coatings

Editorial

Protective Composite Coatings: Implementation, Structure, Properties

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Coatings are being used in more and more areas of life today. Initially, the most common application of coatings was to apply protective layers to protect the substrate, as well as for decorative purposes [1,2]. Recently, the operating conditions of machines and mechanisms have changed, and new production technologies have appeared [3]. All this required the creation of fundamentally new coatings that differ both in composition and in the method of preparation.

Recently, technologies for additive manufacturing (AM) of parts have been actively developing [4]. Gradually, AM technologies moved from prototyping and physical representation of 3D models to secondary use in manufacturing technologies (for example, for making molds [5]). Now, when working parts are being produced by AM methods, the question arises of applying protective coatings to such products. Due to the specificity of AM processes, in particular, laser and electron beam melting, it is necessary to develop new approaches to coating such products.

Ashkenazi, D. et al. [6] reviewed the state-of-the-art methods where the Ag, Au, and Au–Ag were deposited on as-printed disk-shaped AlSi10Mg specimens using a dedicated surface activation method. Moreover, Dr. Ashkenazi herself alongside her colleagues are successfully working on this topic [7–9]. Investigations show that the roughness of all plated specimens was somewhat reduced as the thickness of the coated layer was increased. Adequate quality coatings were obtained for all developed electroless deposition processes. A major advantage of the developed Ag, Au, and Au–Ag coatings is the low processing temperature and the avoidance of environmentally hazardous material.

Slegers et al. [10] describe the method of surface roughness reduction of additive manufactured products by applying a functional coating using ultrasonic spray coating. A higher roughness reduction is achieved without adding material on top of the SLS substrate. It is shown here that a roughness reduction below 5 µm can be achieved solely by process optimization. Moreover, for porous AM parts, the material deposited by ultrasonic spray coating can more easily penetrate the surface structure.

Another way to produce coatings for AM details is the use of the same AM technology but with different material. Köhn et al. [11,12] coated steel surfaces with Co-based tungsten carbide (WC) in an additive printing process. Tribological tests revealed highly constant coefficients of friction that are highly interesting for technical applications. The coating has good adhesion and a homogeneous microstructure. A final mechanical surface treatment procedure after deposition led to wear-resistive WC/Co surfaces that exhibited extremely low wear rates under dry conditions. The so-prepared surfaces exceeded the lifetime of high-quality PVD-coated surfaces by orders of magnitude.

The issues of modeling the processes of coating deposition and modeling the behavior of coatings under various influences are acute.

Recently, the direction of in situ production of coatings has been actively developed. Such processes turn out to be more complex from a technological point of view; however, they lead to the formation of composite coatings with outstanding properties. Jia et al. [13] investigated the novel method of in situ forming of the intermetallic NiAl coating via arc spray technology and plasma spray technology. The results show that $NiAl_3$, Ni_2Al_3, and NiAl intermetallics are in situ formed from a mixture of Ni and Al powders. NiAl was the only stable phase, while $NiAl_3$ and Ni_2Al_3 were all or partly dissolved in liquid Al during the coating formation process. This in situ formed coating allows increasing the high-temperature oxidation resistance after the heat treatment (comparing to the pure Ti substrate without a coating). The thickness and mechanical properties of the coating can be regulated by changing the sintering temperature and high-temperature isothermal holding time since these parameters regulates the elemental Al diffusion to Ni or/and Ti layers. Interesting results are obtained by the same group for Al/Ti [14] and TiB2-NiCr [15] composite coatings.

When working with painted coatings, not only the process of obtaining coatings plays a role but also the processes of post-processing coatings. This issue especially arises in industrial production, when it comes to the production of large batches, where the quality of products may differ within one batch. Blinov and colleagues describe [16] the synthesis and research of a new tool for removing metal inclusions from the surface of paint and varnish car coatings. The composition of the coatings includes sodium laureth sulfate, citric acid, sulfosalicylic acid, hydrogen peroxide and water as a solvent. The optimal composition and concentration was developed, and the maximum pH value achieved is 5.8 ± 0.2. The authors showed that 30–45 s after applying, the developed product removes from the surface metal inclusions and mineral contaminants in the form of sand, earth, clay and other particles containing elements such as potassium, magnesium, aluminum, sodium, silicon, chlorine and calcium.

Of particular interest is the issue of obtaining coatings with different properties near the substrate and near the surface. These coatings can be in multilayer or in gradient form. Kashkarov, Sidelev and colleagues are working on new promising Cr-based coatings for the nuclear fuel industry [17,18]. Investigated coatings are candidates for effective and reliable coatings for accident-tolerant fuel (ATF) under both normal operation (360 °C, 18.6 MPa) and accident (e.g., 1200 °C, water steam) scenarios. Obtained CrN/Cr coatings increases the wear resistance and cracking resistance under thermal cycling of the E110 alloy. The interlayer composed of CrN/Cr multilayers can limit Cr-Zr interdiffusion between the coating and E110 alloy at high temperatures (1200–1400 °C) due to the growth of α-Zr(N) layer underneath the coating.

This Special Issue aims to provide a forum for researchers to share current research findings to promote further research and provide an updated outlook on the applications and structure formation of protective composite coatings, along with demonstrating the modern ways of producing and post-processing of such coatings.

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