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Editorial

Research Progress in Metals and Alloys by Thermal Layering and Deposition

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Over the last 20 years, because of their superior hardness, chemical stability, and outstanding oxidation barrier, many coating systems have now been extensively researched using various deposition processes and employed for wear-resistant protection [1]. These surface coatings have been explored across a variety of technological disciplines, including aeronautics and transportation, tools and die, chemicals and petrochemicals, nuclear research, electronics, and healthcare. Coating technology applies single or several layers of an appropriate substance to a material surface without changing the bulk material's composition, allowing it to function in different environments and overcome challenges caused by abrasion, temperature, fatigue, corrosion, erosion, and friction [2]. Consistent research on innovative coatings has significantly contributed to worldwide economic advances over the past few decades. Depending on the exact use, different coating materials (such as ceramics, metals, composites, or polymers) and coating methods are used [3].

In the production of conventional devices, top-down procedures, such as etching and photolithography, are often used for patterning at the nano scale. However, bottom up procedures are increasingly being looked at as potential substitutes owing to physical restrictions on downscaling those processes. A vapor-phase process called atomic layers deposition is used to deposit thin films on different substrates through a series of self-contained surface reactions [4,5]. Molecular layering (ML) and atomic layers epitaxy (ALE), two techniques that were initially presented in 1970s, form the foundations of ALD [6]. Graphite, graphene, and amorphous state carbon are examples of carbon-based inhibitors that are often deposited via solution methods, such as ion implantation, or chemical vapor deposition (CVD). However, it is challenging to use these techniques on substrates with high aspect ratios [7]. Similar to ALD, a molecular layers deposition (MLD) technique can produce conformal thin films of materials on three-dimensional objects [8]. Substantial thermal stresses occur between the coating and the metallic bond due to the latter's poor fracture toughness and comparatively low coefficient of thermal expansion. Consequently, the thermal cycle life of the single layer covering is often limited [9]. The multilayer concept is an efficient technique used to overcome such drawbacks and enhance shock life due to thermal loading [10]. Additionally, as an outer layer, the multilayer consists of an erosion-resistant layer, thermal barrier layer, corrosion- and oxidation-resistant layer, a layer controlling thermal stress, and a layer resisting diffusion [11].

A total of 13 papers were published in this Special Issue. From these 13 papers, a total of 8 papers focused on surface modification, surface treatment, microstructural examinations and mechanical properties. The published papers form comprehensive and sufficient learning materials that are sure to attract the attention of scholars in the manufacturing field. Authors also made significant efforts to produce qualitative research. For example, Kumar et al. [12] investigated the mechanical properties of nano-composites with a lower concentration of reinforcing nano particles, such as graphene, and ceramics in the matrix epoxy to assess the stability and damping properties of hybridized epoxy,

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employing vibration methods to obtain precise findings. Mechanical testing, such as three-point bending, validates the efficiency of the impact hammer vibration method as a function of the Young's modulus of a nanocomposite. The nanocomposite of graphene contains 1% of epoxy, whereas the nanocomposite of ceramic contains 3% of epoxy. The frequency reduction in the heated environment was found to be much lower hybrid nanocomposites, but the decrease in pure epoxy was high; therefore, advancements in thermal and mechanical stability were found.

Srivastava et al. [13] investigated the surface tribological performance of Al359/Si_3N_4/ Eggshell by friction stir processing (FSP). In the past, researchers explored techniques that will help to develop lightweight materials with dimensional accuracy, a smooth surface finish, and less production cost. With all these abilities, it will become eco-friendly. An aluminum matrix composite is an advanced engineering material in this field of research. The impression of the microstructural properties is to develop a defect-free surface that will help with grain refinement and enhance the mechanical properties of the top surface of the base alloys. Si_3N_4 is used in defense applications due to its ballistic and mechanical properties. Si_3N_4 is evaluated as a standard reinforced material that has a low density, high melting point, high thermal stability, and good chemical stability. Eggshell is a valuable material used as a new, reinforced engineering material as it contains around 95% calcium carbonate ($CaCO_3$), 3% phosphorus, and some other materials, such as zinc, potassium, sodium copper, magnesium, and iron. Many studies have been conducted to improve the mechanical and modified microstructures of matrix materials that have several disadvantages, such as porosity, solute redistribution, and solidification cracking. FSP is a popular technique that is used for versatile, solid-state processing, and green-energy-efficient techniques. It has negligible residual stresses and a refined microstructure, densification, and structural homogeneity. Generally, composites have a high coefficient of friction. Surface composites are made using a vertical milling machine. Al-6% Si_3N_4/Eggshell composites are undertaken to investigate frictional properties with the help of tribological tests. Light microscopy and FE-SEM equipped with EDS mapping are used in microstructural research. SiC, Al_2O_3, and B_4C are reinforced in the metal matrix, improving their tensile strength, yield strength, and hardness but reducing ductility. Liquid- and solid-phase fabrication methods have been successfully conducted to form the desired composite.

Lashin et al. [14] investigated the regulation of dynamic and static factors in order to maximize the welding strength achieved via friction stir spot welding (FSSW). As a novel technique, a control system based on fuzzy logic was applied to improve the process. Static and dynamic conditions influenced the tensile strength of stir spot welding. The collected findings demonstrate that the fuzzy logic system was a simple and low-cost technology that could be applied in the prediction and optimization of FSSW strength [14]. Gunduz et al. [15] discovered that titanium and its alloys had insufficient friction and wear settings due to their poor tribological characteristics. Electroless coatings were discovered to be effective as surface enhancement treatments due to their homogenous thickening, higher hardness, and superior resistance to corrosion. The auto-catalytic reduction in coating processes significantly improved surface quality. To improve weak tribological properties, an electroless coating of Nickel-P-Gr was applied to a Ti6Al4V alloy, and samples were put to abrasion in a linear-type reciprocating ball on plate configuration to examine tribological characteristics. Its hardness increased by approximately 34% with a graphene-reinforced Nickel-P coating in the electroless coatings procedure, whereas it increased by about 73% with applied thermal treatments. Moreover, the substrate's wear rate was nearly 98% greater than the heat-treated nanocomposite coatings. The heat-treated nano composite coatings had the maximum wear resistance.

Saxena et al. [16] investigated the tribological properties of microwave-assisted g-C_3N_4/MoS_2 nanocomposite coatings. The calcination approach was used to produce the g-C_3N_4 nanosheet, and the microwave-assisted method was used to developed nanocomposite with MoS_2. A pin on disc setup was used to investigate tribological qualities. A morphological examination indicated that elements coexisted, and the layered structure of

MoS_2 was evenly distributed over gC_3N_4. The presence of MoS_2 nano particles reduced the pore volume and surface area of the composite, confirming that the pores of calcinated gc_3n_4 were filled by MoS_2. The tribological properties of the nanocomposite were studied under various conditions, such as applied load, sliding speeds, and material compositions. The findings suggest that the inclusion of g-C_3N_4 in nano composites can minimize friction and enhance wear life. These results were superior to those obtained with MoS_2 alone.

Kumar N et al. [17] used three waste materials as a reinforcement to develop surface composites of aluminum alloys using FSP. Currently composites are being used as substitutes for many alloys due to their high strength-to-weight ratio, hardness, and tensile strength. Surface composites can be suitable alternative material to structure and automotive components. Hybrid composites consist of two or more reinforcements, whereas a non-hybrid has only one reinforcement. Biowaste materials also have particles that can strengthen certain materials [18]. Chicken bone powder (CBP) is an example of biowaste material, which is produced in poultry farm. The use of waste in products and its disposal, are great challenges since they form unwanted and harmful. CBP is strengthened by its sufficient amounts of carbon and calcium. Walnut shell powder (WSP) is a green waste formed during the manufacturing of walnuts products, containing cellulose and lignin. It is able to enhance the bonding strength of existing material. Rice husk powder (RHP) is agricultural waste produced by farming. The storage of this waste remains a major issue; many farmers burn this waste, which causes significant pollution. These three biowastes are utilized in the matrix alloy of aluminum and processed with FSP to take advantage of grain refinement and surface treatment. As a result, tensile modulus, yield and ultimate strength, percentage elongation and elastic coefficient are improved by 20%–30% [19].

Saxena et al. [20] attempted to improve the settings for the Pin-on-Disc wear apparatus. Various applied loads, sliding speeds, and the wt. of additive graphitic carbon nitride in a molybdenum disulfide nanocomposite coating on a steel substrate were used in the studies. ANOVA was performed to evaluate the effect of the interactions between different criteria. The maximum influences of applied loads on friction coefficient and wear were found to be approximately 59.6% and 41.4%, respectively, with sliding speed coming in second. The optimum conditions for the lowest coefficient of friction and wear depth in the nanocomposites were established to be at 15 N applied load, 750 mm/s sliding speed, and 9 wt.% of CN. Even at a 95% level of confidence, applied loads were determined to have the greatest impact on COF then sliding speed, whereas material composition had the greatest impact on wear. Taguchi technique and RSM results correlate well with experimental tests.

Wu et al. [21] created liquid crystal compounds (LCs) as a high-performance additive for a base oil that can fulfil a range of operating conditions. The influence of the mesogenic phase temperatures range of LC on tribological characteristics was investigated. Compared to the basic oil, the addition of LCs caused a significant decrease in the fictional coefficient (21.57%) and width of wear (31.82%). Furthermore, LCs exhibited improved tribological properties under temperature conditions of the mesogenic phase.

The above literature constitutes a summary of previously published research. However, some additional papers are still under extensive review to help them fit the scope of this Special Issue.

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