

Surface Treatment Technology of Metals and Alloys

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1. Introduction and Scope

In recent decades, metals and new alloys with modified surface properties have experienced steady development. These new materials are designed to be used both in various industry branches, as well as in biomedical applications. The point is that modified mechanical, electrochemical, and antibacterial properties may be improved thanks to different changes introduced to the surface layer of metals and alloys. The new surface technology engineering covers modifications and improvements introduced by laser treatments, chemical and electrochemical polishing, magnetoelectropolishing, passivation, anodic oxidation, electrophoretic deposition, ion implantation, plasma electrolytic oxidation, chemical or physical vapor deposition, as well as by sol-gel processing. Nowadays, designing materials properties is one of the top scientific domains, allowing for predicting the behavior of a material under extreme environmental conditions. Special attention to surface quality is of importance prior to their production. This Special Issue focuses on new achievements and is intended for everyone interested in widely understood surface engineering of metals and alloys.

2. Contributions

Eleven research papers have been published in Special Issue of Metals titled *Surface Treatment Technology of Metals and Alloys*. All the presented subjects are multidisciplinary, and include shot peening treatment [1], electropolishing [2], low-pressure carburizing [3], oxi-nitrocarburization [4], abrasive blasting [5], hydrothermal treatments [6], laser cladding [7], plasma modification [8], low-temperature vacuum carburization [9], plasma electrolytic oxidation [10], and thermoreactive deposition [11].

Shot peening treatment of high alloy white cast irons (WCI) is as an alternative to global heat treatments, due to its capacity to induce phase transformation and microstructural modification and, at the same time, it improves the mechanical properties of treated materials. The results proved that shot peening treatment can transform residual austenite and increase hardness in the top surface layer of the material. Both effects contribute to improve the erosion wear behavior of the WCI [1].

Electropolishing of stainless steel is widely used in many kinds of industry; however, it is always difficult to transfer laboratory results to an industrial scale. It was found that the best results, both in laboratory and industrial conditions, were obtained at a temperature of 35 °C and a current density of 8 A·dm⁻². It was also noted that high temperatures resulted in the emergence of defects on the surface, in particular for industrial samples [2].

The calculation of the mixture flow in a low-pressure carburizing process was the main issue in the case of process efficiency. Modern carburizing processes should be carried out using an excessive belaying flow of carburizing gases. The steel parts of 16MnCr5 were carburized in a variable-flow carburizing process at a temperature of 960 °C. It was found that the amount of the mixture used in the variable-flow carburizing process may be significantly reduced to 54% of that consumed during the regular constant-flow carburizing without affecting the properties of the hardened layer of the steel parts [3].

The oxi-nitrocarburizing technique for low-carbon steel may be used to reduce the corrosion in gas nitrocarburizing. Gas nitrocarburizing may be performed at 560 °C with an oxidation process with the use of air and steam as oxygen sources. It was noted that the corrosion resistance of the oxi-nitrocarburized specimens showed superior performance compared to those that are untreated. It was also recorded that the nitrogen concentration in the ϵ -phase and γ' -phase increased, which increased the nanohardness of the compound layer [4].

Modification of the surface state of the surface irregularities of pretreated materials by abrasive blasting is a very important issue both scientifically and practically. It was found out that there is a correlation between the measured roughness parameters of the blasted surfaces. It was noted that for surface topography differentiation, the Ra, Rz parameters are best. The blasted surface may be also evaluated by standardized/normalized (RSm) and non-standardized/normalized (RPc) parameters [5].

Hydrothermal treatment of the biodegradable magnesium-matrixes may be used to obtain the homogenous and reproducible hydroxyapatite layer on the proposed Mg-substrates. It was also found that obtained layers by hydrothermal treatment in ethylenediaminetetraacetic acid calcium disodium salt led to the formation of hydroxyapatite layers, which improves both the corrosion resistance and surface wetting properties compared to microcrystalline magnesium [6].

The improving of the wear resistance of titanium alloy Ti6Al4V may be obtained by the laser cladding technique using Ni60, C, TiN, and CeO₂ nanoparticles mixed powders as the pre-placed materials. It was noted that the CeO₂ nanoparticles influence the wear properties of the coatings, i.e., they have higher hardness, lower wear loss, and better wear morphology compared to the coating without CeO₂ [7].

Formation of oxide layer titanium substrate by oxygen plasma modification may be used for the fabrication of biocompatible layers enriched with TiO₂. It was recorded that the obtained hydrophilic film containing nanostructural rutile TiO₂ phase has better hemocompatibility, which should improve tissue healing and then facilitate the osseointegration [8].

Low-temperature vacuum carburization with the use of an acetylene and hydrogen gas mixture may be used for AISI 316L stainless steel treatment. It was noted that the gas ratio is an important parameter for producing free radicals in carburization, because they may remove the natural oxide film by the strong reaction of the hydrocarbons. It was found that with a gas ratio below one, carbon-supersaturated expanded austenite layers formed on the AISI 316L stainless steel had a maximum carbon solubility up to 11.5 % at 743 K, while using a gas ratio above one resulted in a low carbon concentration in the layers, even if the processing time was increased enough to reach the maximum carbon solubility [9].

The plasma electrolytic oxidation (PEO) processes also known as micro-arc oxidation (MAO) may be used for preparing the porous and biocompatible and antibacterial coatings on titanium substrates. It was found that a voltage increase from 500 V_{DC} up to 650 V_{DC}, during the PEO treatment in the electrolyte, based on 1 dm³ of 85% concentrated H₃PO₄, with additions of Ca(NO₃)₂·4H₂O, and Mg(NO₃)₂·6H₂O, and Zn(NO₃)₂·6H₂O, and Cu(NO₃)₂·3H₂O, has an influence on the structure and chemical composition of the formed coating. It was found that the formed layers consist mainly of the amorphous phase, which is more visible for higher voltages, i.e., the higher the voltage, the thicker coating [10].

The effect of a nitride layer on the forming behavior of CrN and (Cr,Fe)₇C₃ multilayers for thermoreactive deposition (TRD) was investigated. Plasma nitriding followed by TRD (PN-TRD) produced a larger coating thickness than the case of direct TRD with no plasma nitriding. For PN-TRD, an Fe₂-3N layer of 10 μm in thickness was produced on AISI 52100 steel using plasma nitriding, followed by TRD using a mixed powder composed of 30 wt % Cr, 2 wt % NH₄Cl, and 68 wt % Al₂O₃. During TRD at 800 °C, a CrN layer of 2 μm in thickness was formed along with a thin layer of mixed carbide (Cr₇C₃) and nitride (CrN) on top. As the deposition temperature was increased to 950 °C, a new layer of Cr₇C₃ was formed underneath the outermost layer composed of mixed Cr₇C₃ and CrN. At 950 °C, a Cr-rich zone indicated a thickness of ~7 μm. As the deposition time increased to 3 h at

950 °C, a new layer of $(\text{Cr,Fe})_7\text{C}_3$ was produced at the interface between the CrN formed at 800 °C and the base metal. This layer formed because of the abundant resources of Cr and C provided from the TRD powder and base metal, respectively. The multilayer and interface were concretely filled without the formation of voids as the TRD time increased to 6 h at 950 °C. The TRD process on a pre-nitrided layer was successfully applied to produce multilayers of CrN and Cr_7C_3 [11].

3. Conclusions and Outlook

Many topics related to the surface treatment technology of metals and alloys have been shown in the present Special Issue. It should be pointed out that the subject is interdisciplinary and includes, inter alia, topics such as electropolishing, plasma electrochemical oxidation, plasma modification, thermoreactive deposition, hydrothermal treatments, and low-temperature vacuum carburization, low-pressure carburizing, oxi-nitrocarburization, laser cladding and shot peening treatment, abrasive blasting, which proves an important aspect of this subject both in terms of scientific and industrial use. The issue of surface treatment is still open for researchers, because the top surface layers, which are fabricated during physical, chemical/electrochemical, and vacuum processes, have different properties from those of treated substrates.

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