The presence of carbonyl groups ($R_2C=O$), characteristic for the MNP organic solvent is confirmed by the band with a peak at 1651 cm^{-1}, which is characteristic for stretching vibrations of C=O bonds. The bands with peaks at 1426 cm^{-1} and 1030 cm^{-1} are due to symmetrical stretching vibrations of B-O bonds in BO_3 groups. The band with a peak at 1100 cm^{-1} describes symmetrical stretching vibrations of N-C bonds in CH_3N–C groups, characteristic for the MNP solvent. The band with a peak at 692 cm^{-1} reveals asymmetric stretching vibrations of B-O bonds in BO_3 groups, while the band with a peak at 460 cm^{-1} can be referred to bending vibrations of B-O bonds in BO_4 groups, and also to bending vibrations of Ni-O bonds in NiO-oxides and Co-O bonds in CoO-oxides.

A very weakly expressed band with a peak at 1361 cm^{-1}, exists on the FTIR spectrum in Fig. 22. It can be assigned to the symmetric stretching vibrations of C-N and C-H bonds, characteristic for NAG used during the synthesis of Co-Ni nanoparticles. A strongly expressed band with a peak at 1437 cm^{-1} describes asymmetric stretching vibrations of B-O bonds in BO_3 groups, but could be also due to bending vibrations of C-H bonds in CH_2 groups.

The results, obtained from the FTIR spectroscopy analysis and respectively, the FTIR spectra of the synthe-

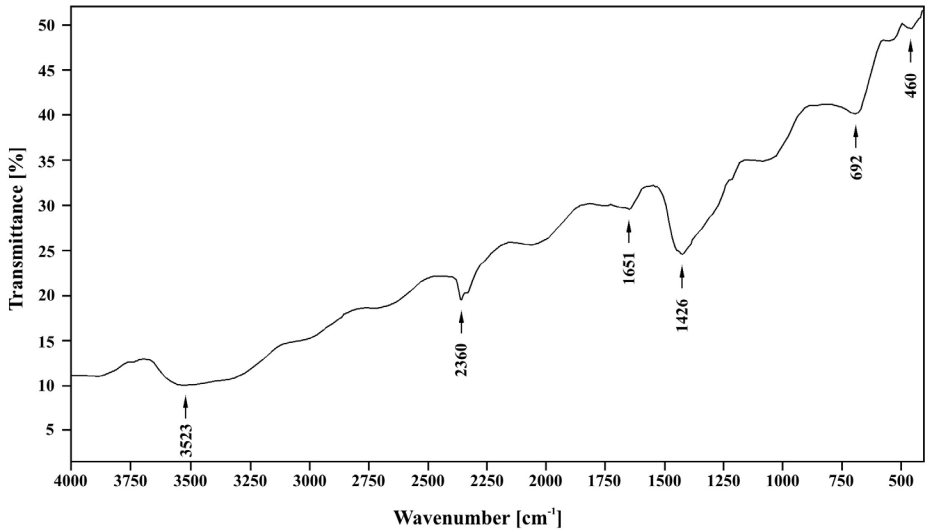


Fig. 21. FTIR spectrum of Co-Ni nanoparticles synthesized at a ratio Co:Ni = 1:1 with a graphite support in the presence of NMP.

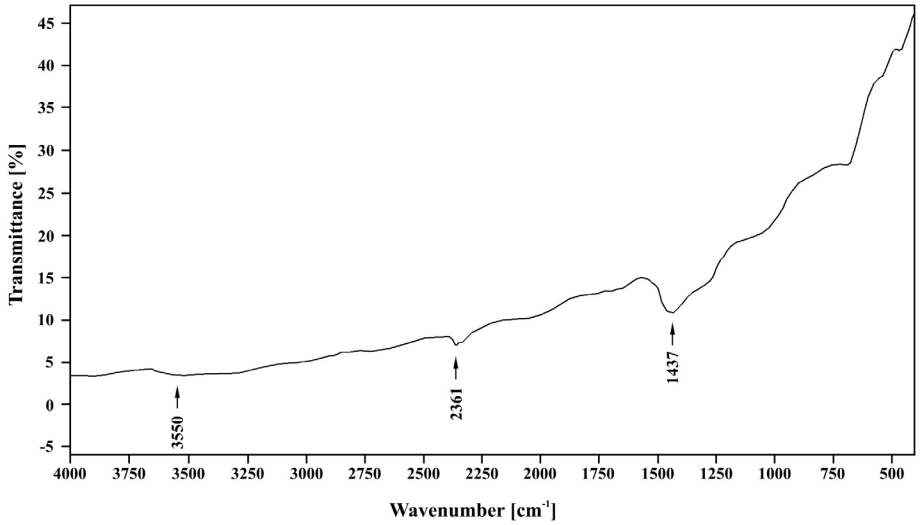


Fig. 22. FTIR spectrum of Co-Ni nanoparticles synthesized at a ratio Co:Ni = 1:1 With a graphite support in the presence of NAG.

sized intermetallic Co-Ni core/carbon shell nanoparticles prove that this spectroscopic investigation technique is sensitive to study the nanosurface phenomena.

CONCLUSIONS

The Co-Ni nanoparticles, synthesized at a ratio Co: Ni=1:1, using a fluorinated graphite support in the presence of different organic solvents (β-cyclodextrine, N-Methyl-2-Pyrrolidone and N-acetyl-D-glucosamine), have identical morphology characterized by nanosized particles, spherical in shape. The particles are apt to aggregation. The carried out EDS analysis shows that the ratio of Co:Ni = 1:1, a priory set up in the reaction solutions, is kept very precisely at the synthesized nanoparticles. This means that both the borohydride reduction and the template technique using a support, are precise and reproducible methods. According to the implement elemental analysis, there is a significant quantity of oxygen as a result of the oxidizing processes, accomplished during the synthesis of the nanoparticles at atmospheric pressure. The X-ray diffraction analysis confirms that

Table 4. Experimental results from FTIR spectroscopy study of Co-Ni (Co:Ni = 1:1) nanoparticles.

Support used	Wavenumber, cm^{-1}	Type of vibration	Atom group
CF+β-CDx	3564 3303 3011 2360	Symmetrical stretching vibrations of O-H bonds	C-OH CH_2-OH H_2O
	2687	Stretching vibrations of C-H bonds	CH_2-OH
	1416 1030	Asymmetrical stretching vibrations of B-O bonds	BO_3 BO_4
CF+NMP	352 2360	Symmetrical stretching vibrations of O-H bonds	C-OH H_2O
	1651	Stretching vibrations of C-O bonds	$R_2C=O$
	1426 1030	Symmetrical stretching vibrations of B-O bonds	BO_3
	1100	Symmetrical stretching vibrations of N-C bonds	CH_3N-C
	629	Asymmetrical stretching vibrations of B-O bonds	BO_3
	460	Bending vibrations of B-O bonds Bending vibrations of Ni-O and Co-O bonds	BO_4 NiO CoO
CF+NAG	1361	Symmetrical stretching vibrations of C-N and C-H bonds	C-$NHOCH_3$
	1437	Asymmetrical stretching vibrations of B-O bonds Bending vibrations of C-H bonds	BO_3 CH_2

amorphous phases of Co and Ni are formed, in accordance with the phase diagram of the binary Co-Ni system at ratio Co:Ni = 1:1. The FTIR spectroscopy analysis of the Co-Ni nanoparticles, synthesized with graphite support in the presence of β-cyclodextrine, N-Methyl-2-Pyrrolidone and N-acetyl-D-glucosamine, proves the formation of O-H, C-O, C-H, C-N bonds in atom groups characteristic for the organic solvents used during the synthesis. The CH-OH, C-OH, C=O groups are typical for the β-cyclodextrine; C-OH, N-CH_3, C=O groups are due to the N-Methyl-2 Pyrrolidone and OH-CH_2, CH-OH, CH-NH groups are assigned to the N-acetyl-D-glucosamine. The shift of the absorption bands to the lower frequencies characterizes the interaction of the organic solvent used with the surface of the Co-Ni nanoparticles during the synthesis. The results obtained for the morphology, elemental and phase composition as well as, the nanosurface state of the synthesized Co-Ni nanoparticles, are a precondition for good magnetic properties that are required for their biomedical applications as diagnostic tools and smart treatment agents in cancer and other diseases. The magnetic properties expected to be obtained for these Co-Ni core/carbon shell nanostructures have no deleterious impact on biological tissues. That is why the next step in our study will be to examine the magnetic properties of the synthesized Co-Ni nanoparticles.

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