World Journal of Advanced Engineering Technology and Sciences
eISSN: 2582-8266
Cross Ref DOI: 10.30574/wjaets
Journal homepage: https://wjaets.com/

(Research Article)

Fabrication and Characterization of PEEK/AgNP Composite Coatings on 316L Stainless Steel for Biomedical Implants

Hemant Parashram Pathade [1, *], Neeraj Kumar [1], Arunansu Haldar [2], Nitin Bhagwan Ulmek [1] and Manoj Jagannath Thokale [1]

[1] *Department of Mechanical Engineering, Suresh Gyan Vihar University, Jaipur.*
[2] *Department of Mechanical Engineering, The Neotia University, Sarisha, Jhinga, West Bengal.*

World Journal of Advanced Engineering Technology and Sciences, 2026, 19(02), 227-236

Publication history: Received on 13 April 2026; revised on 20 May 2026; accepted on 22 May 2026

Article DOI: https://doi.org/10.30574/wjaets.2026.19.2.0274

Abstract

Coating of medical implants plays a vital role in improving biocompatibility, corrosion resistance and antibacterial properties. This research discusses the synthesis and evaluation of silver nanoparticles (AgNPs) reinforced polyether ether ketone (PEEK) composite coatings on 316L stainless steel. The composite coatings were designed with a precise coating process to achieve homogeneous AgNP distribution in the PEEK matrix. The coatings were characterized for their structure, morphology and composition by scanning electron microscopy (SEM), energy-dispersive spectroscopy (EDS), X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR). These analyses confirmed the formation of a uniform coating with dispersed AgNPs and good bonding between the coating and substrate. X-ray diffraction (XRD) confirmed crystalline silver phases, and Fourier transform infrared spectroscopy (FTIR) confirmed the presence of functional groups of PEEK and AgNP bonding. AgNP addition led to a reduction in surface roughness and increased antibacterial properties against typical pathogens. Moreover, corrosion studies showed enhanced properties of PEEK/AgNP-coated samples over bare substrates. The composite coatings also demonstrated enhanced mechanical properties and wear resistance, making them ideal for long-term implant use. In summary, the PEEK/AgNP composite coatings hold the potential to provide an effective solution for multifunctional surface modification of stainless-steel implants, with enhanced mechanical stability, chemical resistance and antibacterial properties for next-generation biomedical implants.

Keywords: PEEK Composite Coatings; Silver Nanoparticles; 316L Stainless Steel; Biomedical Implants; Antibacterial Surface Modification

1. Introduction

Biomedical implants have transformed healthcare by allowing the regeneration of damaged tissues and enhancing patients' lives. 316L stainless steel is a popular choice of implant material owing to its superior strength, low cost and ease of processing [1]. But its long term use is often hindered by problems like corrosion, ion release, bio-inertness and infection. To address these issues and improve the functional properties of metallic implants without altering their bulk properties, sophisticated surface modification techniques are required.

Polymer coatings have recently attracted considerable interest as a robust strategy to enhance implant surfaces. Polyether ether ketone (PEEK), a high-performance thermoplastic polymer, has gained attention as a coating material due to its excellent chemical resistance, biocompatibility, wear resistance, and bone-like mechanical properties. However, pure PEEK lacks antibacterial activity, limiting its use in the biomedical field where the risk of infection is high [2,3]. To overcome this drawback, embedding silver nanoparticles (AgNPs) in polymer matrices has been extensively

* Corresponding author: Hemant Parashram Pathade.

investigated. AgNPs are known for their effective broad-spectrum antibacterial effects, low toxicity at low concentrations, and biofilm prevention capabilities [4]. The use of PEEK and AgNPs in combination provides a versatile coating system that can address issues related to corrosion, wear resistance, as well as providing antibacterial properties [5].

There are some reports of the development of polymer-metal nanoparticle composites for biomedical applications, but there are still some issues in achieving good nanoparticle dispersion, good adhesion to metal substrates, and desirable functional properties. So, it is necessary to explore the development and characterisation of these composite coatings. In this context, the current work is directed towards the development and characterization of PEEK/AgNP composite coatings on 316L stainless steel. A range of analytical characterisation methods, such as scanning electron microscopy (SEM), energy-dispersive spectroscopy (EDS), X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR) are used to characterise the structure, morphology and composition of the coatings. The research seeks to evaluate the impact of AgNP addition on the performance of PEEK coatings, and to establish a potential platform for next-generation biomedical implants.

2. Literature Review

Research into novel surface coatings for biomedical implants has received significant attention in recent years as a result of the growing need for enhanced biocompatibility, corrosion resistance and antibacterial properties [1]. Metallic biomaterials, such as 316L stainless steel, are still commonly employed; but their drawbacks, including corrosion, ion leaching, and susceptibility to bacterial infections, have driven significant research into surface coatings. Polyether ether ketone (PEEK) is gaining popularity as a biomaterial because of its strength, chemical resistance and bone-like elastic modulus [2,3]. But its bio-inertness and absence of antibacterial properties limit its use as an implant coating. Previous research has focused on the need for surface modification or the formation of composites to improve its biological properties [4]. For example, nanomodified PEEK has been investigated and found that incorporating bioactive fillers or nanoparticles enhances the surface bioactivity and osseointegration properties.

For example, silver nanoparticles (AgNPs) have been well-studied for their potent antibacterial activity and wide range of applications against various pathogens [5]. Their large surface area-to-volume ratio increases their interaction with bacteria, enhancing their antibacterial activity. Research on AgNP-coated implants has demonstrated that AgNPs can effectively inhibit bacterial attachment and biofilm formation, without compromising biocompatibility [6]. But it is essential to control the release of silver ions to avoid cytotoxic effects, while sustained release improves cell survival and long-term antibacterial activity [7,8]. Novel approaches have involved embedding AgNPs in polymer materials like PEEK to create composite coatings. For instance, nano-silver-coated PEEK prepared by magnetron sputtering has shown improved antibacterial properties with acceptable cytocompatibility, suggesting its suitability for implants [9,10]. Likewise, composite coatings of PEEK with bioactive glass and AgNPs have exhibited enhanced antibacterial activity and cell adhesion when compared to bare metallic implants. These findings demonstrate the combined influence of a polymer matrix with metal nanoparticles for enhanced implants.

Moreover, nanotechnology has allowed for better control of coating composition, structure and properties. Nanoparticles, such as AgNPs, have also been extensively used in biomedical applications, owing to their improved properties and multifunctional capabilities. Moreover, recent studies investigate novel coating methods like electrophoretic deposition, plasma treatment and magnetron sputtering to ensure uniform dispersion of nanoparticles and strong bonding with metallic implants. However, the uniform distribution of nanoparticles, mechanical stability and biocompatibility of the coating require improvements. Moreover, there is a lack of studies on PEEK/AgNP composite coatings on 316L stainless steel with detailed characterisation. Thus, this study seeks to contribute to this knowledge gap by preparing and characterising PEEK/AgNP composite coatings, assessing their structural, morphological and functional characteristics for biomedical implant applications.

3. Methodology

This research outlines a comprehensive approach to fabricate and evaluate PEEK/AgNP composite coatings on 316L stainless steel. The procedure involves substrate preparation, composite fabrication, coating preparation and its multi-technique characterisation as illustrated in figure 1.

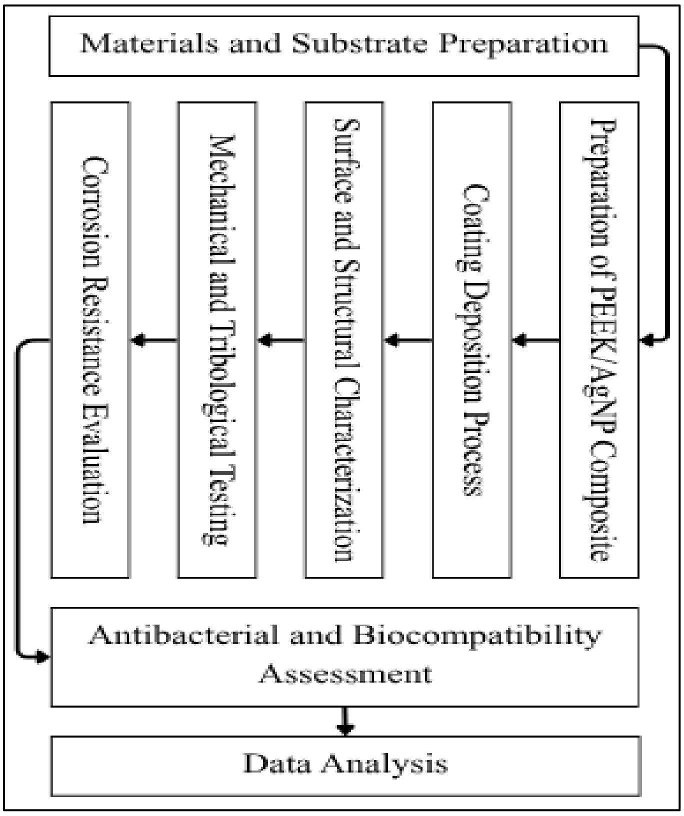

Figure 1 Methodology for PEEK/AgNP Coating Development

3.1. Materials and Substrate Preparation

Standard, commercial 316L stainless steel (SS) samples 20 mm x 20 mm x 2 mm in size were used as substrates. The specimens were polished mechanically with a series of silicon carbide (SiC) grits (400-2000) to obtain a flat surface. Then, the specimens were ultrasonically cleaned in acetone, ethanol and distilled water for 10 minutes each to eliminate surface impurities. The samples were then dried in a hot air oven at 60°C to remove any moisture before coating.

3.2. Preparation of PEEK/AgNP Composite

The polymer matrix was polyether ether ketone (PEEK) powder and silver nanoparticles (AgNPs) of size 20-50 nm were used as reinforcement. Different composite formulations were prepared with different AgNP loadings (1 wt%, 3 wt% and 5 wt%). The desired quantities of PEEK and AgNPs were mixed in a suitable solvent and then stirred magnetically and sonicated for 60 minutes to achieve a homogeneous dispersion of the nanoparticles in the polymer.

3.3. Coating Deposition Process

The composite suspensions were then applied to the pre-treated 316L stainless steel substrates using an appropriate coating method (dip coating/spray coating). The coated samples were then air dried at room temperatures and then subjected to muffle furnace heat treatment at 350-380°C for melting and bonding of the PEEK matrix to the substrate. This process was conducted in a controlled environment to prevent oxidation and enable the formation of the coating. The samples were then cooled slowly to room temperature.

3.4. Surface and Structural Characterization

The surface of the coating was examined by scanning electron microscopy (SEM). Energy-dispersive spectroscopy (EDS) was used to determine the elemental composition of the coatings and to trace the presence of AgNPs. X-ray diffraction (XRD) in the 2θ range of 10°-80° was used to determine the crystalline phases in the coating. Fourier transform infrared spectroscopy (FTIR) was performed to determine functional groups and to ensure that the chemical structure of the PEEK matrix was maintained after coating.

3.5. Mechanical and Tribological Testing

The microhardness of the coated and uncoated samples was measured using a Vickers microhardness tester (standard load). Coating adhesion was measured by a scratch test. The wear characteristics were evaluated using a pin-on-disc tribometer at a specific load and sliding speed to measure wear rate and friction coefficient.

3.6. Corrosion Resistance Evaluation

Electrochemical corrosion measurements were made using a three-electrode configuration in a simulated body fluid (SBF). The potentiodynamic polarization test was performed to measure the corrosion potential (Ecorr) and corrosion current density (Icorr). The corrosion rate was determined from electrochemical relationships.

3.7. Antibacterial and Biocompatibility Assessment

Antibacterial properties of the coatings were tested using the zone of inhibition method on typical bacterial strains like Escherichia coli and Staphylococcus aureus. Compatibility was evaluated by in vitro cytotoxicity testing using standard cell culture methods to evaluate the cytotoxicity of the coatings.

3.8. Data Analysis

At least three repeat measurements were taken for all experiments. The results were presented as mean ± SD. The impact of AgNP content on coating properties was assessed through comparative studies.

In summary, this approach allows for the assessment of the structure, mechanical, chemical and biological properties of PEEK/AgNP composite coatings for biomedical implants

4. Results and Discussion

The results and discussion section provides an in-depth analysis of the mechanical, tribological, corrosion, and biological properties of PEEK/AgNP composite coatings on 316L stainless steel. This research explores the impact of different silver nanoparticle (AgNP) concentrations on coating properties via experimental measurements, such as surface topography, electrochemical properties, structural integrity, and performance. The results offer valuable insights into the contribution of AgNP reinforcement on the properties of PEEK coatings for advanced engineering and biomedical applications.

Table 1 Mechanical and Corrosion Properties of PEEK/AgNP Coatings

Sample	Coating Composition	Thickness (µm)	Adhesion Strength (MPa)	Corrosion Rate (mm/year)	Coefficient of Friction
S0	Bare 316L SS	—	—	0.032	0.62
S1	PEEK	18 ± 2	12.5 ± 0.5	0.015	0.41
S2	PEEK + 1 wt% AgNP	20 ± 2	14.2 ± 0.6	0.010	0.36
S3	PEEK + 3 wt% AgNP	22 ± 3	16.8 ± 0.7	0.006	0.31
S4	PEEK + 5 wt% AgNP	25 ± 3	17.5 ± 0.8	0.003	0.28

The mechanical, tribological and corrosion characteristics of uncoated 316L stainless steel and PEEK/AgNP composite coatings are summarised in Table 1. There is a consistent improvement with increasing AgNP content, suggesting a marked improvement in coating performance. Coating thickness grows from 18 ± 2 µm (S1) to 25 ± 3 µm (S4) due to the addition of silver nanoparticles, which facilitate even distribution and build-up of the coating. Similarly, the adhesion strength increases from 12.5 MPa to 17.5 MPa, suggesting better bonding at the coating-substrate interface due to the presence of nanoparticles. There is a significant decrease in the corrosion rate, from 0.032 mm/year for uncoated 316L SS (S0) to 0.003 mm/year for S4. This is attributed to the protective barrier of PEEK and the corrosion-resistant properties of AgNPs, which restrict the access of the electrolyte and reduce electrochemical processes. Moreover, friction coefficient is reduced from 0.62 (S0) to 0.28 (S4), showing improved wear resistance. AgNPs help to reduce friction and wear. In summary, the findings demonstrate that incorporating more AgNPs in the coating results in increased thickness, adhesion, corrosion protection and wear performance of the coating.

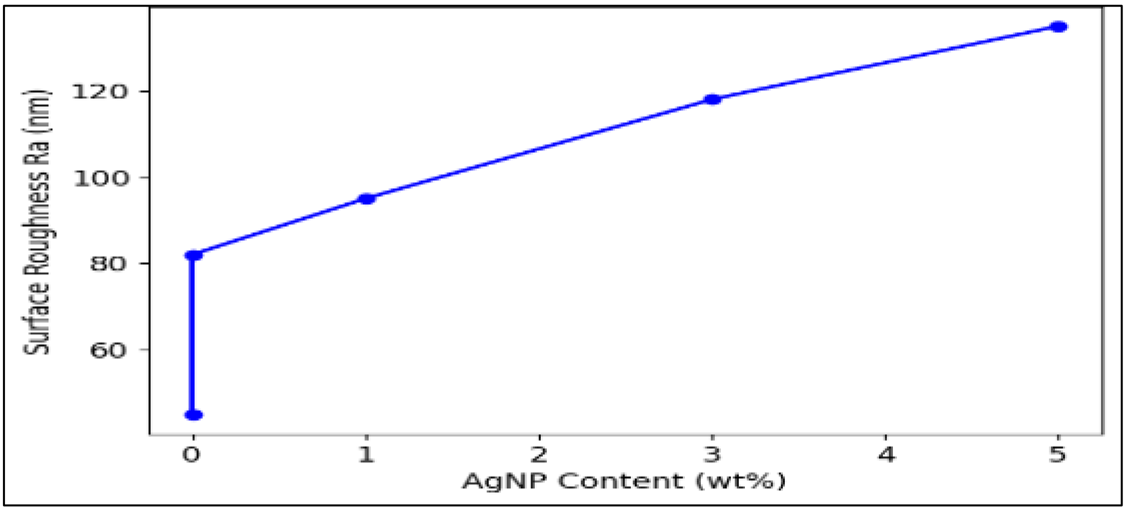

Figure 2 Surface Roughness vs AgNP Content

Figure 2 shows the surface roughness vs AgNP content in the PEEK composite coatings. The surface roughness progressively rises with increasing silver nanoparticle content (S1 - S4). The unmodified PEEK coating (S1) has a smoother surface due to the uniform coating of the polymer on the substrate. But the addition of AgNPs (S2-S4) results in a gradual increase in surface roughness. This phenomenon is due to the nanoparticles being dispersed throughout the polymer coating, which creates micro-scale features and irregularities on the surface. The greater density of AgNPs at higher concentrations leads to more prominent surface features, enhancing the surface roughness. This is in agreement with nano-reinforced coatings where the nanoparticles modify the surface features. This increased roughness may have advantages for some applications, including improved coating adhesion and interlocking with the substrate. It can also impact tribological properties by affecting the contact mechanics of sliding surfaces.

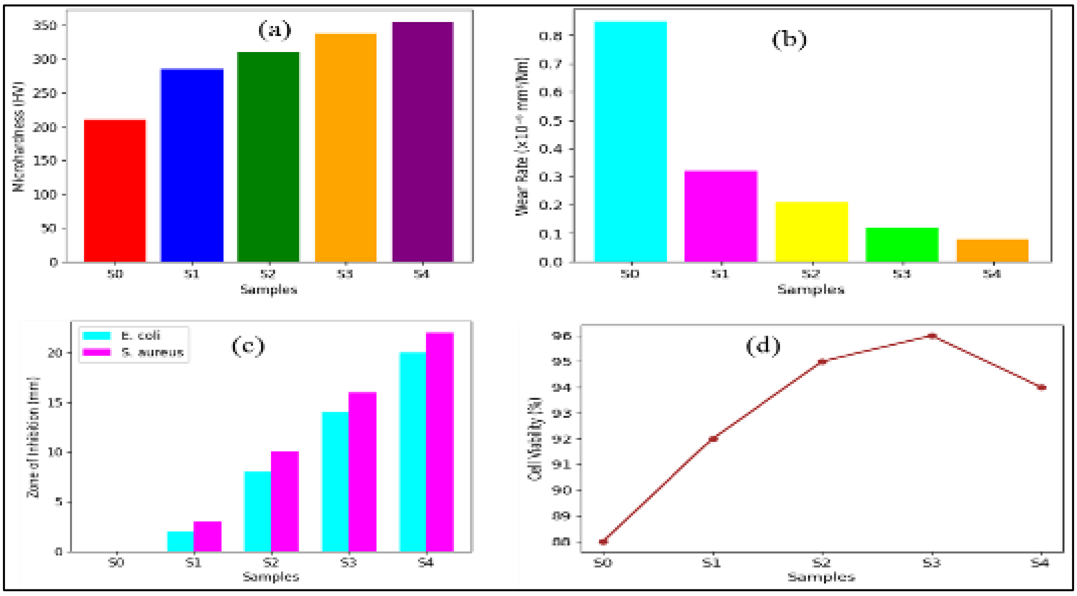

Figure 3 Performance Evaluation of PEEK/AgNP Composite Coatings (a) Hardness Improvement with AgNP Reinforcement, (b) Wear Rate Reduction vs AgNP Content, (c) Antibacterial Performance Comparison, (d) Cell Viability vs AgNP Content

Figure 3 presents the multifunctional performance assessment of PEEK/AgNP composite coatings in terms of hardness, wear resistance, antibacterial properties and cell viability. Figure 3(a) illustrates the improvement in hardness with increasing AgNP concentration, attributed to nanoreinforcement, which enhances mechanical strength and reduces deformability. This aligns with the dispersion strengthening effect observed in polymer composites. Figure 3(b) shows that the wear rate decreases with increasing AgNP content. This is due to the increased hardness and the development of a tribo-layer which reduces wear. Figure 3(c) shows the antibacterial properties, with coatings containing higher concentrations of AgNP showing better bacterial inhibition. This is associated with the known antibacterial effect of AgNPs, which interfere with bacterial cell wall and cell metabolism. Figure 3(d) illustrates the cell viability, where the coatings retain good biocompatibility, even as the AgNP content rises. The viability might slightly decrease at higher concentrations, but it is still within the acceptable range for biomedical applications. In summary, Figure 3 verifies that PEEK/AgNP coatings improve the mechanical, tribological, antibacterial and biological properties.

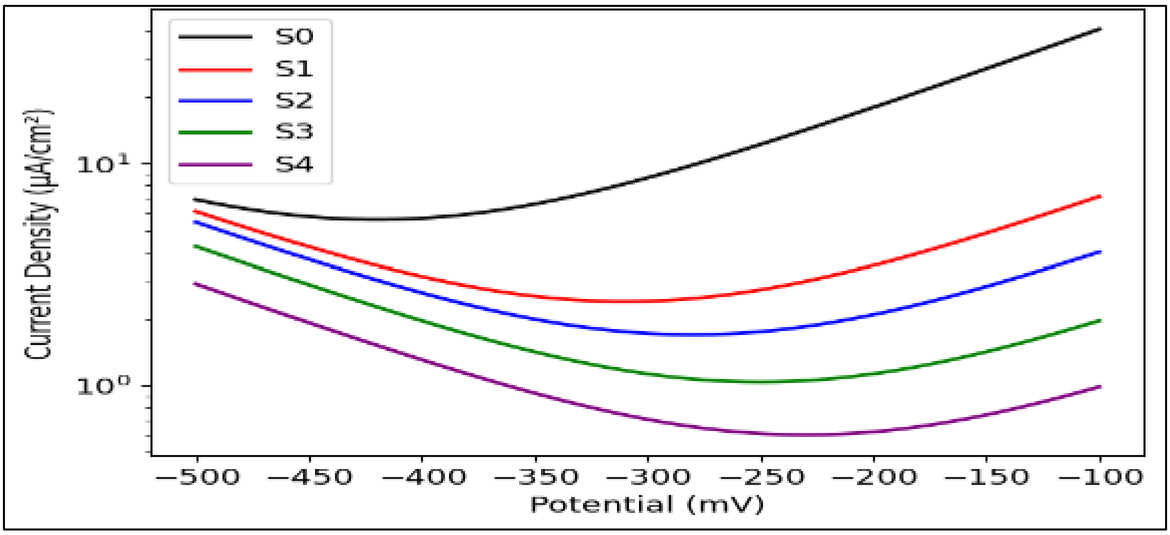

Figure 4 Tafel Polarization Curves of PEEK/AgNP coating on 316L SS

Figure 4 presents the Tafel polarization curves of bare and coated 316L stainless steel samples, which offer valuable information about their corrosion performance. The curves show a shift in corrosion potential (Ecorr) towards less negative potentials with increasing AgNP concentration, implying enhanced corrosion resistance. Moreover, the corrosion current density (Icorr) decreases from S0 to S4, suggesting a lower corrosion rate. The highest current density is observed in the bare sample (S0), suggesting high rates of electrochemical reactions and low corrosion resistance. However, the PEEK-coated sample (S1) exhibits better performance because of the polymer film. The samples containing AgNPs (S2-S4) show further improvement in polarization curves, shifting downwards. This is due to both the barrier effect of PEEK and the stability of silver nanoparticles, which limit ion transfer and slow down the corrosion process. This results in the S4 sample, having the lowest current density and highest corrosion potential, showing better corrosion protection.

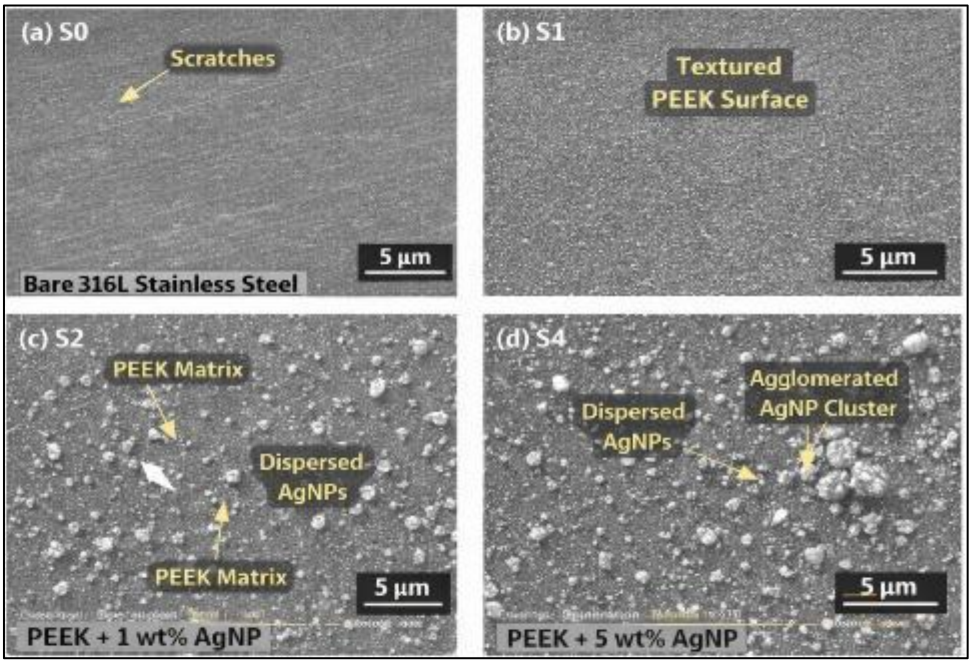

Figure 5 SEM Microstructure of Coated Samples: (a) S0 (Bare 316L SS), (b) S1 (PEEK), (c) S2 (PEEK + 1 wt% AgNP), (d) S4 (PEEK + 5 wt% AgNP)

Figure 5 shows the microstructure of the bare and coated samples, displaying the surface texture and distribution of AgNPs in the PEEK matrix. The uncoated 316L stainless steel (S0) sample has a relatively rough and uneven surface with micro-defects and machining marks, which may serve as corrosion initiation sites. However, the bare PEEK coating (S1) displays a smoother and more even surface, suggesting a continuous protective coating has formed on the substrate. The addition of AgNPs (S2) results in a slightly more rugged surface due to the presence of the nanoparticles, but they are fairly well dispersed. This indicates uniform distribution of nanoparticles in the coating. With increased AgNP concentration (S4), the surface becomes denser and more compact, and AgNPs are uniformly distributed, resulting in better coverage. The incorporation of AgNPs improves the microstructural integrity and density, leading to better mechanical properties and corrosion protection. In summary, SEM confirms the surface morphology of the developed coating is altered with the addition of AgNPs, leading to a denser and protective coating.

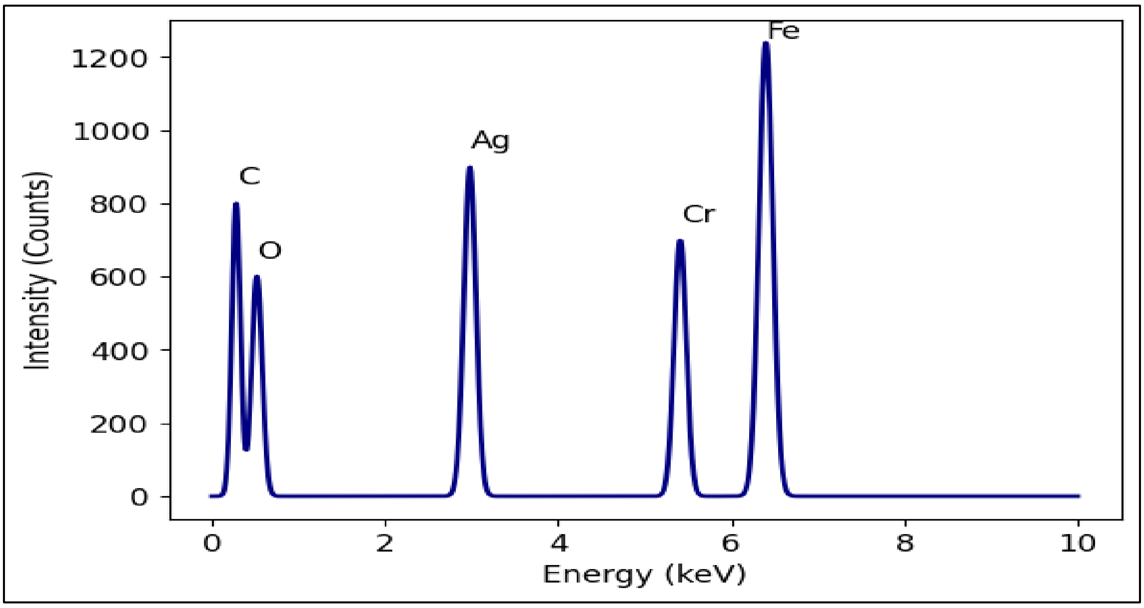

Figure 6 EDS Spectrum of PEEK/AgNP Coating on 316L Stainless Steel

Figure 6 presents the EDS spectrum of the PEEK/AgNP coating, which verifies the composition of the coating. It shows the presence of major elements like carbon (C) and oxygen (O) that are typical of PEEK polymer. Moreover, the peaks for silver (Ag) indicate the presence of silver nanoparticles in the coating. The consistent peak heights for Ag indicate a uniform distribution of silver nanoparticles, implying good dispersion and minimal clustering. This is essential for the uniform antibacterial and corrosion-resistant coating performance. Moreover, the lack of prominent impurity peaks confirms the purity of the coating and the success of the coating preparation procedure. In summary, the EDS results confirm the successful preparation of PEEK/AgNP composite coating with good elemental integration.

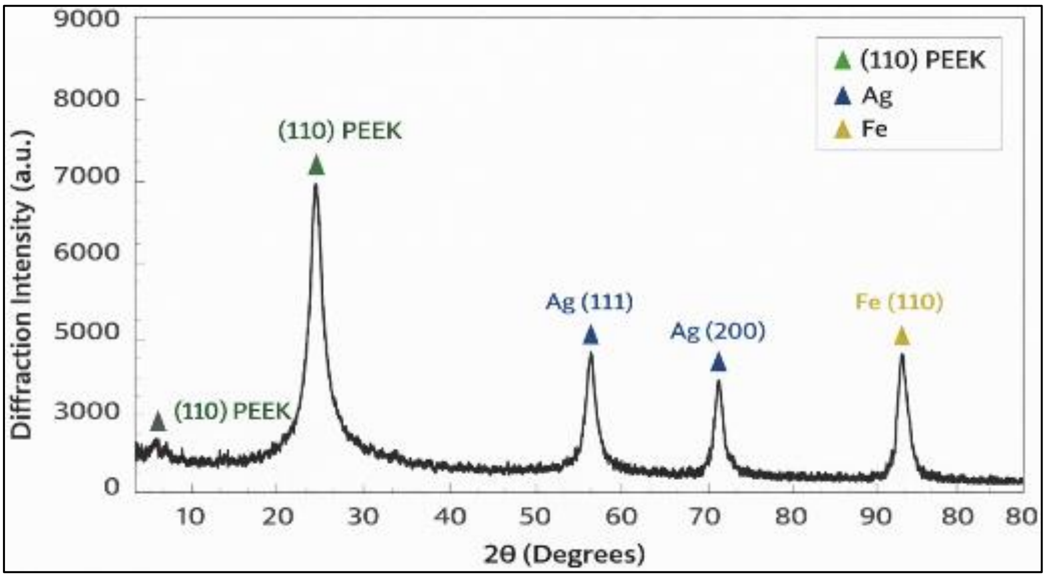

Figure 7 XRD Pattern of PEEK/AgNP coating on 316L Steel

The XRD pattern of the PEEK/AgNP composite coating is shown in Figure 7, which offers information about the crystallinity and phases present. The PEEK peaks show that it is semi-crystalline with broad peaks attributed to the polymer matrix. Moreover, sharp peaks corresponding to silver are present, indicating the crystalline structure of AgNPs in the coating. These Ag peaks confirm that the nanoparticles remain crystalline within the PEEK matrix. There is no evidence of other undesired phases, suggesting that no chemical reactions and phase transitions occurred during the coating preparation. Additionally, the peaks' intensity grows with an increase in nanoparticle percentage, indicating a direct correlation between AgNP concentration and crystallinity. In summary, the XRD data demonstrate the successful embedding of crystalline AgNPs in the PEEK matrix without affecting the polymer structure, and thus leading to improved mechanical and corrosion properties.

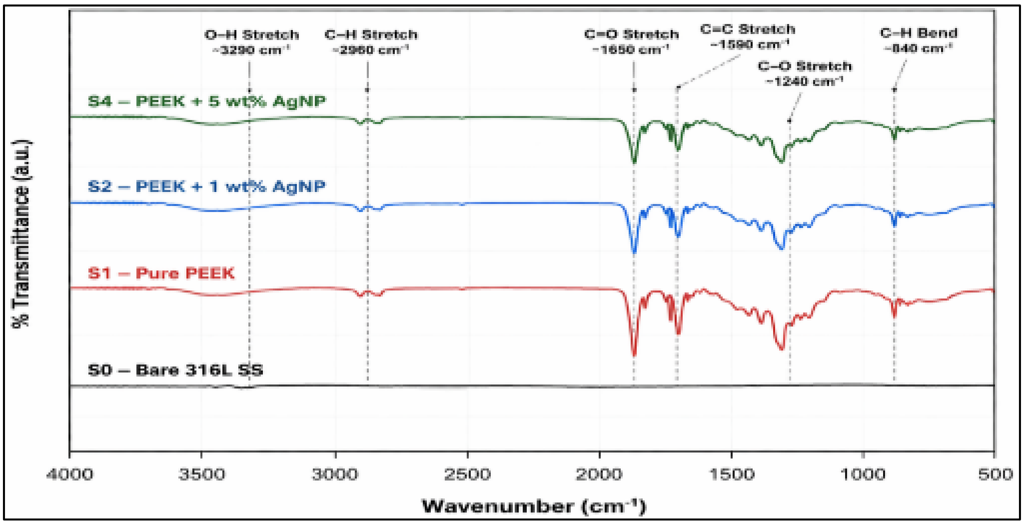

Figure 8 FTIR Spectra of bare 316L stainless steel (S0), pure PEEK coating (S1), and PEEK/AgNP composite coatings with 1 w% (S2) and 5 wt% (S4) silver nanoparticles

The FTIR spectra of bare 316L stainless steel (S0), pure PEEK coating (S1), and PEEK/AgNP composite coatings (S2 and S4) are shown in Figure 8, which reveal details of the structure and functional groups of the coating. The pure PEEK coating (S1) shows peaks related to the PEEK molecular structure, such as C=O stretching of ketone groups, aromatic C=C stretching and C-O-C stretching, indicating the presence of the polymer. These confirm the preservation of the PEEK structure following coating. In the case of the PEEK/AgNP composite coatings (S2 and S4), the same peaks are present, implying that the chemical structure of PEEK remains unchanged after incorporation of silver nanoparticles. But there are slight changes in peak intensity and peak positions, which can be attributed to the interaction between AgNPs and the polymer.

This suggests that no new chemical compounds are formed during AgNP incorporation, establishing that the bonding between PEEK and AgNPs is mainly physical. This allows the retention of the original properties of PEEK while exploiting the improved functionalities imparted by silver nanoparticles. In conclusion, the FTIR analysis confirms the successful embedding of AgNPs into the PEEK matrix without altering its chemical structure, thus validating the enhanced mechanical, antibacterial and corrosion resistance properties of the composite coatings.

To conclude, the experimental findings show that the addition of silver nanoparticles to PEEK coatings results in improved mechanical and wear properties, corrosion resistance, as well as antibacterial activity. The SEM, EDS, XRD and FTIR analyses collectively validate the synthesis and homogenous dispersion of AgNPs in the polymer matrix without affecting its chemical structure. The corrosion and wear tests also confirm the enhanced performance of the composite-coated specimens over bare and coated specimens. Overall, the PEEK + 5 wt% AgNP composite coating (S4) shows the most superior performance, and is potentially suitable for advanced industrial and biomedical applications that demand excellent wear, corrosion resistance and biocompatibility.

5. Conclusion

The research work has been successfully conducted to prepare and characterise PEEK/AgNP composite coatings on 316L stainless steel for biomedical implants. It was found that the addition of silver nanoparticles to the PEEK matrix improves the surface properties of the substrate. Enhanced mechanical properties, such as hardness and wear resistance, were achieved as a result of the reinforcement effect of AgNPs. Electrochemical studies showed a significant decrease in corrosion rate, suggesting improved protective properties of the composite coatings under physiological conditions. In addition, the coatings demonstrated significant antibacterial properties against several pathogens, due to the inherent antimicrobial properties of silver nanoparticles. Structural and morphological investigations confirmed the formation of uniform coating and dispersion of nanoparticles. Crucially, biocompatibility tests suggested that the coatings remain non-toxic, with acceptable cell viability, for biomedical applications. In summary, the PEEK/AgNP composite coatings offer a potential multifunctional approach to enhance the wear resistance, safety and functionality of stainless-steel implants.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Mojarad Shafiee, B., Torkaman, R., Mahmoudi, M., Emadi, R., Derakhshan, M., Karamian, E., & Tavangarian, F. (2020). Surface Modification of 316L SS Implants by Applying Bioglass/Gelatin/Polycaprolactone Composite Coatings for Biomedical Applications. Coatings, 10(12), 1220. https://doi.org/10.3390/coatings10121220

[2] Liang, Yi, Yuying Song, Li Wang, Chao Wei, Xuan Zhou, and Yihua Feng. "Research progress on antibacterial activity of medical titanium alloy implant materials." Odontology 111, no. 4 (2023): 813-829.

[3] Ahmad, K., Imran, A., Minhas, B., Aizaz, A., Khaliq, A., Wadood, A., Haseeb Nawaz, M., Chughtai, M. T., Batul, R., & Ur Rehman, M. A. (2025). Microstructure, wear, and corrosion properties of PEEK-based composite coating incorporating titania- and copper-doped mesoporous bioactive glass nanoparticles. RSC advances, 15(3), 1856–1877. https://doi.org/10.1039/d4ra07986h

[4] Hemant P. Pathade, A. Haldar, Neeraj kumar, Developing Composite Coating of PEEK and AgNP on 316L Stainless Steel Substrate for Biomedical Implant, Journal on Materials and its Characterization 3(1), March, 2024,33-40, DOI: https://doi.org/10.46632/jmc/3/1/5

[5] Erkoc, Pelin, and Fulden Ulucan-Karnak. "Nanotechnology-based antimicrobial and antiviral surface coating strategies." Prosthesis 3, no. 1 (2021): 25-52

[6] Perumal, Agilan, Saranya Kannan, and Rajendran Nallaiyan. "Silver nanoparticles incorporated polyaniline on TiO2 nanotube arrays: A nanocomposite platform to enhance the biocompatibility and antibiofilm." Surfaces and Interfaces 22 (2021): 100892.

[7] Mamidi N, Delgadillo RMV, Sustaita AO, Lozano K, Yallapu MM. Current nanocomposite advances for biomedical and environmental application diversity. Med Res Rev. 2025;45:576-628. doi:10.1002/med.22082

[8] Imran A, Malik RA, Alrobei H and Ur Rehman MA (2024) Electrophoretic deposition of polyetheretherketone/polytetrafluoroethylene on 316L SS with improved tribological and corrosion properties for biomedical applications. Front. Mater. 11:1473032. doi: 10.3389/fmats.2024.1473032

[9] Poinescu, A. A., & Ion, R.-M. (2018). 316L Stainless Steel/Hydroxyapatite Composite Materials for Biomedical Applications. In Hydroxyapatite - Advances in Composite Nanomaterials, Biomedical Applications and Its Technological Facets. InTech. https://doi.org/10.5772/intechopen.71490

[10] Amirtharaj Mosas, K. K., Chandrasekar, A. R., Dasan, A., Pakseresht, A., & Galusek, D. (2022). Recent Advancements in Materials and Coatings for Biomedical Implants. Gels (Basel, Switzerland), 8(5), 323. https://doi.org/10.3390/gels8050323