Journal of Achievements in Materials and Manufacturing Engineering
Volume 73 • Issue 2 • December 2015
International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

Metallographic research of selected alloys used in dentistry

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ABSTRACT

Purpose: The purpose of this article is to characterize and compare the metallic biomaterials used in dentistry and analyze their structure, properties and chemical composition.

Design/methodology/approach: In the research a sample of the following materials was used: Modiral S (cobalt alloy), Heraenium NA (nickel alloy), ARGELOY NP BE-FREE (nickel alloy), ARGENCO 75 SA (gold alloy). Observations was made using a scanning electron microscope Zeiss Supra 35 using secondary electrons and backscattered electrons at the maximum magnification of 20000x. Chemical composition analysis was performed using the scattered X-radiation detector EDS. The research included taking a series of photos of the structure of metallic biomaterials using optical microscope MEF4A ANNIVERSARY. Photos were taken with magnification at 100x, 200x, 500x, 1000x. Hardness testing of various materials was performed using a Vickers hardness tester FM-700.

Findings: Studies confirmed a typical dendritic structure for all the alloys. In the structures of the tested alloys compact pores and discontinuity of the structures were observed. On the basis of microhardness of alloys, cobalt alloys, nickel and gold alloy, it was found that cobalt alloy Modiral S has the highest hardness (400 HV).

Practical implications: The structure and mechanical properties of alloys determine their particular usage and applications which is important in the selection of materials for specific applications. The Modiral S alloy is used in production of prostheses and combined works. In contrast: Heraenium NA, ARGENCO 75 SA and ARGELOY NP BE-FREE are used in production of dental crowns and bridges.

Originality/value: Metal alloys used in dentistry have varying properties. The appropriate structure and mechanical properties of these alloys determine their specific use in dentistry.

Keywords: Properties; Metallic biomaterials; Chemical composition; Structure

Reference to this paper should be given in the following way:

P. Malara, K. Gołombek, M. Szczęsna, Metallographic research of selected alloys used in dentistry, Journal of Achievements in Materials and Manufacturing Engineering 73/2 (2015) 65-71.

MATERIALS

1. Introduction

Biomedical material is a material which can be used to manufacture components and devices used in direct contact with body tissues. Medical progress has caused the production of more and better materials, aimed at improving the quality of life of people [1,2]. The purpose of this article is to characterize and compare the metallic biomaterials used in dentistry and to analyze their structure, properties and chemical composition.

2. Methods and materials

The research shows the results of tests of the following metallic biomaterials: Modiral S (cobalt alloy), Heraenium NA (nickel alloy), ARGELOY NP BE-FREE (nickel), ARGENCO 75 SA (gold alloy). The Tables 1-5 show the chemical composition and physical properties of engineering materials studied [2-4].

Table 1.
Chemical composition of the Modiral S

Co	Cr	Mo	Different
61.0%	31.5%	5.0%	2.5 (Si, C, Mn)

Table 2.
Chemical composition of Heraenium NA

Ni	Cr	Mo	Different
59.3%	24%	10%	6.7 (Fe, Mn, Ta, Si, Nb)

Table 3.
Chemical composition of ARGELOY N.P.BE-FREE

Ni	Cr	Mo	Fe	Nb	Ta	Different
54%	22%	9%	4%	4%	4%	3%

Table 4.
Chemical composition of ARGENCO 75 SA

Au	Ag	Pd	Cu	Zn
55.8%	25%	4.1%	13.87%	1.23%

Table 5.
Technical and physical properties of materials

	Modiral S	Heraenium NA	ARGELOY N.P.BE-FREE	ARGENCO 75 SA
Density [g/cm^3]	8.3	8.3	8.3	13.5
Vickers hardness[1] [HV]	350	200[1]	240	250
Melting range ° C	1280 - 1360	1190 - 1300	1200 - 1230	860 - 910
Yield strength[2] [MPa]	650	360[2]	-	-
Young's Modulus - E [MPa]	220	227	-	-
Tensile strength[3] [MPa]	890	650[3]	579	745

[1] hardness after sintering of ceramics
[2] 0.2% yield strength after sintering ceramics
[3] tensile strength after sintering ceramics

Observations were performed using a scanning electron microscope Zeiss Supra 35 using secondary electrons and backscattered electrons at the maximum magnification of 20000x. Chemical composition analysis was performed using the scattered X-radiation detector EDS. In the study, there were made a series of photographs of the structure of metallic biomaterials specimens using optical microscope MEF4A ANNIVERSARY. Photos of the specimens were taken using magnification at 100x, 200x, 500x, 1000x.

The samples were prepared using Struers devices. Preparation of the metallographic specimens consisted of the following steps:
• mounting of samples,
• grinding,
• polishing using a disc of synthetic fibers and abrasive diamond paste suspension in water,
• digestion.

Hardness testing was made using a Vickers hardness tester FM-700.

3. Results and Discussion

3.1. Scanning electron microscope

The structures taken with scanning electron microscope are shown in Fig. 1-4.

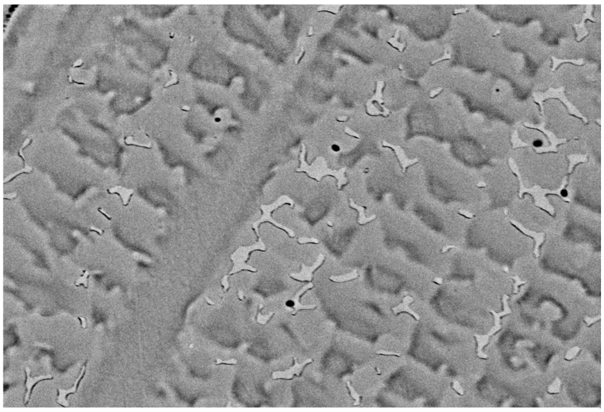


Fig. 1. The structure of the alloy Modiral S - SEM, accelerating voltage 20 kV, magnification 5000x

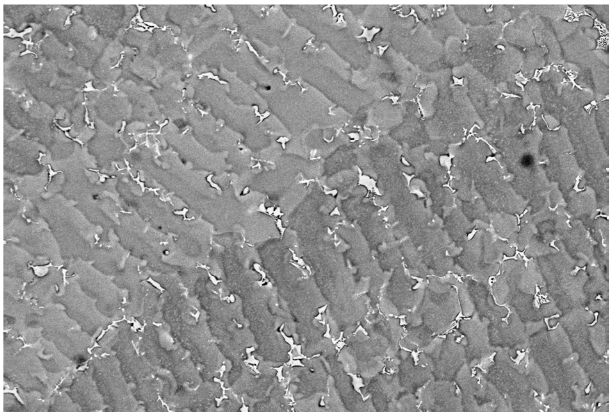


Fig. 2. The structure of the alloy Heraenium NA - SEM accelerating voltage 20 kV, magnification 5000x

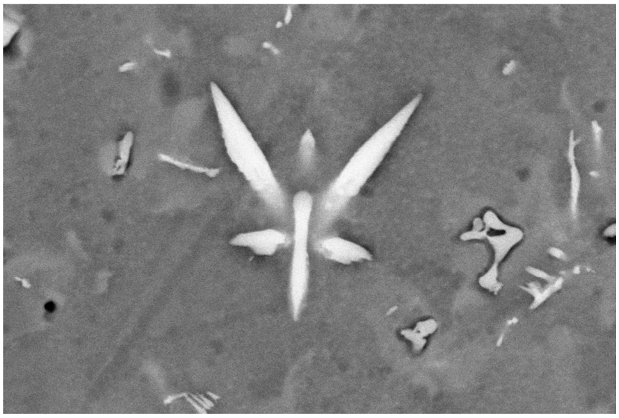


Fig. 3. The structure of the alloy ARGELOY N.P.BE-FREE - SEM accelerating voltage 20 kV, magnification 2000x

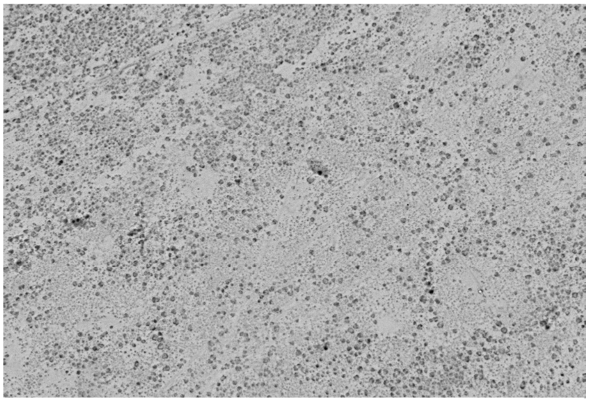


Fig. 4. The structure of the alloy ARGENCO 75 SA - SEM accelerating voltage 20 kV, magnification 5000x

3.2. Optical microscope

The research of the structure of metallic biomaterials performed using optical microscopy LECIA MEF4A. Photographs are taken at magnifications of 100x, 200x, 500x and 1000x. The structures are shown in Figs. 5-8.

Fig. 5. The structure of the alloy Modiral S, magnification 500x

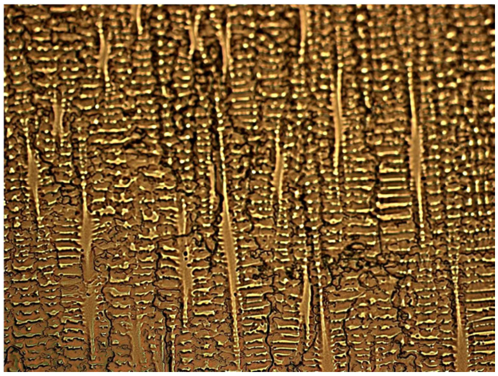


Fig. 6. The structure of the alloy ARGENCO 75 SA, magnification 500x,

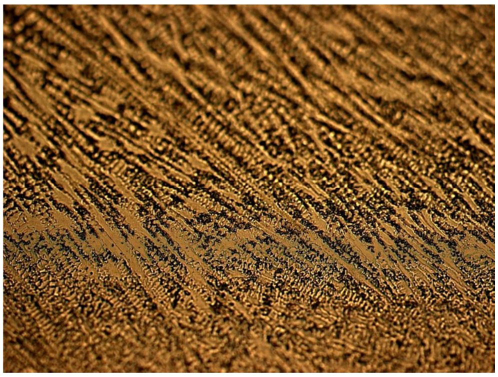


Fig. 7. The structure of the alloy Heraenium NA, magnification 500x

3.3. Analysis of the chemical composition

Analysis of the chemical composition was performed using the energy dispersive spectroscopy. The results are shown in Figs. 9-12 and Tables 6-9.

Studies conducted on the chrome-cobalt-molybdenum alloy (Modiral S) confirmed the composition indicated by the manufacturer. In phase A found higher levels of silicon, molybdenum and chromium and cobalt concentrations lower than in phase B (Fig. 9, Table 6).

Chemical composition of Heraenium Na specified by the manufacturer is similar to the chemical composition of the test sample. The phase shown in Fig. 10 shows higher levels of Tantalum and lower the Nickel concentration compared to the total surface of the sample (Table 7).

Chemical composition of the sample ARGELOY N.P. BE-FREE specified by the manufacturer is similar to the chemical composition of the test sample. In the phase indicated in Fig. 11 a significantly higher concentrations of Niobium and a lower concentration of Nickel (Table 8).

Chemical composition of the alloy samples of Gold ARGENCO 75 SA is similar to the chemical composition specified by the manufacturer (Fig. 12, Table 9).

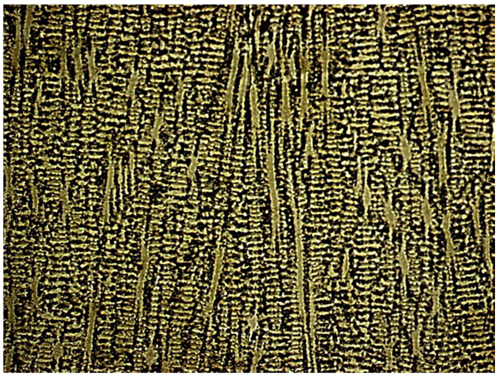


Fig. 8. The structure of the alloy ARGELOY NP BE-FREE, magnification 500x

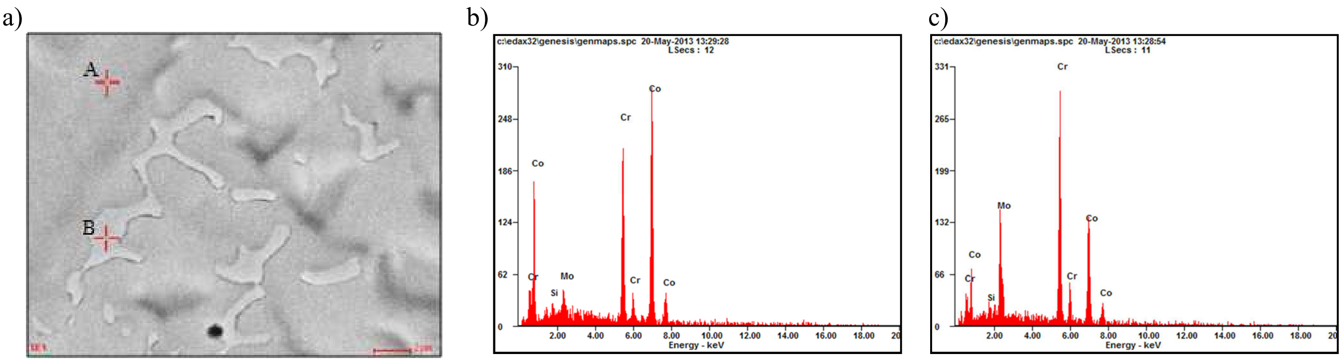


Fig. 9. a) The structure of the alloy Modiral S, SEM, b) diagram of energy-dispersive X-ray spectroscopy at point A, c)) diagram of energy-dispersive X-ray spectroscopy in point B

Table 6.
The results of the analysis of energy-dispersive X-ray spectroscopy of alloy Modiral S on the surface as shown in Fig. 9a

Point A			Point B		
Element	Wt%	At%	Element	Wt%	At%
SiK	01.53	03.21	SiK	00.86	01.75
MoL	18.60	11.41	MoL	04.94	02.96
CrK	42.35	47.92	CrK	27.46	30.30
CoK	37.52	37.46	CoK	66.74	64.99
Matrix	Correction	ZAF	Matrix	Correction	ZAF

a) b)

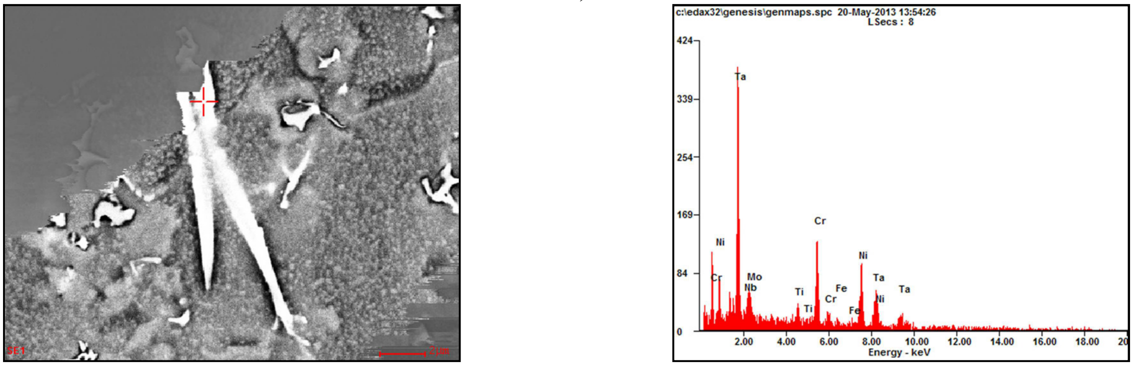


Fig. 10. a) The structure of the alloy Heraenium NA, SEM, b) diagram of energy-dispersive X-ray spectroscopy

Table 7.
The results of the analysis of energy-dispersive X-ray spectroscopy of alloy Heraenium NA on the surface as shown in Fig. 10a

Element	Wt%	At%
NbL	04.12	03.85
MoL	04.27	03.86
TiK	02.56	04.64
CrK	16.31	27.25
FeK	01.27	01.97
NiK	24.11	35.68
TaL	47.37	22.74
Matrix	Correction	ZAF

a) b) c)

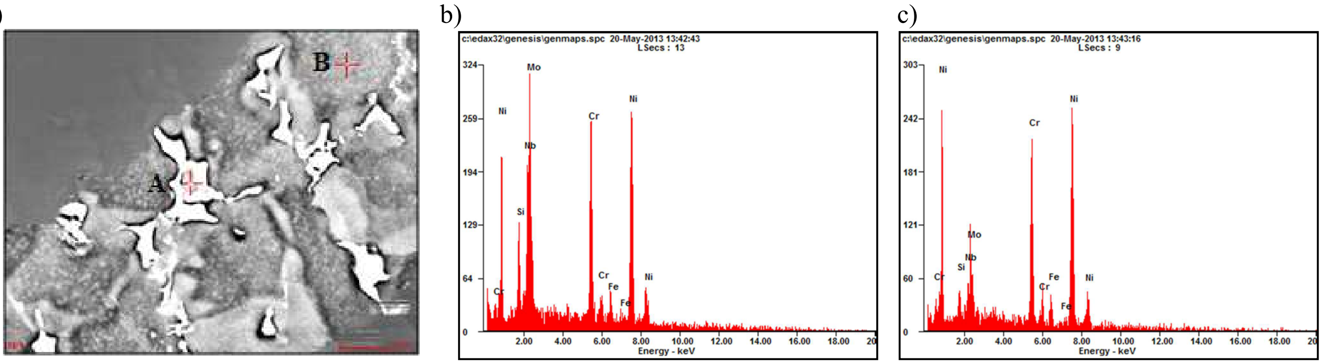
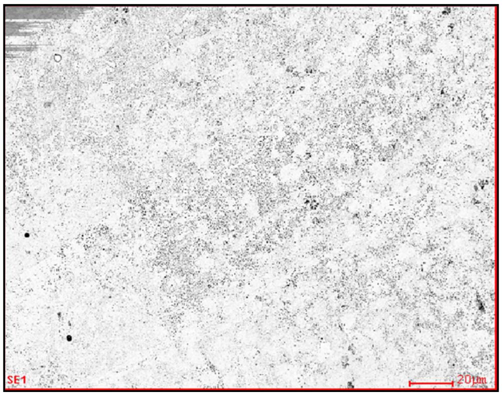


Fig. 11. a) The structure of the alloy ARGELOY N.P. BE-FREE, SEM, b) diagram of energy-dispersive X-ray spectroscopy in point A, c) diagram of energy-dispersive X-ray spectroscopy in point B

Table 8.
The results of the analysis of energy-dispersive X-ray spectroscopy of alloy ARGELOY N.P. BE-FREE on the surface as shown in Fig. 11a

Point A			Point B		
Element	Wt%	At%	Element	Wt%	At%
SiK	04.21	09.16	SiK	01.95	04.07
NbL	13.64	08.99	NbL	04.09	02.58
MoL	15.90	10.14	MoL	09.16	05.59
CrK	18.73	22.04	CrK	23.02	25.93
FeK	02.60	02.85	FeK	03.87	04.06
NiK	44.92	46.82	NiK	57.91	57.77
Matrix	Correction	ZAF	Matrix	Correction	ZAF

a)



b)

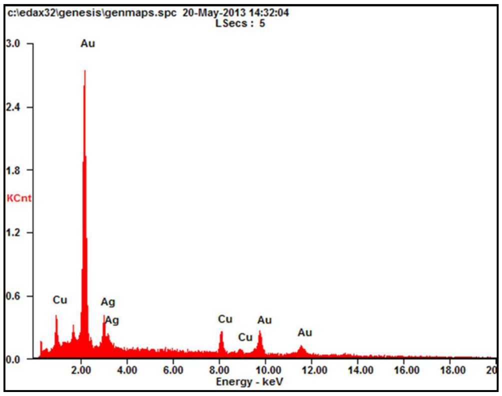


Fig. 12. a) The structure of the alloy ARGELOY N.P. BE-FREE, SEM, b) diagram of energy-dispersive X-ray spectroscopy

Table 9.
The results of the analysis of energy-dispersive X-ray spectroscopy of alloy ARGELOY N.P. BE-FREE on the surface as shown in Fig. 12a

Element	Wt%	At%
AgL	13.13	17.74
CuK	11.57	26.54
AuL	75.31	55.73
Matrix	Correction	ZAF

3.4. Analysis of the chemical composition

The measurements of hardness are made several times for each sample, the median result are show in Table 10.

Table 10.
The results of the hardness measurement

	Modiral S	Heraenium NA	ARGELOY N.P. BE-FREE	ARGENCO 75 SA
Hardness [HV]	400	200	240	200

4. Conclusions

Metallographic tests made by optical microscopy and scanning electron microscope allow to conclude a dendritic structure which is typical for all alloys.

The structures of the tested alloys have not contained visible pores and voids.

The micro-hardness testing has shown that most of the tested materials hardness distinguished Modiral S Cobalt alloy, whose hardness is 400 HV, and the lowest hardness is Heraenium NA, which is 200 HV.

The structure and mechanical properties of alloys determine their particular usage and applications. The Modiral S alloy is used in production of prostheses and combined prosthetic appliances. In contrast - Heraenium NA, ARGENCO 75 SA and ARGELOY NP BE-FREE are used in production of dental crowns and bridges.

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