Corrosion resistance of sintered AISI 316L–hydroxyapatite biomaterials in Ringer’s solution

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AISI 316L–hydroxyapatite biomaterials were produced by the conventional powder metallurgy technology. In the case of materials such as these, proper and long-term functioning in the aggressive environment of body fluids is very important. Therefore, the purpose of this study was to determine the effect of hydroxyapatite content and sintering temperature on the properties including sintered density, open porosity, and in particular corrosion resistance of AISI 316L–hydroxyapatite biomaterials in Ringer’s solution. The measurement of sintered density and open porosity of studied materials was carried out by the water-displacement method. The corrosion behaviour was studied by open circuit potential measurement and potentiodynamic polarization method. It was stated that the properties of studied biomaterials are dependent on chemical composition of powders mixture and sintering temperature. The results showed that higher sintering temperature ensured to obtain lower values of corrosion current density and corrosion rate, and higher value of polarization resistance. The addition of 5 wt % hydroxyapatite provided to a significant improvement of corrosion resistance in Ringer’s solution in comparison to AISI 316L steel, while a slight decrease in corrosion resistance was observed for AISI 316L–10 wt % hydroxyapatite biomaterials. Passivation ability and better corrosion resistance indicate that sintered at 1240°C AISI 316L–5 wt % hydroxyapatite biomaterials is more appropriate for long-term functioning implants than AISI 316L steel. This biomaterial possessed good densification and the best corrosion resistance among all studied materials, as evidenced by the lowest corrosion current density and corrosion rate combined with the highest polarization resistance.

Key words: biomaterials, AISI 316L, hydroxyapatite, corrosion resistance, powder metallurgy.

1. INTRODUCTION

The lengthening of human lifetime, diseases of old age, increase in the number of accidents increase the demand in implants and significant progress in the medicine and bioengineering of materials results in an enlargement of the biomaterials application area in medicine [1].

Many years of clinical experiences have shown that biomaterials must meet quite high and varied requirements including biocompatibility, but also excellent mechanical properties, corrosion resistance, wear resistance and suitable technological properties [1÷17]. Generally, surgical and also dental implants are made of metals, especially austenitic stainless steels and titanium alloys [1÷29]. Austenitic stainless steels were the earliest adapted for implantation in the human body. They exhibit high mechanical properties, relatively good corrosion resistance and at the same time a low production cost and availability. However, austenitic stainless steels are particularly susceptible to destruction due to the rather high tendency to naturally self-passivate (e.g. in comparison to titanium alloys) and a strong susceptibility to electrochemical corrosion in the environment of body fluids [1, 5, 10, 11, 14÷18, 23, 30]. Moreover, the products of corrosion get to the surrounding tissues and may cause the occurrence of allergic reactions, inflammations or metallosis [3].

Ceramic biomaterials have been arousing the special interest among scientists for a long time. It can be stated that hydroxyapatite (HA) is one of the most investigated bio ceramics [2, 31÷38]. Besides mineral origin hydroxyapatite occurring for example in igneous rocks, metamorphic limestone or phosphate sedimentary rocks, there is also a natural hydroxyapatite (mainly in the bones and teeth of vertebrates) and a synthetic hydroxyapatite. The synthetic hydroxyapatite does not exhibit complete biocompatibility with the human bone and teeth and also it is relatively expensive material. That is why during past years there have been many attempts to obtain the natural hydroxyapatite. The natural hydroxyapatite has the greatest biocompatibility with the tissues of the human body and it is much cheaper in comparison to synthetic HA. Currently, natural hydroxyapatite is prepared from different natural materials, which are the waste eg. in animal husbandry. The examples of such natural materials are: bones of animal (eg. cattle, goats, pigs, sheep), egg-shells, and coral skeletons or even human teeth [31, 33÷38].

It is known that hydroxyapatite exhibits excellent biocompatibility and osteoconductive properties due to similarity of its chemical and mineralogical composition as well as crystallographic structure to the mineral constituents of human bones and teeth [2]. However, hydroxyapatite has low mechanical properties, such as toughness and yield strength. In particular, it should be pointed out low fracture toughness. The value of KIC coefficient of hydroxyapatite ceramic is in the range of 1.1÷1.2 MN m–1/2 (in comparison to KIC = 2÷12 MN m–1/2 for bone) [23]. The low mechanical properties (brittleness and low strength) of ceramic hydroxyapatite impedes its medical applications as long term load-bearing implants [14÷18, 23]. Despite mentioned above weaknesses, hydroxyapatite has been widely used in medicine, especially in dentistry, maxillofacial surgery, orthopedics, otolaryngology and plastic surgery [2, 18, 23, 31÷38]. There are several clinically used forms of HA, i.e. powders (or other particulate forms), solid or porous ceramic blocks and as coatings for metallic prostheses in order to improve their biological properties [2]. Hydroxyapatite can be also an effective reinforcing agent for a metal matrix composite. The combination of high strength and toughness of metals along with very good biocompatibility and corrosion resistance in an environment of body fluids of hydroxyapatite can results in a bioactive material with improved corrosion resistance, but also tribological properties [3÷5, 9÷30, 36÷38].

Based on the literature review [3, 4, 9÷25], it can be stated that the proportions of 316L and hydroxyapatite, the manufacture process influence the properties of composites and enable the design of materials characteristics desirable for use in medicine.

It was found [24] that in the case of 316L–(20, 30%) HA composites HP–HT method led to obtaining a lower corrosion resistance in Ringer’s solution in comparison to conventional powder metallurgy.
techniques what has been confirmed by the higher value of polarization resistance and corrosion potential and lower corrosion current density. Regardless of the method of producing 316L–HA composites had greater corrosion resistance than 316L steel. The highest corrosion resistance (\( R_{\text{polt}} = 57.4 \text{kO} \cdot \text{cm}^2, \ i_{\text{corr}} = 0.0005 \text{mA} \cdot \text{cm}^{-2} \)) was obtained for 316–20% hydroxyapatite composite [11].

The corrosion behaviour of sintered 316L SS–(5, 20 and 50 wt %) HA biocomposites in Ringer’s solution was investigated using electrochemical techniques. These materials were fabricated by mechanical alloying technique, isostatic pressing (200 MPa) and sintering (1200°C, 2 h, vacuum). It was stated that these materials exhibit high corrosion resistant in Ringer’s solution with corrosion current density in the order of \( 10^{-6} \text{A} \cdot \text{cm}^{-2} \). The corrosion resistance decreases with increasing HA content [9].

Also, nickel-free austenitic stainless steel–(0, 5, 10 and 15 wt %) hydroxyapatite biocomposites (produced by mechanical alloying and nitrogen absorption treatment) are passive in Ringer’s solution [7]. The addition of HA caused considerable decrease in the corrosion current density and the shift of the corrosion potential to a more negative value. It was pointed out that corrosion resistance of these composites increased with increasing HA content up to 10%. But further increase of HA content led to decrease of corrosion resistance. The calculated values of polarization resistance were 14 385 and 28 143 Ω⋅cm² for biocomposites with 5% and 10% of HA, respectively. For comparison, the value of \( R_{\text{polt}} \) for nickel-free austenitic stainless steel was 3747 Ω⋅cm².

The previous studies [14–17] related to the influence of hydroxyapatite in the range of 0–15 wt % on sintering behaviour, microstructure and selected properties of sintered AISI 316L–HA biomaterials. The aim of this study was to determine the effect of hydroxyapatite content and sintering temperature on the properties, in particular corrosion resistance of sintered AISI 316L–HA biocomposites in Ringer’s solution.

2. MATERIALS AND METHODS

In this study the following materials were used:

– water atomized powder of AISI 316L austenitic stainless steel (produced by Höganäs) with particles size <150 µm. The chemical composition of AISI 316L is shown in Table 1;

– natural origin hydroxyapatite powder obtained by extracting the cortical part of the long bone of the pig. Procedure of preparation of the natural hydroxyapatite involves the following steps: cooking bone in distilled water, the mechanical removal of tissues and parts of the spongy bone residue, leaching of organic matter by 4 molar sodium hydroxide solution, rinsing in distilled water until a constant pH, drying at 120°C to constant weight, milling [14–17, 31, 33, 35, 36]. The results of quantitative chemical analysis shown that hydroxyapatite powder contained: 17.45% P and 39.51% Ca. The value of Ca/P ratio was 1.75.

Described above powders of AISI 316L steel and hydroxyapatite were used to prepare the following mixtures:

– AISI 316L–5 wt % HA,

– AISI 316L–10 wt % HA.

In addition, pure powder of AISI 316L steel was used to compare results.

In the present study cylindrical samples with a diameter of 20 mm and a height of 5 mm were used. The preparation procedure of these samples included: preparation of powders mixtures, pressing and sintering. The mixing process was conducted in Turbula mixer for 120 minutes. The uniaxial pressing in a rigid matrix was performed at a pressure of 600 MPa. The sintering process took place in Nabertherm P330 (a laboratory tube furnace) in an atmosphere of dry (dew point below −60°C) and high purity (99.9992%) hydrogen. Sintering was performed at two temperatures: 1180°C and 1240°C. The time of isothermal sintering was 60 minutes. The heating rate to the sintering temperature as well as cooling rate to room temperature was 10°C/min.

The measurement of sintered density and open porosity was carried out by the water-displacement method according to the requirements of PN-EN ISO 2738: 2001.

Corrosion studies was performed using Atlas EU & IA 0531 potentiostat with installed Atlascorr05 software. The corrosion resistance of investigated materials was evaluated in Ringer’s solution at a temperature of 37±1°C. The qualitative and quantitative chemical composition of Ringer’s solution is presented in Table 2.

A standard three-electrode system consisting of a working electrode, a reference electrode and a counter electrode was used for the electrochemical study. The reference electrode was a saturated calomel electrode (SCE). As the counter electrode was used a platinum electrode. The working electrode was the cylindrical sample of sintered AISI 316L–hydroxyapatite composites as well as AISI 316L steel. The exposed area of samples was 1.33 cm². The preparation of samples surface included the following steps, grinding up to a 2000 grit, cleaning in ethyl alcohol in an ultrasonic cleaner and compressed-air drying.

Open circuit potential (OCP) measurement and potentiodynamic polarization method were performed to evaluate corrosion behaviour of investigated materials. The open circuit potential was recorded versus time. A period of immersion in Ringer’s solution was 1 hour. When the potential reached a stable value, the potentiodynamic polarization measurement was started by increasing the potential. The potential was increased from −0.8 V up to 0.5 V. The scan rate was 1 mV⋅s⁻¹. The potentiodynamic polarization corrosion test allows to determine parameters such as corrosion potential (\( E_{\text{corr}} \)), corrosion current density (\( i_{\text{corr}} \)), polarization resistance (\( R_{\text{polt}} \)), breakdown potential (\( E_b \)) and passive current density (\( i_{\text{pass}} \)). The polarization resistance was evaluated using linear polarization method (called Stern method) and Tafel extrapolate method (called Stern-Geary method). Based on the ASTM G 102-89:2004, corrosion rate in terms of penetration rate (\( CR \)) and mass loss rate (\( MR \)) were calculated.

Metallographic cross-sections were prepared. The microstructural study of the biomaterials was done with scanning electron microscopy. An EDS analysis was also performed. It allows identification of elements constituting the studied material and points out the differences in chemical composition of observed microstructural constituents. A spectrum of EDS presents a dependence of the number of counts as a function of the radiation energy.

3. RESULTS AND DISCUSSION

In the case of sintered materials which are produced using conventional powder metallurgy technology the corrosion resistance depends on, among other things, porosity. It is known the porosity depends on lots factors like pressing pressure, sintering conditions (mostly temperature and time), as well as size and shape of powder particles. The influence of porosity is associated with increase the
active surface exposed to corrosion. It is estimated that real surface is about two orders of magnitude higher than the apparent surface. Interconnected porosity greatly favours the formation of corrosion cells and then it promotes the onset and development of pits. Furthermore, it should be mentioned about a lack of passivation within the pores of a sintered materials. Therefore, it can be stated that corrosion resistance of sintered materials can be significantly improved through increasing density.

Figure 1 presents the values of sintered density of the investigated materials depending on the sintering temperature and amount of hydroxyapatite introduced into AISI 316L steel. The values of sintered density determined in accordance with the rule of mixtures (square markers) in comparison with the measured density values of studied AISI 316L–HA composites with different weight percent of hydroxyapatite are also presented in Figure 1. The rule of mixtures is commonly known because of its usefulness to predict various properties of composites. It allows to determine theoretical values of properties such as density, elastic modulus, ultimate tensile strength, thermal conductivity, and electrical conductivity. That is why in this study the rule of mixtures was used to evaluate the sintered density of studied composites.

Figure 2 shows the values of open porosity of AISI 316L steel and AISI 316L–hydroxyapatite composites depending on the sintering temperature. Analysis of presented results (Fig. 1 and 2) lead to the conclusion that both the sintering temperature and chemical composition of the powders mixture affects the physical properties of the studied materials. The increase in sintering temperature ranging from 1180°C to 1240°C results in an increase in sintered density and simultaneously decrease in open porosity of all investigated materials, wherein the lowest differences can be observed in the case of sintered austenitic steel. As expected the sintered density decreases with increasing hydroxyapatite content. This dependence may be noted for both sintering temperatures. It is in accordance with the rule of mixtures. Namely, the introduction of reinforcement having lower density to a matrix material with higher density leads to decrease density of composite. However, the values of the theoretical density are higher than the measured values and the difference between them increases with increasing hydroxyapatite content. Only in the case of AISI 316L–5 wt % HA composite (sintered at 1240°C), the values of theoretical and experimental densities are almost the same. As seen in Figure 2, the open porosity increases with increasing hydroxyapatite content. Nevertheless, the sintering process at a higher temperature results in the same values of open porosity of AISI 316L steel and AISI 316L–5 wt % HA composite.

Figure 3 presents the variation of open circuit potential with time for sintered AISI 316L steel and AISI 316L–HA composites. Generally, the open circuit potential determines the thermodynamically stable state of the system. The open circuit potential (OCP) is defined as the potential difference between the anode and cathode at zero current flow. It is an important parameter in corrosion studies as it can indicate the corrosion susceptibility of a material. A more negative OCP indicates greater corrosion tendency. The data presented in Figure 3 show that the OCP values generally decrease with increasing hydroxyapatite content, which is consistent with the decrease in density observed in Figure 1. This trend is more pronounced at higher sintering temperatures, which suggests that the sintering process affects the OCP as well. However, the difference between theoretical and experimental OCP values increases with increasing hydroxyapatite content, which indicates that the sintered density values are higher than the measured OCP values. The OCP values of AISI 316L steel and AISI 316L–5 wt % HA composite (sintered at 1240°C) are almost the same, which is consistent with the results observed in Figure 2.
tendency of a material to electrochemical corrosion reactions with a corrosive medium.

As seen in Figure 3, in the initial period the OCPs of AISI 316L steel and AISI 316L–HA composites increase gradually and then reaches stable values before 1 hour immersion in Ringer’s solution. The values of initial and final OCPs for all materials are equal the lowest and the highest potentials values respectively. It can be observed that the higher sintering temperature, the higher OCP value. The shift of the OCP in the positive values direction suggesting the formation of passive layer on the sample surface. Stable potential value indicates thermodynamic stability of the formed layer and its resistance to chemical degradation in Ringer solution. Such behaviour increases the corrosion resistance of material. Therefore, materials sintered at 1240°C possess higher corrosion resistance. This improvement is supported by a noble shift of open circuit potential.

It was observed for materials sintered at lower temperature that the OCPs values (measured after 1 h immersion in Ringer’s solution) shifted in the negative direction with increasing hydroxyapatite content. It was found that the same dependence for austenitic stainless steel–HA composites in Ringer’s solution [23] what means that hydroxyapatite addition turned the composites less noble. It can be clearly seen that the same tendency was not found for studied materials sintered at 1240°C because AISI 316L–5 wt % HA composite possessed higher OCP value compared to AISI 316L steel.

The polarization curves of AISI 316L stainless steel and AISI 316L–HA composites in Ringer’s solution are presented in Figure 4. The shape of presented polarization curves (cathodic and anodic branches) is similar for all investigated materials. Moreover, in the anodic branch the current density is lower than that in cathodic branch. It was found that for AISI 316L–5 wt % HA composite sintered at 1240°C, cathodic and anodic current densities indicate the lowest values in the definite measuring range. The cathodic branches are related to hydrogen evolution. As regards the anodic branch, it is observed a „plateau” corresponding to the passive region. A strongly increase in anodic current density follows after reaching breakthrough potential. This is due to the formation and development of pits. Shift of breakdown potential in the direction of higher values and the broader range of passivation results in greater corrosion resistance in Ringer’s solution for AISI 316L–5 wt % HA composite sintered at 1240°C.

Corrosion current density, corrosion potential, polarization resistance, breakdown potential and passive current corrosion were determined and the values of these parameters are shown in Table 3 for all studied materials. Table 4 presents calculated values of corrosion rate in the form of CR and MR parameters.

Table 3. The values of corrosion potential (E_corr), corrosion current density (i_corr), polarization resistance (R_pol), breakdown potential (E_b) and passive current corrosion (i_pass) for sintered AISI 316L stainless steel and AISI 316L–HA composites

<table>
<thead>
<tr>
<th>Sintering temperature</th>
<th>E_corr [V]</th>
<th>i_corr [A·cm⁻²]</th>
<th>R_pol [Ω·cm²]</th>
<th>E_b [V]</th>
<th>i_pass [A·cm⁻²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>AISI 316L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1180</td>
<td>-0.380</td>
<td>3.18·10⁻³</td>
<td>1640</td>
<td>2423</td>
<td>0.002</td>
</tr>
<tr>
<td>1240</td>
<td>-0.441</td>
<td>1.67·10⁻³</td>
<td>2873</td>
<td>4364</td>
<td>0.048</td>
</tr>
</tbody>
</table>

Based on analysis of data contained in Tables 3 and 4, it can be concluded that the values of corrosion parameters such as: the corrosion potential, the corrosion current density, polarization resistance and corrosion rate depend on material composition as well as the sintering temperature. For all studied materials, higher temperature of sintering process ensured to obtain lower values of corrosion current density and corrosion rate. The lowest values of i_corr, CR and MR parameters were obtained in the case of AISI 316L–5 wt % HA composite, while AISI 316L–10 wt % HA composite exhibited the highest values of these parameters. A similar dependency can also be observed in the case of polarization resistance. It means, the higher the sintering temperature, the higher the value of R_pol. Moreover, AISI 316L–5 wt % HA composite reached the highest value of polarization resistance, while the lowest R_pol value was found for AISI 316L–10 wt % HA. AISI 316L–5 wt % HA composite also possessed the highest E_corr value and the higher sintering temperature shifted the corrosion potential in the direction of positive values. Likewise, the breakdown potential shifted in the positive direction with increasing sintering temperature. It indicates a lower susceptibility to pitting. The most positive value of E_corr was found for AISI 316L–5 wt % HA composite.

Based on the results of potentiodynamic polarization method it can be stated that sintered at 1240°C temperature AISI316L–5 wt % HA composite reached the highest corrosion resistance in Ringer’s solution. It was confirmed by the highest value of polarization.

Table 4. The values of CR and MR parameters characterizing the corrosion rate in Ringer’s solution of the AISI 316L steel and AISI 316L–HA composites

<table>
<thead>
<tr>
<th>Material</th>
<th>Sintering temp. [°C]</th>
<th>CR [mm·y⁻¹]</th>
<th>MR [g·cm⁻²·(μA·m⁻²)⁻¹]</th>
</tr>
</thead>
<tbody>
<tr>
<td>AISI 316L</td>
<td>1180</td>
<td>0.40</td>
<td>0.71</td>
</tr>
<tr>
<td>1240</td>
<td>0.20</td>
<td>0.37</td>
<td></td>
</tr>
<tr>
<td>AISI 316L–5 wt % HA</td>
<td>1180</td>
<td>0.02</td>
<td>0.04</td>
</tr>
<tr>
<td>1240</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>AISI 316L–10 wt % HA</td>
<td>1180</td>
<td>0.96</td>
<td>1.43</td>
</tr>
<tr>
<td>1240</td>
<td>0.80</td>
<td>1.26</td>
<td></td>
</tr>
</tbody>
</table>
The comparable values of corrosion parameters (for example, $i_{corr} = 6.7 \times 10^{-2}$ A cm$^{-2}$, $E_c = 0.214$ V vs SCE, $E_{corr} = -0.229$ V vs SCE) were found for 316L–5 wt % HA composite which was produced (using the hydroxyapatite prepared by wet precipitation method) by mechanical alloying technique, isostatically pressing and sintering at 1200°C for 2 h [9]. A decrease in corrosion resistance was observed for AISI 316L–10 wt % HA composite, regardless of sintering temperature. It was reflected in the lowest value of polarization resistance and the highest values of corrosion rate and corrosion current density.

The composition of powders mixture as well as the sintering temperature affects the sintered density and open porosity, and thus the corrosion resistance of studied materials.

Because the microstructure evaluation of studied materials was presented elsewhere [14–17], an exemplary microstructure of surface is shown in Figure 5.

The results of EDS microanalysis are presented in Figures 6a–d. As seen, the spectrum (Fig. 6c) reveals the presence of elements such as iron, chromium and nickel. They are the main elements of AISI 316L stainless steel chemical composition. While the spectrum in Figure 6d shows peak indicating the presence of phosphorus. Obviously, peaks pointing out the presence of iron, chromium and nickel are also here. It means that the phosphorus diffused from hydroxyapatite into the austenitic matrix (during sintering process). It is known that hydroxyapatite is a calcium phosphate. Based on the results of EDS analysis (presented in Figures 6a and b), it can be stated that the elements such as oxygen and calcium are present in points 1 and 2, but the peaks from phosphorus are very small. The spectrums reveals also peaks from chromium. This is associated with decomposition of hydroxyapatite and some reaction between the elements.

The influence of hydroxyapatite content and sintering temperature on properties such as density, porosity and corrosion resistance was evaluated. The corrosion behaviour of these materials in Ringer’s solution was studied by open circuit potential measurement and potentiodynamic polarization method.

It can be concluded that higher temperature of sintering process results in the better densification and greater corrosion resistance for all studied materials. Among all studied materials, AISI 316L–10 wt % HA composite possessed the lowest sintered density (and relative density) and simultaneously the highest open porosity.

4. CONCLUSION

AISI 316L-hydroxyapatite biomaterials were produced by conventional powder metallurgy technology comprising the following steps: preparing the mixture of AISI 316L steel and natural origin hydroxyapatite powders, pressing in the rigid matrix and then sintering.

The influence of hydroxyapatite content and sintering temperature on properties such as density, porosity and corrosion resistance was evaluated. The corrosion behaviour of these materials in Ringer’s solution was studied by open circuit potential measurement and potentiodynamic polarization method.

It can be concluded that higher temperature of sintering process results in the better densification and greater corrosion resistance for all studied materials. Among all studied materials, AISI 316L–10 wt % HA composite possessed the lowest sintered density (and relative density) and simultaneously the highest open porosity.

While, almost the same values of open porosity as well as relative density were found for AISI 316L steel and AISI 316L–5 wt % HA composite. All investigated materials showed the passive behaviour. Compared to the sintered AISI 316L stainless steel, AISI 316L–5 wt % HA composite biomaterial (with similar open porosity) exhibited a significant improvement of corrosion resistance in Ringer’s solution, while a slight decrease in corrosion resistance was observed for AISI 316L 10 wt % HA composite. Such dependency was found for each of the sintering temperature. Thus, the highest corrosion resistance in Ringer’s solution possessed AISI 316L–5% HA biomaterial sintered at 1240°C temperature. This was confirmed by following corrosion parameters: the greatest values of polarization resistance, corrosion potential and breakdown potential, and the lowest values of corrosion current density and corrosion rate. Whereas, AISI 316L–10 wt % HA composite had the worst corrosion resistance because of the highest corrosion current density and corrosion rate combined with the lowest polarization resistance.

REFERENCES


Opporność na korozję spiekanych biomateriałów AISI 316L–hydroksyapatyt w roztworze Ringera

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Słowa kluczowe: biomateriały, AISI 316L, hydroksyapatyt, odporność na korozję, metalurgia proszków.

1. CEL PRACY

W przypadku biomateriałów właściwe i długotrwałe funkcjonowanie w agresywnym środowisku płynów ustrójowych jest bardzo ważne. Austenityczne stałe nierdzewne przy dobrych właściwościach mechanicznych wykazują jednak znaczną podatność na korozję elektrochemiczną, natomiast hydroksyapatyt charakteryzuje się bardzo dobrą biogododnością i odpornością na korozję. Wprowadzenie dodatku hydroksyapatytu może wpłynąć na poprawę odporności korozjowej, biogododności, ale także właściwości tribologicznych stali AISI 316L. W pracy dokonano oceny odporności na korozję w roztworze Ringera spiekanych biomateriałów AISI 316L–hydroksyapatyt. Ponadto określono gęstość i porowatość otwartą otrzymanych materiałów. Na podstawie przeprowadzonych badań potencjodynamicznych i wyznaczonych parametrów korozyjnych określono wpływ zawarty hydroksyapatytu i temperatury spiekania na odporność na korozję badanych materiałów.

2. MATERIAŁ I METODYKA BADAŃ