Editorial

Electrochemical Properties of Metallic Coatings

Fengting Cao, Guangyao Gao, Yameng Feng, Belay Abakuma Getachew and Tiegang Wang *

Tianjin Key Laboratory of High-Speed Cutting and Precision Machining, Tianjin University of Technology and Education, Tianjin 300222, China
* Correspondence: tgwang@tute.edu.cn; Tel.: +86-22-8828-6992

Abstract: The metallic coating is an outstanding corrosion-protection option with extensive applications, especially in high-temperature environments. Considering the close relationship between anti-corrosion ability and constitutions, it is necessary to acquire the electrochemical properties of metallic coatings for optimizing their corrosion resistance, and further provide guidance for coating design based on the protection mechanism. Thus, this Special Issue aims at collecting research articles focusing on the electrochemical properties of various metallic coatings, especially on the application of new electrochemical techniques for analyzing the corrosion protection process and mechanism of these coatings. Both experimental and theoretical types of research are welcome for the contribution.

Keywords: metallic coatings; electrochemical property; coating design; corrosion

1. Introduction

Metallic coatings can improve the corrosion resistance of steel, copper, and other metals in various environments, and thus extend the service life of metal constructions. Particularly, metallic coatings can be used in a wide variety of industrial applications in which metals are subjected to elevated temperatures and aggressive conditions, where organic coatings will encounter serious thermal degradation and thermal conductivity issues. For example, the use of inorganic coatings containing anions such as chromates or molybdates have been tested because of their relative temperature stability [1,2]. Metallic diffusion coatings can significantly improve the corrosion resistance of low-cost alloys such as carbon steel. It also has been reported that Cr- or Ni-coated 409 SS specimens exhibit corrosion-resistant properties similar to that of superalloys in high-temperature chemical heat pump environments. Thus, coated steels possess the potential of replacing expensive alloys and reducing the capital cost of equipment.

Metallic coatings have developed significantly in these years, ranging from single-layer coating to multi-layer gradient coating and micro-stack coating, from alloy coating to the current ceramic coating and composite coating. Up to date, protective metals and alloys such as Zn [3], Ni [4], Al [5], Ti [6], Hf [7], Cr [6], and Cu [8], for various applications have been studied for metals that are prone to corrosion. Al and Al alloy coatings are commonly used for corrosion protection of metal components. The open corrosion potential of aluminum coating in seawater showed a relatively low corrosion potential, which could provide cathodic protection for carbon steel [9]. Al-based amorphous coatings have also been widely studied for their excellent wear and corrosion resistance. Compared with Al coating, amorphous alloy coatings, such as Al88Ni6La6 and Al86Ni6La6Cu2, have higher corrosion potential and lower corrosion current density [10]. Ni and its alloys can maintain high strength and good corrosion resistance in seawater, sulfuric acid, and alkaline liquid, and are widely used in corrosive industrial fields. Ni-based amorphous metallic coatings [4] have a lower corrosion rate when compared with some typical Fe-based, Zr-based amorphous alloys, the electroplated-Cr, and stainless steel [11]. This makes the Ni-based fully amorphous metallic coating a good candidate for anticorrosion applications. Ni-Cr coating, as a sacrificial layer of high-temperature resistance and acid...
and alkali corrosion resistance, is widely used in a high-temperature environment such as boiler and waste incinerator [12]. Ni53Nb20Ti10Zr8Co6Cu3, a fully amorphous metallic coating has been deposited by using gas-atomized powders [13]. Besides Al, Ni, and Cu alloys mentioned above, Ti and other alloys, such as Zn-Al-Si, were also used as anticorrosive coatings and composite coatings [14]. During the last few decades, there has been considerable interest in the corrosion resistance of amorphous alloys [15,16]. Recently, some attempts have been made to prepare Fe-based amorphous alloy coatings, for example, Fe-Cr-Mo-(C, B, P) and Fe-Cr-B-based amorphous coatings, which expressed prominent erosion resistance. All these researches illustrate the extensively applied prospect of these metal coatings [17].

The metallic coatings mentioned above could be divided into three categories according to their anti-corrosive mechanisms: (i) forms a passive film. A physical barrier consists of compact and dense oxide films formed between the metal parts and the corrosive medium can be found in Al-based or Cr-based coatings, and these oxide films could prevent the water and oxygen in the environment from reaching the protected matrix, and play the role of physical isolation and blocking [5]; (ii) serves as a sacrificial anode. Since the self-corrosion potential of the coating (such as Zn) is lower than that of the steel matrix, the metal coating, as a sacrificial anode, preferentially reacts with the electrolyte by losing electrons and plays a cathodic protection role on the steel matrix [3]; (iii) supplies soluble ions used as corrosion inhibitors. By electrochemical properties, amorphous Al-Co-Ce alloys can release corrosion-inhibiting ions Ce3+ from the metallic coating via a pH-controlled mechanism [18,19] These released inhibitor ions diffuse and migrate toward the damage site, reach critical concentration and finally suppress the corrosion [20].

Methods used for studying metallic coatings are of great importance to analyze their properties and protection mechanism. Optical microscopy, scanning electron microscopy, X-ray diffraction, and other surface analysis techniques are always employed to determine the microstructure and composition of corrosion products, while salt spray tests and weight loss methods are frequently adopted to evaluate the corrosion resistance of metallic coatings. However, these techniques are far from enough to illustrate clearly the features and the anti-corrosion mechanisms of these metallic coatings. Surface analysis techniques and weight loss methods could merely provide a certain state of the corrosion process, while salt spray test is not quantitative and is limited to giving a general idea of the corrosion rate in an aggressive environment. The electrochemical properties of metallic coatings, which don’t exist in the insulated organic coatings, could provide additional messages about the coatings and thus give an insight into the corrosion protection process.

Conventional electrochemical testing methods, such as open-circuit potential (OCP), electrochemical impedance spectroscopy (EIS), and potentiodynamic polarization curve (PDP), could not only evaluate the corrosion resistance of the metallic coatings but also provide direct evidence and details of the corrosion protection process. There are many other electrochemical techniques that are of great potential for assisting the investigation on the corrosion mechanism of metallic coatings and thus prompt a wiser strategy for coating design. For example, the cyclic polarization curve, a mainly used method to evaluate the pitting ability of the materials or the self-repair ability of passive films [21] can also be chosen to indicate the tendency of a metallic coating to undergo pitting corrosion [22]. Current-time transients, where changes in current as a function of time were determined at an applied polarization potential, could also be used as an indicator of corrosion resistance of coatings [22].

Additionally, due to the influence of various factors, the cathode and anode regions in the metal-electrolyte interface may exhibit different characteristics. Conventional electrochemical methods often reflect the macroscopic surface of the sample, but cannot be used to study its corrosion behavior in microcosmic scope, which brings difficulties to the analysis of the corrosion protection mechanism of metallic coatings. In these cases, micro area electrochemical technologies are necessary to be employed, such as Scanning Vibrating Electrode Technique (SVET) [23], Local Electrochemical Impedance Spectroscopy (LEIS) [24].
which have been used widely in self-healing organic coatings. This technique can map the current density changes inside and around the coating defects at the microscopic scale, which are very essential for analyzing the corrosion protection mechanism deeply.

For metallic coatings, researchers nowadays pay more attention to their mechanical properties such as wear resistance, while their electrochemical properties are relatively rare to be reported, and the electrochemical testing methods are also limited. Actually, it has a lot of work to do to analyze the protective mechanism of metallic coatings by electrochemical technology, which can provide beneficial guidance for the design and preparation of coatings in the future.

2. Conclusions

The electrochemical properties of metallic coatings can not only directly reflect the corrosion protection on the substrate materials, but also provide sufficient information about the thermodynamic and kinetic processes of corrosion, thus provide insight into the corrosion mechanism and further guidance for the coating design. From this point of view, the electrochemical properties of metallic coatings are a worthy and important topic for corrosion and protection in the past, present, and future. This Special Issue aims to exchange the progress and frontier of corrosion-protection knowledge for metallic coatings based on various electrochemical techniques, including (but not limited to) CV, Tafel, EIS, SVET, LEIS, and LSV. We sincerely invite high-quality contributions that present innovative and significant findings and experiences on this topic.

Author Contributions: Conceptualization F.C. and T.W.; investigation G.G. and F.C.; methodology Y.F. and B.A.G.; project administration T.W.; writing—original draft preparation F.C. and B.A.G.; writing—review and editing T.W. All authors have read and agreed to the published version of the manuscript.

Funding: Tianjin University Science and Technology Development Fund Project (No. 2020KJ103, 2021ZD005), Tianjin Science and Technology correspondent project (No. 22YDTPJC00450).

Data Availability Statement: Not applicable.

Acknowledgments: The authors acknowledge the support provided by Tianjin Municipal Education Commission, and Tianjin Municipal Science and Technology Bureau.

Conflicts of Interest: The authors declare no conflict of interest.

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