coatings

Editorial

Special Issue: Surface Modification of Engineering and Functional Materials

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The ongoing development of both engineering and functional materials is leading to new requirements in terms of their surface properties. In most cases, a special coating or surface modification is required to improve mechanical characteristics or to protect the material from external conditions [1,2]. To date, there are a lot of methods to solve these problems on the macro-, micro-, and nanoscale levels. The impact on the surface of nanoparticles or nanostructured materials is usually chemical or electrochemical [3,4], and is often aimed at changing functional properties: absorption [5], drug delivery abilities [6], biocompatibility [7], etc. An understanding of the interface properties between bulk material and the coating or modified surface layer, along with their morphology, is the basis for the improvement of existing methods of surface modification and the development of new ones.

In recent years, special attention has been paid to the additive manufacturing of various metallic details, since modern techniques have provided unprecedented opportunities in terms of shape and structure design [8]. One of the most common additive techniques dealing with metallic materials is selective laser melting or laser powder bed fusion. This technique uses a metallic powder with spherical particles as feedstock and represents layer-by-layer melting under laser irradiation according to the 3D CAD model. Selective laser melting is characterized by ultra-high cooling and solidification rates, leading to a fine grain structure. As a rule, 3D-printed material is harder and stronger than casted material. However, a non-equilibrium structure that could contain meta-stable phases results in increased the chemical activity and poor protective properties of the surface. Thus, the coating and surface modification of additively manufactured materials is a separate scientific challenge, especially when dealing with complex shapes such as spatial lattices and other porous materials. Since the use of objects such as heat exchangers, implants, membranes, filters, etc., shows outstanding potential from the perspective of the development of reliable experimental methods, protecting them from the environment is of great importance.

The surface modification and coating of feedstock materials (powders, fibers, etc.) further used for synthesis (powder metallurgy, additive manufacturing, spraying, etc.) could be highlighted as a promising direction for investigation. Core–shell-type particles, the modification of reinforcement for stronger adhesion/bonding, grain boundary and interparticle infiltration, and other approaches have shown impressive results, both for construction and functional materials [9,10]. Most previous investigations dealing with composite materials and core–shell particle creation used spherical particles of matrix metallic powder and coated them with different phases, such as ceramics, nano-fibers, and thin layers. Such approaches gave significant results compared with the simple mechanical mixing of matrix and reinforcing powders, but insufficient wettability and the inhomogeneous distribution of reinforcement usually occur. The difference in laser absorption coefficients, thermal properties, and morphology between reinforcing particles and matrix material often leads to the increased porosity of metal matrix composites. The presence

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of porosity, which acts as a stress concentrator, resulted in the lower mechanical performance of the manufactured parts, limiting the advantages of additive manufacturing and encouraging further research into the design of powder feedstock.

Thus, another promising direction of investigation is metallic coating formation around reinforcing particles, especially nanoparticles, obtaining near-spherical powder suitable for selective laser melting [11]. Such particles coated by the same metal or alloy with matrix should provide excellent matrix-reinforcement wettability and improved bonding, leading to low porosity and improved properties. Additionally, such a prior coating method can minimize the interfacial reaction between reinforcing particles and the matrix metal, leading to defect-free 3D printing with the uniform distribution of particulates. Among potential methods for achieving this coating are physical vapor deposition, electrolysis plating, and chemical vapor deposition. The synthesis of composite materials from such feedstock powder should lead to a significant strengthening of lightweight alloys such as aluminum, titanium alloys, etc., which is still one of the main scientific tasks to be addressed in additive manufacturing nowadays. To this end, investigations of approaches allowing the creation of such coatings and spherical feedstock powders are of great interest, as they may lead to improvements in the additive manufacturing of matrix-reinforced composites. The tailored design of feedstock powders by prior coating could potentially result in the improvement of the multi-materials 3D printing concept, where interfacial bonding is one of the main issues; a problem which calls for further research.

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