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ABSTRACT:

A Critical Review on the Properties and Microstructure of Thermal Sprayed Coated Substrate Surface for biomedical Applications

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In the field of surface engineering and depositions techniques, plasma spray coatings have been vital, as these offer unique combination of mechanical and, thermal insulation, wear and corrosion resistance, and other desirable surface properties. Plasma spray coatings are useful in surface treatment, improved surface functionalization, nanostructured coatings, and multifunctional coatings. However, several limitations must be overcome while using plasma spray coatings in biomedicine and healthcare applications, including biocompatibility, tissue toxicity, homogeneity, adhesion and delamination, cost-effectiveness and scalability, porosity control, and compliance. Different models of plasma spray coatings have been explored to enhance their biocompatibility, mechanical properties, and overall performance.

In this category belong novel medically-oriented metals, polymers, composites, and ceramics.

Several surface functionalization methods were developed to improve PS coatings by incorporating bioactive substances, growth factors, or antibacterial agents. Ceramic, cermet, and metal coatings prepared on various substrates—metals, plastics, and ceramics with the help of a versatile spraying technology—plasma. The high-temperature plasma melts the powder materials, which are then rapidly deposited onto a substrate. A plasma spray may be used to apply coatings of various thicknesses, porosities, and surface roughness according to the requirements of the envisaged application. Plastazote coatings are used in orthopaedic, dental, spinal, and trauma

care. Titanium – hydroxyapatite (HA) coatings available in different thicknesses, surface phases, and properties are excellent biomaterials for dental implants, providing high-performance coatings on joint implants, which may be significantly enhanced using ion implantation. Normally, plasma spraying and cold spraying are done at lower temperatures and onto a metallic substrate. However, some attempts have recently been made to deposit Ti on a polymer surface such as polyetheretherketone (PEEK) using the above processes. Ti powders are melted and quickly sprayed on the substrate with the TPS method; this is accomplished by melting the powder and feeding it into a stream of plasma.

The plasma spray coatings can be applied in tissue integration and healing and used to eliminate the danger of infections regarding implanted devices. Nanotechnology utilized in plasma spray enables the generation of surfaces with better adhesivness, controlled medicinal chemicals release, and elevated surface area, among other improved characteristics. As a result, coatings with nanoparticles or nanostructured materials were developed to attain excellent functionality. Numerous researchers are making efforts in developing the plasma spray coatings having a wide range of improved characteristics such as better mechanical properties, tissue regeneration, anti-bacterial, and drug delivery. The general purpose of the PS coatings is in fabrication of biomedical implants. Coating deposition, thickness, and composition can now be more precisely controlled with the help of advancements in PS technology. Various coating process such as high-velocity oxy-fuel (HVOF) spraying, atmospheric plasma spraying (APS), and suspension plasma spraying (SPS) provide better density, homogeneity, and adhesion to irregularly shaped substrates.

Rapid development of novel materials and functional additives has posed more challenging to ensure the compatibility of plasma spray coatings. To analyse possible harmful effects and tissue reactions to the coatings, thorough biocompatibility evaluations are needed to be explored more comprehensively. For complex-shaped implants or large-scale production, it is very tough to achieve uniformity and regulate porosity in plasma spray coatings. The coating's density, thickness, and porosity can impact the implants' mechanical integrity and performance. Biomedical implants cannot remain stable and effective in long term without proper coating-substrate adherence. Under physiological conditions, there is still a need to improve adhesion strength while minimizing the danger of delamination or coating failure.

Biomedical coatings present unique problems for researchers and scientists in meeting regulatory criteria such as sterilization validation, biocompatibility testing, and compliance with international standards (e.g., ISO 10993). It is crucial for clinical translation and commercialization to ensure safety and efficacy while navigating regulatory channels. The scalability and cost-effectiveness of plasma spray coatings for large-scale biomedical applications are key factors to consider, even with technological breakthroughs. The most pressing issues confronting the sector right now are the optimization of production processes,

the reduction of material waste, and the optimization of production costs—all without sacrificing quality. Addressing these challenges while leveraging recent advancements in plasma spray coating technology holds the potential to further enhance the performance, reliability, and clinical impact of biomedical implants and devices. Collaboration between researchers, clinicians, industry stakeholders, and regulatory agencies is essential to drive innovation and accelerate the translation of these advancements into clinical practice.
For the future prospective, the plasma spray coatings are at present might be useful in biomedical applications however there are many obstacles in this field. Improving patient outcomes and progress the area of biomedical engineering can be achieved through encouraging communication and cooperation among researchers, physicians, industry stakeholders, regulatory agencies, and ourselves.

Keywords: Thermal Spray techniques; Advanced surfaces; Microstructure; Biomedical engineering