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A study on biocompatibility of steel 316L in plasma (human body liquid) By using biomedical engineering approach

ABSTRACT

Department of biomedical engineering has started becoming increasingly popular worldwide. There are four undergraduate and two master programs continuing in the Universities in Turkey and also new departments have been continuing to be implemented increasingly although biomedical engineering has been a field recently known in Turkey. As being one of the major subjects in biomedical engineering department, biocompatibility has been considered as one of the subjects persistently researched. It has been known that biomedical implants have been applied to eleven million people in the United States at least once in a year.

In this study, two pieces of steel 316L (austenitic) samples were used for examination in Antalya, Turkey. First of all, those samples were sterilized in 180° C in the autoclave instrument used in the Practice and Research Hospital of Akdeniz University. One of the sterilized samples was coated with golden palladium. Other sample was not coated. The coated and non-coated samples were kept in 0 Rh^- human body liquid (plasma) in 36,5° C in incubator instrument during 90 days. In the end of this period, surface condition of each sample (steel 316L) was examined by testing with SEM (Screening Electron Microscope) and X-RD (X-ray Diffractometer), and it was researched whether they are biocompatible with human body liquid (plasma) or not.

INTRODUCTION

Scientists have been making great efforts in biomaterial science in order to develop new materials that will be biocompatible with the biological systems in human body when they interact. Biomaterials are natural or synthetic materials, and those materials are permanently or temporarily in contact with human body liquids (plasma) [1].

Metals and their compounds have been used as implant materials in surgeries in orthopedics due to their outstanding mechanical features. Materials that are used extensively in orthopedics are: stainless steels (for example; 316L), Ti6A14V and Co-Cr alloys[2].

Stainless steel 316L has been used extensively in the knee and hip joints prosthesis. That is because steel 316L is cheaper than other biomaterials and it is acceptable in biocompatibility[3].

Although these steels have outstanding corrosion resistance, they have low hardness and weak tribological features. This situation causes damage especially in orthopedic applications in which abrasion and fatigue are considered important. Some methods should be applied on the material surfaces in order to prevent damage. Mostly used ones of these methods are: anodization, passivation, thermo chemical process (as plasma nitruration), coating process with biocompatible fine film and duplex process [4, 5].

MATERIALS AND METHODS

Two pieces of steel 316L samples were used in this study. These samples, which belong to variety of 316L, were sterilized in 180°C with autoclave instrument. One of the sterilized samples was coated with golden palladium. Other was not coated. The coated and non-coated samples were kept in 0 Rh- human body liquid (plasma) in 36,5 ^{0}C in incubator instrument during 90 days.

After taking them out of human body liquid, condition of each steel 316L sample surface was tested with SEM (Screening Electron Microscope), and researched whether they were available for human body or not.

Operation principles of SEM and X-RD which are used in this study are specified in the following paragraphs.

What is Screening Electron Microscope (SEM)?

SEM microscope is a research means when optical microscope cannot provide enough magnification. Electron cluster which is transferred onto the sample interacts with the sample, and forms various signals in Screening Electron Microscope (SEM). These signals (secondary electrons, retro-reflected electrons, x-rays, etc.) can be collected with proper detector and also elemental information can be provided in addition to the figure obtainment.

What is X-RD Microscope?

X rays of which wavelength is within the range of 0,5 Å - 2 Å are transferred onto the sample in X- ray diffraction. X-rays that are diffracted from crystalline phases according to Bragg law, form a pattern. Crystalline material phases, structural features (size and orientation) and concentration profile can be determined with these diffraction patterns[6].

What is the feature of Steel 316 L

Two pieces of material 316L used in this study are specified in the following tables:

Table 1. Chemical Composition of Material 316L

Element	Composition (%)
C	0,03 max
Mn	2,00 max
P	0,03 max
S	0,03 max
Si	0,75 max
Cr	17,00-20,00
Ni	12,00-14,00
Mo	2,00-4,00
Fe	%(60-65)

The element percentages in weight that should be required according to ASTM (American Society for Testing and Materials) [7]:

Table 2. Mechanical Features of Material 316L [8].

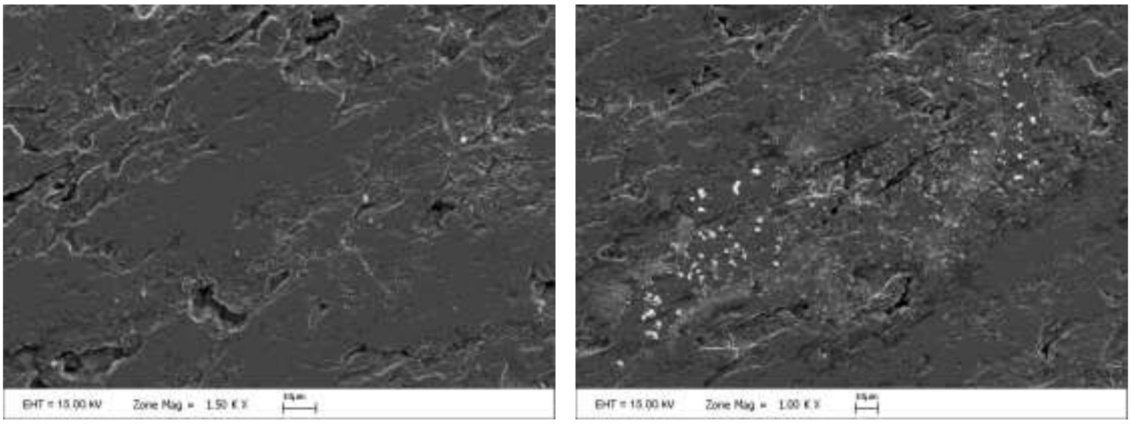
Tensile stress (Mpa) Min	Yield stress % 2 (Mpa) Min	Stretching %50 (mm) Min	Rockwell B (HRB) Max	Brinell (HB) Max
485	170	40	95	217

Table 3. Physical Features of Material 316L [8].

Density (kg/m^3)	Flexibility Factor (Gpa)	Thermo-Expansion Factor μm/m/^{0}C			Thermo Conductivity Factor	Electrical Resistance of Specific Heat		
8000	193	0-100^{0}C	At 100^{0}C	0-315^{0}C	0-538^{0}C	At 500^{0}C	0-100J/kgK	nΩm
		15,9	16,3	16,2	17,5	21,5	500	740

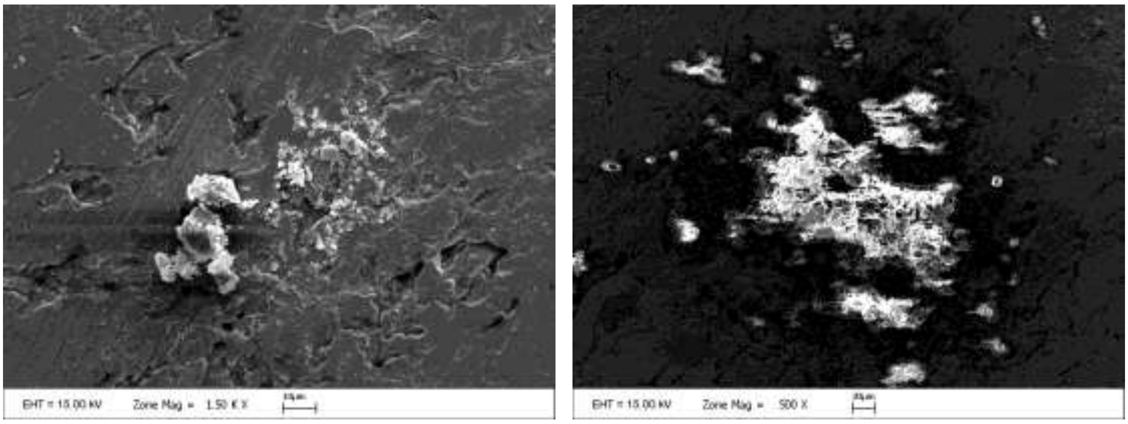
Exterior surface analysis of each sample is performed by examining surface structure with SEM on two parts from different sections of each material, and the structure formed after the test is showed as follows.

SEM FIGURES



(a) (b)

Figure 4. SEM figures of steel 316 coated with golden palladium (a, b)



(a) (b)

Figure 5. SEM figures of steel 316L not coated with golden palladium (a, b)

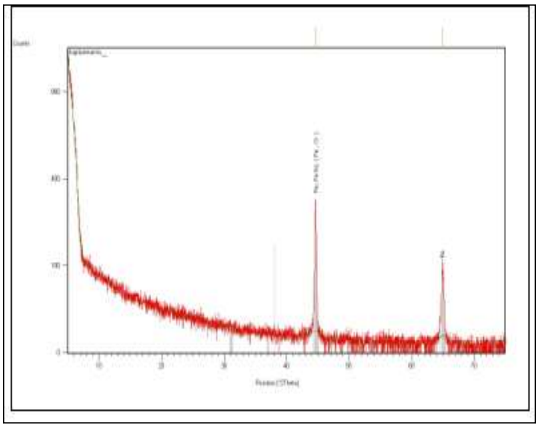


Figure 6: X-RD spectrum figure of the non-coated sample,

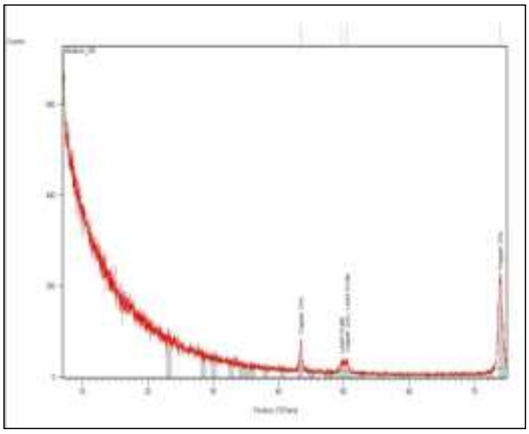


Figure 7:X-RD spectrum figures of the coated sample

CONCLUSION

Besides Ni and Al, stainless steel (316 L) of which bio corrosion behavior is bad, and also its other varieties have been extensively used nowadays. It has been supposed that the detached particles due to abrasiveness and the disintegrated particles due to bio-corrosion are not compatible with body tissue although mechanical behaviors of these material types have been improved. Further researches are required to eliminate the negative features of biomedical materials that are currently used worldwide, in the fields such as abrasion, corrosion and biocompatibility [9].

In this study, it appears that condition of steel 316L sample which was coated with golden palladium has been suffered less corrosive effect than non-coated sample by considering SEM images.

Also, it has been determined that the interaction between biomedical material and biological environment has increased for the coated sample since the roughness formed on surface of the coated sample was proportionally equal.

X-RD spectrum data for coated and uncoated samples (Figure 6.7) are given in. Spectrum peaks is examined. peak value of uncoated sample was less patelliform. Peak value of coated sample is less broad than uncounted sample. As can be seen from here, concluded there is no uniform distance between the layers of uncoated sample.

REFERENCES

[1] (http://www.baskent.edu.tr/~mustafak/BME-201/dokumanlar/biyouyumlulukdoc.pdf., (Accessing Date: 15/09/2010)

[2] SHACKELFORD, J. F., "*Bio-Ceramics-Current Status and Future Trends*", Trans Tech Publication, 103, Switzerland, 1999.

[3] GIL, L., BRÜHL, S., JIMENEZ, L., LEON, O., GUEVARA, R. AND STAIA, M., "*Corrosion Performance of the Plasma Nitrided 316L Stainless Steel*", Surface and Coating Technology, 201, 4424-4429, 2006.

[4] USTA, M., ONEY, I., YILDIZ, M., AKALIN, Y. AND UCISIK, H., "*Nitrating of AISI 316L Surgical Stainless Steel in Fluidized Bed Reactor*", Vacuum, 73, 505-510, 2004.

[5] SHIH, C.C., SHIH, C. M., SU, Y. Y., SU, L. H. J., CHANG, M.S. AND LIN, S. J., "*Effect of Surface Oxide Properties on Corrosion Resistance of 316L Stainless Steel for Biomedical Applications*", Corrosion Science, 46, 427-441, 2004.

[6] ISSI A., A Presentation on "*Characterization Techniques of Historical Findings*", Anadolu University, 2005.

[7] American Society for Testing and Materials, 1992, F139-86, p 61.

[8] www.azom.com, Stainless Steel - Grade 316L - Properties, Fabrication and Applications

[9] AKDOGAN, G., **"**Ti-6Al-4V, Investigation of Alloy Biocorrosion and Biocompatibility Properties," Ph.D. Thesis, page: 133, Ankara, 1999, Turkey.