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Fund “Nauka” Project № 21003 Resume – Competition-Based Session 2021:

“Corrosion of laser treated chromium-nickel stainless steel in biological fluids”

Project leader: Prof. Tsanka Dimitrova Dikova, PhD, DSc

Aim: To study the corrosion in biological fluids of chromium-nickel stainless steel after laser surface treatment.

Tasks:

1. To examine the corrosion on the surface of chrome-nickel stainless steel after laser treatment;
2. To prepare transverse cross-sections for investigation of the microstructure;
3. To study the development of corrosion in depth of the sample.
4. To perform a statistical analysis of the obtained results;
5. To perform a comparative analysis of the corrosion of untreated and laser-melted surface layers of chromium-nickel stainless steel in different biological fluids.

Materials and methods:

The project will deal with investigation of austenitic chrome-nickel stainless steel surface melted with a laser and subjected to corrosion tests in Ringer's solution and artificial saliva with different acidity. The examination will be carried out by:

1. Visual inspection and observation with an optical microscope (OM) on the surface of the samples;
2. Preparation of transverse cross-sections by cutting, grinding, polishing and etching;
3. Study of corrosion in the depth of the laser melted layer by OM;
4. Capturing images with a digital camera;
5. Statistical and comparative analysis of data.

Expected results:

1. To confirm the higher corrosion resistance of the laser melted surface layers of chromium-nickel stainless steel in biological fluids than that of the untreated metal;
2. To clarify the mechanism of corrosion propagation in the depth of the laser melted layers;
3. To formulate prescriptions for the application of laser technologies – welding, cutting and surface melting in the production of implants and dental constructions of chromium-nickel alloys.

Achieved results:

The corrosion in Ringer's solution of chrome-nickel AISI 321 stainless steel after laser surface melting was investigated within the framework of this project. The activities performed are in full accordance with the set goal and tasks. Initially, the corrosion damage on the steel surface was investigated with an optical microscope (OM). Samples were then made by cutting cross-sections, grinding, polishing and etching with a reagent to reveal the microstructure. The development of corrosion cracks in depth was investigated by OM and digital camera. A comparative analysis of the corrosion of untreated and laser-melted layers (LML) of AISI 321 steel in Ringer's solution was made.

A difference was found in the microstructure of the base metal and the laser-melted layer. The microstructure of the base metal consists of coarse-grained austenite with an equiaxed grain shape and delta-ferrite in the form of stripes. The microstructure of LML is more homogeneous and fine-grained with a dendritic morphology, with dendrites consisting of austenite and delta-ferrite in the interdendritic spaces. Numerous corrosion pittings of irregular shape and sizes between 20-100 μm were observed on the surface of the base metal after electro-chemical corrosion tests in Ringer's solution, while pitting on laser-melted surfaces has a random distribution, regular equiaxed shape and larger sizes (50-250 μm). Therefore, the more homogeneous microstructure of LML is a prerequisite for its higher corrosion resistance in Ringer's solution compared to the base metal, which confirms the first hypothesis.

The development of corrosion damage in depth of the base metal occurs along the boundaries of the two austenite-ferrite phases, mainly destroying the delta-ferrite grains. This is the reason why many deep and narrow corrosion cracks are observed. Corrosion damage on the surface of LML occurs along the boundaries of the dendrites, destroying mainly the delta phase. This leads to the formation of corrosion pittings with a larger diameter and smaller depth. In this way, the second working hypothesis regarding the development of corrosion cracks in depth is also confirmed.

Scientific contributions: 1) An optimized methodology for studying the microstructure of a base metal and a laser-melted layer of the same sample has been developed; 2) The development of corrosion damage in depth of base metal and laser melted layer has been established; 3) The conducted studies show that the laser melting of the surface layers of Cr-Ni stainless steel AISI 321 leads to an increase in the corrosion resistance in Ringer's solution. 4) Therefore, such technological processes can be used in the fabrication of dental constructions and implants from AISI 321 steel.

Other contributions:

- The "Laboratory for histomorphometry of solid sections and materialography" at the Faculty of Dental Medicine is equipped with consumables for metallographic studies of the main types of alloys used in implantology, dentistry and general medicine.
- The tasks and activities carried out in this research project are part of the PhD thesis of assist. prof. Natalina Konstantinova Panova from the Department of Physics and Biophysics for acquisition of PhD degree.