Chapter

Prologue: Coating Technology

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1. Introduction

The advanced technological application demands value-added materials of requisite surface properties. In most of the cases, the metallic materials are employed as prime part of the instrument/device. But after certain period of repeated use, passivation/inactiveness of the surface has been realized. This is mainly due to the corrosion of the metallic surface. Corrosion is nothing but the physicochemical interaction of a metal surface with the surrounding environment leading to change the original properties of that metal. Further it impairs the function of the metal as well as the environment and the technical equipment of which these form a part. Therefore methods/technologies are strictly indispensable to protect the metal surface from the detrimental effect of the environment as well as to preserve its integrity. Although many technological prospects have been formulated, still now focus is given on the development of methods for surface modification/functionalization of materials. The definition of surface modification/functionalization directs the employment of a procedure to introduce new properties to an existing material to fulfil the requirement for a particular application. These techniques have been used from the ancient times aiming for an improved response of a material when it interacts with the environment. After the evolution of nanoscale materials and nanotechnology, this functionalization is performed in either by manipulating the material composition in molecular level or by making an optimized coating onto the material surface. Basically the surface modification is performed by applying advanced coatings onto the material surface. These coatings offer an efficient physical barrier clogging the approach of corrosive species to the metal surface, thereby lengthening the lifetime of the equipment. Additionally these coatings are capable to suppress the corrosion process, if the protective barrier is disrupted by any means. Hence these corrosion protective materials require the use of anticorrosion pigments or corrosion inhibitors which will protect the underlying metallic surface. Further the thickness of coating and optimization of the number of layers strictly depends on the application for which it is intended. Generally the thickness varies from micro to millimetres, and the number of layers varies according to the targeted application. Each of the layers is designed to aim specific functionalities like as adhesive to the metal surface or in between the metal and other coating layers, corrosion inhibitor, water-repellent, antifouling/wear resistive agent, etc.

From the heritage of mankind, animal fat, gelatins, beeswax, clay minerals, and different vegetable oils have been employed as the coating material to protect the surface of metallic articles from corrosion, to retain brightness, for lubrication, etc. [1]. Later on with the passage of time, the boost on nanomaterials and nanotechnology developed many advanced routes for surface coating, but still now some of the ancient coating materials are in use. Afterwards the chromate-based surface treatments are developed and show efficient corrosion protective properties; however the use of hexavalent chromium is imposed legislatively (because of its carcinogenic properties) in most of the areas excluding the aerospace industries. Therefore more focus has been paid to design advanced, nontoxic (low-volatility, organic, hexavalent chromium- and isocyanate-free compounds), and low-cost coatings for corrosion protection. In this regard, many of the nanomaterial-based coatings (organic, inorganic, or composites) have been formulated and demonstrated successfully.

2. Materials and processes

These coating materials are applied in various sectors to prevent corrosion and to retain the integrity of the metal performance. Generally two main strategies have been considered to achieve the required functionalities into coatings: (a) encapsulation or loading of the active species in host carriers and (b) manipulation in composition of the coating matrix to include bulk or surface functional groups. The former one involves the intermixing of carriers of active agents (polymeric capsules, nanotubes, mesoporous inorganic particles, clays, etc.) along with the functional species (cerium ions, benzotriazole, nitrates, silyl esters, etc.) with the coating matrix. These carriers act as the reservoirs that store the active material and release at the time of requirement. It is necessary to maintain the compatibility and to check the long-term stability of the carrier material with the coating matrix. A number of carriers, functional species, and coating matrix have been summarized in **Table 1**.

In addition to the above-discussed processes, an alternative route is also explored and demonstrated successfully for corrosion protection. It constitutes the functionalization of the coating surface or bulk matrix by manipulating its molecular structure and composition [11–16]. Out of others, the process involving the manipulation of cross linking/molecular structure of the polymeric matrixes by integrating different additives (like cyclic carbonates, amines, and siloxanes) is considered as the greener route to surface functionalization. As a result a thin and dense cost-effective coating is formed showing improved protective action with better durability. Some examples on the coating materials based on surface modification is presented in **Table 2**.

Substrate	Coating Matrix	Active agent	Carrier	Reference
Steel	Epoxy polymer	Polysiloxanes	Urea-formaldehyde microcapsules	[2]
Aluminium	Sol-gel	Cerium (III), Lanthanum (III), Salicylaldoxime, 8-hydroxyquinoline	Hydroxyapatite particles	[3]
Steel	Primer	Silver	Silica	[4]
Galvanised steel	Silane	Cerium ions	CeO_2 nanoparticles	[5]
Glass	Silane	Sodium montmorillonite	Sodium montmorillonite	[6]
Steel	Polyester coating	Benzalkonium chloride	Mesoporous silica	[7]
Aluminium and Galvanneal	Epoxy	Mercaptobenzothiazole	Polyelectrolyte nanocapsules	[8]
Steel	Acrylic paint	Silver	Polymer microparticles	[9]
Al alloys	Epoxy	Silyl ester	Polymeric capsules	[10]

Table 1.
Examples of different active agents, carriers, and coating matrixes used for coatings to protect the metallic surface from corrosion.

Substrate	Coating matrix	Active agent	References
Al alloys	Polyester	Various silane	[17]
AZ31	Epoxy	Various silanes aminosilanes	[14]
Steel	Acrylics	Inorganic fillers	[18]
Zinc and AA2024	Polyvynilbutyral	PANI-emeraldine salt of paratoluene sulphonic acid	[19]
AA2024	Epoxy	PANI-lignosulfonate	[20]
Steel panels	Commercial resins	Glycidyl carbamate	[21]
Steel	Silicone rubber	Inorganic nanoparticles	[22]
Tin	Poly(methyl methacrylate)	Mixture of silanes	[16]
Steel	Epoxy-ester	dodecylbenzenesulfonic acid polyaniline	[23]

Table 2.
Examples of different active agents used in manipulation of the coating matrix to make effective coatings for corrosion protection.

3. Conclusion

The encapsulation of coating matrixes with active agents provides an advanced route to maintain the properties of metallic materials used in different technological applications. Also the functionalization of surface with active materials by manipulating the molecular composition adds another route to prevent corrosion. Further the coating thickness and number of layer optimization is strictly needed to achieve an efficient coating. Therefore not only on the material development but also focus should be given to manage the compatibility among the coating layers and efficiencies of carrier material to hold active agents for targeted applications. This book aims to present detailed information and current advancements in the coatings technology applied to prevent the metallic substrates from corrosion maintaining its integrity.

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References

[1] Montemor MF. Functional and smart coatings for corrosion protection: A review of recent advances. Surface and Coating Technology. 2014;**258**:17-37. DOI: 10.1016/j.surfcoat.2014.06.031

[2] Cho SH, White SR, Braun PV. Self-healing polymer coatings. Advanced Materials. 2009;**21**:645-649. DOI: 10.1002/adma.200802008

[3] Snihirova D, Lamaka SV, Taryba M, Salak AN, Kallip S, Zheludkevich ML, et al. Hydroxyapatite microparticles as feedback-active reservoirs of corrosion inhibitors. ACS Applied Materials & Interfaces. 2010;**2**:3011-3022. DOI: 10.1021/am1005942

[4] Le Y, Hou P, Wang J, Chen JF. Controlled release active antimicrobial corrosion coatings with Ag/SiO_2 core–shell nanoparticles. Materials Chemistry and Physics. 2010;**120**:351-355. DOI: 10.1016/j.matchemphys.2009.11.020

[5] Montemor MF, Ferreira MGS. Analytical characterization of silane films modified with cerium activated nanoparticles and its relation with the corrosion protection of galvanised steel substrates. Progress in Organic Coating. 2008;**63**:330-337. DOI: 10.1016/j.porgcoat.2007.11.008

[6] Miccichè F, Fischer H, Varley R, van der Zwaag S. Moisture induced crack filling in barrier coatings containing montmorillonite as an expandable phase. Surface and Coating Technology. 2008;**202**:3346-3353. DOI: 10.1016/j.surfcoat.2007.12.003

[7] Zheng Z, Huang X, Schenderlein M, Borisova D, Cao R, Möhwald H, et al. Self-healing and antifouling multifunctional coatings based on pH and sulfide ion sensitive nanocontainers. Advanced Functional Materials. 2013;**23**:3307-3314. DOI: 10.1002/adfm.201203180

[8] Plawecka M, Snihirova D, Martins B, Szczepanowicz K, Warszynski P, Montemor MF. Self healing ability of inhibitor-containing nanocapsules loaded in epoxy coatings applied on aluminium 5083 and galvanneal substrates. Electrochimica Acta. 2014;**140**:282-293. DOI: 10.1016/j.electacta.2014.04.035

[9] Szabó T, Mihály J, Sajó I, Telegdi J, Nyikos L. One-pot synthesis of gelatin-based, slow-release polymer microparticles containing silver nanoparticles and their application in anti-fouling paint. Progress in Organic Coating. 2014;**77**:1226-1232. DOI: 10.1016/j.porgcoat.2014.02.007

[10] García SJ, Fischer HR, White PA, Mardel J, González-García Y, Mol JMC, et al. Self-healing anticorrosive organic coating based on an encapsulated water reactive silyl ester: Synthesis and proof of concept. Progress in Organic Coating. 2011;**70**:142-149. DOI: 10.1016/j.porgcoat.2010.11.021

[11] Twite RL, Bierwagen GP. Review of alternatives to chromate for corrosion protection of aluminum aerospace alloys. Progress in Organic Coating. 1998;**33**:91-100. DOI: 10.1016/S0300-9440(98)00015-0

[12] Chattopadhyay DK, Raju KVSN. Structural engineering of polyurethane coatings for high performance applications. Progress in Polymer Science. 2007;**32**:352-418. DOI: 10.1016/j.progpolymsci.2006.05.003

[13] Mathiazhagan A, Joseph R. Nanotechnology—A new prospective in organic coating—Review. International Journal of Chemical Engineering and Applications. 2013;**2**: 225-237. DOI: 10.7763/ijcea.2011.v2.108

[14] Brusciotti F, Snihirova DV, Xue H, Montemor MF, Lamaka SV,

Ferreira MGS. Hybrid epoxy-silane coatings for improved corrosion protection of Mg alloy. Corrosion Science. 2013;**67**:82-90. DOI: 10.1016/j.corsci.2012.10.013

[15] Qian M, Mcintosh Soutar A, Tan XH, Zeng XT, Wijesinghe SL. Two-part epoxy-siloxane hybrid corrosion protection coatings for carbon steel. Thin Solid Films. 2009;**517**:5237-5242. DOI: 10.1016/j.tsf.2009.03.114

[16] Kunst SR, Cardoso HRP, Oliveira CT, Santana JA, Sarmento VHV, Muller IL, et al. Corrosion resistance of siloxane-poly(methyl methacrylate) hybrid films modified with acetic acid on tin plate substrates: Influence of tetraethoxysilane addition. Applied Surface Science. 2014;**298**:1-11. DOI: 10.1016/j.apsusc.2013.09.182

[17] Pathak SS, Khanna AS. Investigation of anti-corrosion behavior of waterborne organosilane–polyester coatings for AA6011 aluminum alloy. Progress in Organic Coating. 2009;**65**:288-294. DOI: 10.1016/j.porgcoat.2008.12.006

[18] Achar S, Procopio LJ. Developments in waterborne thermal insulation coatings. Journal of Protective Coatings Linings. 2013;**30**:48-59. Available from: https://search.proquest.com/openview/aa4d92247d81dd5738dca7d30118465b/1?pq-origsite=gscholar&cbl=36623

[19] Williams G, Gabriel A, Cook A, McMurray HN. Dopant effects in polyaniline inhibition of corrosion-driven organic coating cathodic delamination on iron. Journal of the Electrochemical Society. 2006;**153**:B425-B433. DOI: 10.1149/1.2229280

[20] Gupta G, Birbilis N, Cook AB, Khanna AS. Polyaniline-lignosulfonate/epoxy coating for corrosion protection of AA2024-T3. Corrosion Science. 2013;**67**:256-267. DOI: 10.1016/j.corsci.2012.10.022

[21] Upadhyay V, Harkal UD, Webster DC, Bierwagen GP. Preliminary investigation of the impact of polymer composition on electrochemical properties of coatings as determined by electrochemical impedance spectroscopy. Journal of Coating Technology and Research. 2013;**10**:865-878. DOI: 10.1007/s11998-013-9497-z

[22] Arianpour F, Farzaneh M, Kulinich SA. Hydrophobic and ice-retarding properties of doped silicone rubber coatings. Applied Surface Science. 2013;**265**:546-552. DOI: 10.1016/j.apsusc.2012.11.042

[23] Arefinia R, Shojaei A, Shariatpanahi H, Neshati J. Anticorrosion properties of smart coating based on polyaniline nanoparticles/epoxy-ester system. Progress in Organic Coating. 2012;**75**:502-508. DOI: 10.1016/j.porgcoat.2012.06.003