International Journal of Engineering Applied Sciences and Technology, 2024
Vol. 9, Issue 01, ISSN No. 2455-2143, Pages 173-176
Published Online May 2024 in IJEAST (http://www.ijeast.com)

ENHANCEMENT OF HYDROXYAPATITE-ZIRCONIA (10 WT %) COMPOSITE MICROWAVE CLADDING ON SS-316L

Himanshu Basotra, Shivdev Singh
Mechanical Engineering Department,
Sri Sai College of Engineering and technology,
Badhani Pathankot 145001, India

Shivinder Singh, Sahil Sharma
Mechanical Engineering Department,
Chandigarh Engineering College,
CGC-Jhanjeri, Mohali-140307, India

Abstract: **Microwave processing of materials is fundamentally different from traditional techniques. In microwave processing, energy is directly transferred to the material through interaction of electromagnetic waves with molecules leading to volumetric heating. This leads to higher heating efficiency with faster processing. In case of microwave heating, it is the absorption of the microwave energy followed by volumetric heating involving a conversion of electromagnetic energy into thermal energy. The present work is based upon the fabrication of HA+10wt% ZrO_2 cladding on the SS-316L substrate by using Microwave Hybrid Heating (MHH) technique. The 10% weight proportions of the hard particle are considered as optimum proportions of the reinforcement in the HA powder. It can be founded that average micro hardness value of SS-316L substrate was improved by 9.75%, 13.17%, 27.80% and 56.09% respectively at as-deposited, heat treated temperatures. The in-vitro test conducted in the simulated body fluid (SBF) condition reveals the formation of apatite layer on the clad specimens at all conditions.**

Keywords: **Microwave energy, Microhardness, Microwave hybrid heating**

I. INTRODUCTION

The industries are looking forward to new and enhanced processing techniques that may be used for a wide range of materials, including ceramics, metallic, non-metallic, and composites, in the context of rapidly developing technologies and competitive technical advancements. Researchers have focused on processing techniques that use less power and processing time while producing high-quality results as a result of the push to reduce environmental degradation and increase energy efficiency in processing methods [1-2]. Due of the peculiarities of microwaves, scientists have been investigating the possibilities of microwave heating in different fields. Microwaves have numerous significant benefits when it comes to heating operations [3-4]. The process of microwave heating is difficult when processing large quantities of metallic materials because of its low energy usage, high heating rates, and quick processing periods. The main benefits of microwave processing for bulk materials include superior microstructure, extremely low defect rates, increased efficiency with lower energy consumption, and lower heating costs when compared to traditional heating methods. Lin et al. [5] have targeted on process of chemical compound layers by the microwave plasma system on a medicine stainless-steel substrate. In plasma reactorAST-MW1200W the layers of nitride were obtained by the means of exploitation. A steady 700W of microwave radiation at a frequency range of 2.45GHz was used to create the microwave plasma. Bansal et al. [6] have administrated the butt joining of alloy 718 plates by taking nickel powder of mesh size 0.2 millimeters in the interface layer. The 900-watt power range of the home microwave was used to administer the method of change of integrity. The researchers discovered that the faying surfaces were solidly bonded and consolidated with reasonable scientific discipline bonding on each side of the base material after using a variety of characterisation techniques. Zafar and Sharma [7] explained the development of two WC–12Co based clad powders with particle sizes in the region of micrometric and nanometric on austenitic stainless steel using MHH. The nanometric clads form dendrites like structure and cluster of carbide which is uniformly distributed in metallic matrix. Das and Shukla [8] examined the coatings of HA on high nitrogen stainless steel (254SS) for orthopedic implant applications by use of the pulsed laser deposition technique. The pulsed laser deposition process was used to improve the physiological response of 254SS. Scanning electron microscopy and atomic force microscopy were used to analyse the surface morphology of the deposited hydroxyapatite coatings, and X-ray diffraction was used to evaluate the phase composition of the deposited hydroxyapatite coatings. Singh et al. [9] investigated the use of a low-cost microwave method for Inconel-625 based cladding on a mild-steel (MS) substrate. Cladding was done using an industrial microwave running at 2.45 GHz and 1.2 kW. The XRD observation shows that the fusion zone microstructure of the clad specimen contains Laves and inorganic compound phases in addition to a mostly face-centered-cubic (fcc) matrix based on Ni, Cr, and Fe. An even and dense microstructure with a consistent distribution of hard carbides in the soft matrix is revealed by the microstructural characterization.

Problem Formulation

Based on the literature survey, it has been found that microwave clad specimen exhibits superior mechanical properties than thermal spray and laser clad specimens. Therefore, it can be concluded that the formation of pure HA and reinforced HA+10wt%ZrO2 cladding on the metallic bio-implant may be effectively achieved by utilizing the principles of microwave hybrid heating. The detailed data on the structure-property-correlation of bio-implant cladding provide the new solution to provide superior mechanical and biocompatibility properties to the metallic bio-implant.

The objective of present investigation is to use the principles of microwave hybrid heating (MHH) approach to generate reinforced Hydroxyapatite (HA+10wt%ZrO2) cladding on surgical grade low carbon austenite stainless steel (SS-316L). Furthermore, investigation has been done to examine as-sprayed and heat-treated composite coatings for comparison in terms of mechanical and micro-structural characteristics.

II. MATERIAL AND METHODOLOGY

SS-316L was taken as a substrate material in the present investigation for enhancing its bioactivity by using HA+10wt%ZrO_2 powder. The actual chemical compositions (wt%) of base material used in the present investigation is illustrated in table 1. Hydroxyapatite (HA) powder has been selected as coating material because of its bio-compatibility and resemblance with the main phase present in the bone. The 10% weight proportions of the hard particle are considered as optimum proportions of the reinforcement in the HA powder.

Table 1. Actual chemical composition (wt%) of SS-316L as determined by using spark spectroscopy.

Element	**Cr**	**Ni**	**Mo**	**C**	**Mn**	**P**	**S**	**Si**	**N**	**Fe**
wt%	17.5	13.7	2.8	0.025	1.8	0.04	0.03	.52	0.1	Balance

Therefore, 10wt% ZrO_2 was taken as optimum percentage as a reinforcement in the HA based powder for the surface modification of the SS-316L substrate material by using hybrid microwave heating approach. The desired powder is obtained after the addition of 90 wt% HA and 10 wt% ZrO_2 in the clad powder. For the preparation of clad from substrate material, spraying of reinforced powder (90wt% HA + 10wt%ZrO_2) on the workpiece material (SS 316L substrate) take place.

In the present investigation, a clad specimen was subjected to an annealing treatment in a muffle furnace for two hours at 400°C, 600°C, and 800°C. The specimen is then prepared to cool down for two hours at room temperature. These specimens of clad are cut by the wire EDM for further investigation of microstructure through Field emission scanning electron microscopy (FESEM/EDS).

III. RESULTS AND DISCUSSION

Using a household multimode microwave oven operating at 2.45 GHz, composite clads of HA+10wt%ZrO2 have been effectively produced on SS-316L substrate in the current investigation. The clads were created at a power level of 900W via the Microwave Hybrid Heating (MHH) process. FESEM along with EDS revealed about the surface morphology and elemental composition of HA+10% ZrO_2 clad powder. The size particle of HA powder was nearly about 15-30µm and the size particle of Zirconia powder was nearly about 2-10µm by visually seen in figure 1**.** The elemental compositions in wt% of the powders (HA and ZrO_2) is given at spectrum 1, and spectrum 2 respectively..

International Journal of Engineering Applied Sciences and Technology, 2024
Vol. 9, Issue 01, ISSN No. 2455-2143, Pages 173-176
Published Online May 2024 in IJEAST (http://www.ijeast.com)

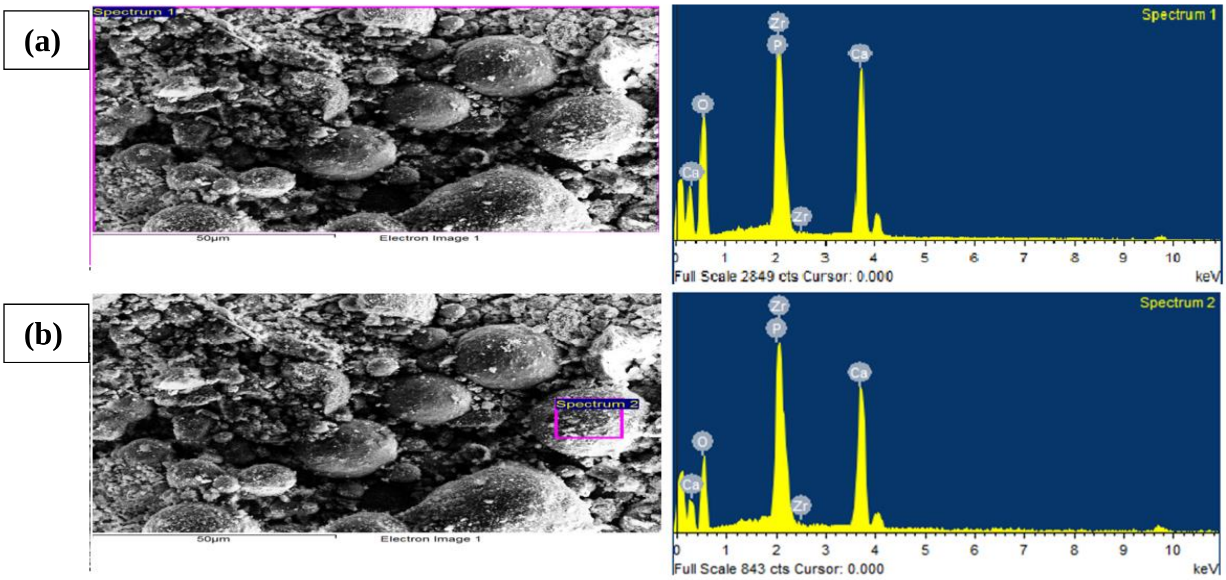

Figure 1. FESEM with EDS of HA+10% ZrO_2 clad powder at (a) Spectrum 1 (b) Spectrum 2.

It has been observed that the weight % of zirconia has increased by 6% in the spectrum 2 along with reduction in the wt% of oxygen by 6% in the same spectrum 2. Element maps are also necessary for showing distribution of different elements in textural context, particularly for displaying compositional zonation. Line mapping is shown to determine the distribution of elements over selected line inside the SEM image in figure 2.

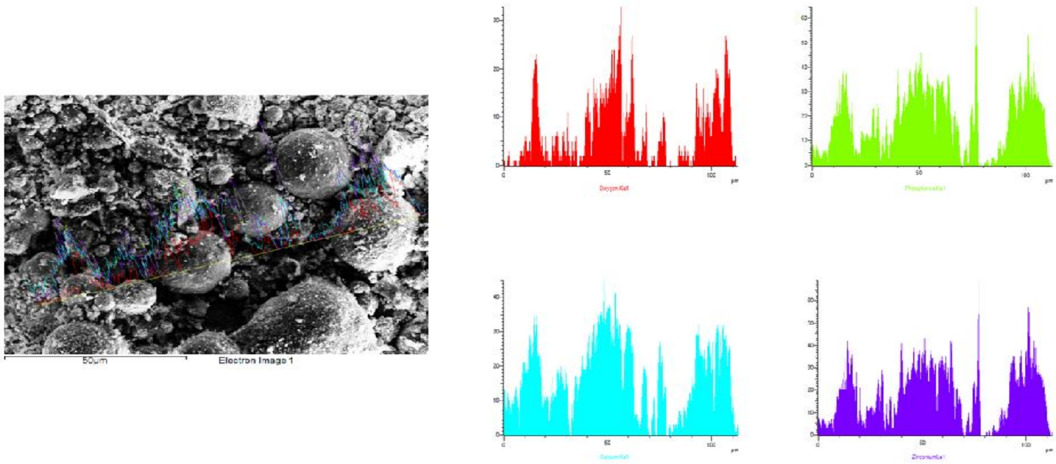

Figure 2. Line mapping of HA+10% ZrO_2 clad powder.

Microhardness

The Micro Vickers Hardness Tester was used to conduct the microhardness investigation. As seen in figure 3, the average microhardness values at the SS-316L substrate, as-deposited, annealed at 400˚C, 600°C, and 800°C were determined to be 205 ± 18 HV, 225 ± 16 HV, 232 ± 14 HV, 262 ± 12 HV, and 320 ± 10 HV respectively. It has been founded that average microhardness of SS-316L substrate was improved by 9.75%, 13.17%, 27.80% and 56.09% respectively at as-deposited, heat treated 400°C, 600°C and 800°C temperatures. The average microhardness value more at 800˚C (320 ± 10 HV) due to fully melted structure. Microhardness values rise with little variation during the annealing temperature as a result of clad densification, porosity reduction, and microstructural changes.

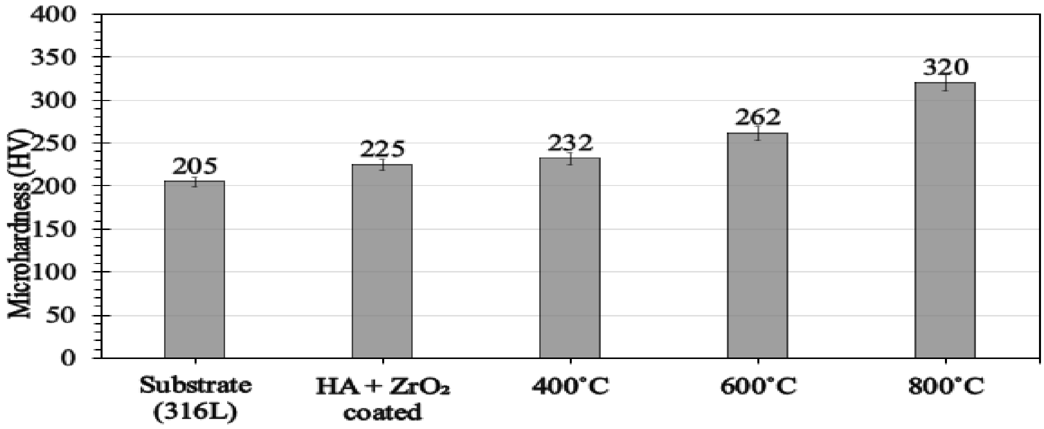

Figure 3. Substratum microhardness (SS-316L), as-deposited and annealed specimens at 400°C, 600°C, and 800°C

IV. CONCLUSIONS

1.) The HA+10% wt. ZrO_2clad was successfully developed using domestic microwave hybrid heating technique at 2.45 GHz frequency and 900W power on the SS-316L substrate surface.

2.) The FESEM analysis reveals the partial dilution of substrate with clad powder by line mapping.

3.) The microhardness analysis indicates that clad densification and microstructural changes cause the microhardness value to increase on the clad surface as the annealing temperature rises.

V. REFERENCES

[1]. D. Wang, C. Song, Y. Yang, and Y. Bai, “Investigation of crystal growth mechanism during selective laser melting and mechanical property characterization of 316L stainless steel parts,” Materials & Design, vol. 100, pp. 291–299, Jun. 2016, doi: 10.1016/j.matdes.2016.03.111.

[2]. D. S. Gomes, A. M. C. Santos, G. A. Neves, and R. R. Menezes, “A brief review on hydroxyapatite production and use in biomedicine,” Cerâmica, vol. 65, no. 374, pp. 282–302, Jun. 2019, doi: 10.1590/0366-69132019653742706.

[3]. S. Singh, D. Gupta, V. Jain, and A. K. Sharma, “Microwave Processing of Materials and Applications in Manufacturing Industries: A Review,” Materials and Manufacturing Processes, vol. 30, no. 1, pp. 1–29, Jan. 2015, doi: 10.1080/10426914.2014.952028.

[4]. M. Oghbaei and O. Mirzaee, “Microwave versus conventional sintering: A review of fundamentals, advantages and applications,” Journal of Alloys and Compounds, vol. 494, no. 1–2, pp. 175–189, Apr. 2010, doi: 10.1016/j.jallcom.2010.01.068.

[5]. L.-H. Lin, S.-C. Chen, C.-Z. Wu, J.-M. Hung, and K.-L. Ou, “Microstructure and antibacterial properties of microwave plasma nitrided layers on biomedical stainless steels,” Applied Surface Science, vol. 257, no. 17, pp. 7375–7380, Jun. 2011, doi: 10.1016/j.apsusc.2011.01.065.

[6]. A. Bansal, A. K. Sharma, P. Kumar, and S. Das, “Joining of Mild Steel Plates Using Microwave Energy,” AMR, vol. 585, pp. 465–469, Nov. 2012, doi: 10.4028/www.scientific.net/AMR.585.465.

[7]. S. Zafar and A. K. Sharma, “Dry sliding wear performance of nanostructured WC–12Co deposited through microwave cladding,” Tribology International, vol. 91, pp. 14–22, Nov. 2015, doi: 10.1016/j.triboint.2015.06.023.

[8]. A. Das and M. Shukla, “Surface morphology, bioactivity, and antibacterial studies of pulsed laser deposited hydroxyapatite coatings on Stainless Steel 254 for orthopedic implant applications,” Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications, vol. 233, no. 2, pp. 120–127, Feb. 2019, doi: 10.1177/1464420716663029.

[9]. G. Singh, H. Vasudev, A. Bansal, S. Vardhan, and S. Sharma, “Microwave cladding of Inconel-625 on mild steel substrate for corrosion protection,” Mater. Res. Express, vol. 7, no. 2, p. 026512, Feb. 2020, doi: 10.1088/2053-1591/ab6fa3.