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Editorial

Corrosion of Materials after Advanced Surface Processing, Joining, and Welding

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Corrosion has been a subject of keen scientific research for the past 150 years. It has a great impact on the safety and reliability in wide range of applications and also on the economy. Corrosion plays a crucial role in determining the lifecycle performance, safety, and cost of engineered products. Further, with the increasing demand for materials with multiple performance capability, advanced surface processing, surface coatings, joining, and welding techniques are being employed. As these materials and methods will be utilized in technologies for high-end applications (e.g., aerospace and nuclear engineering), investigation of corrosion of advanced surfaced materials becomes essential.

Metal joining is a controlled process that is widely employed to fuse similar/dissimilar metals. Among the several metal joining techniques, welding is one of the most widely used for a variety of applications. Metallurgical, physical, and chemical changes caused by welding processes severely affect the corrosion resistance of welds [1, 2]. Some of the recent and advanced welding processes include use of electron beam and laser beam for welding, and they have the advantage of narrow heat affected zone [3]. Even with the use of such advanced welding techniques, materials are still prone to corrosion, invariably due to (i) variation in composition, (ii) accumulation of residual stress, and (iii) modification in microstructure in the weld zone [1]. Similarly, solder joints undergo corrosion depending upon the local environmental conditions. Solder joints are severely prone to galvanic corrosion as they are comprised of dissimilar metals or alloy components that are in contact with each other. In particular, the phenomenon of electromigration is prevalent in solder joints, wherein corrosion causes build-up of by-product material between the two metal structures of different electrical potentials, resulting in a short-circuit [4].

Another major corrosion phenomenon which is accelerated by the presence of stress is stress corrosion cracking (SCC). In SCC, the imposition of mechanical loads (in particular tensile stress) on the structure causes increased sensitivity to corrosion. The required tensile stress for SCC crack growth may be in the form of directly applied stress (i.e., external stress) or in the form of residual stress (internal) [5]. SCC causes catastrophic failure in weldments. Recently, nanocrystalline (NC) materials (i.e., average grain sizes < 100 nm) are under intense research for their surface properties. In particular, nanocrystalline Ni-coatings are preferred as corrosion resistant coatings for metallic substrates [6]. The small grain size and the high volume fraction of grain boundaries would result in corrosion behavior different from that of polycrystalline materials. However, the effect of nanocrystallinity on the corrosion behavior is reported to vary among metal systems and corrosion environments. This makes it difficult to predict the electrochemical behavior of nanocrystalline coatings from that of their coarse-grained counterparts [7].

While corrosion can act as a single most dominant form of degradation in metallic structures, in real-time applications, it is still a difficult problem to characterize, quantify, and eliminate. With advancement in analytical techniques and superior instrumentation, future research work will provide more efficient solutions to control, monitor, and prevent corrosion.

This special issue encompasses recent research on corrosion of materials after advanced surface processing, joining, and welding. It contains 6 original research articles addressing various aspects related to welding, stress corrosion, soldering, and nanocrystalline coatings used in a wide variety of applications, summarized as follows.

1. Corrosion of Weldments

1.1. Research Article: "Corrosion Behavior of Welded Joint of Q690 with CMT Twin". In this research article, low-alloy steel of Q690 was welded with the method of CMT Twin. Cold metal transfer (CMT) process is a combination of 2 independently functioning arc-welding processes into one single process. Q690 steel is low carbon bainitic steel used in offshore industry. The exposure of the steel to saline environment usually leads to severe corrosion problems. In particular, the presence of Cl^- ion from salts such as NaCl and $MgCl_2$ in the chloride environment destroys the protective film and increases the severity of corrosion. In this paper the corrosion behaviour of CMT weld joint in 3.5% NaCl solution was reported. Hardness increase due to the appearance of troostite has been observed. While the corrosion products of regions with varying microstructure remained the same, at the welded joints Fe $(OH)_2$ changed to Fe $(OH)_3$. Interestingly, the CMT weld zone showed lower corrosion when compared to the overheated zone and the base metal. The better corrosion behaviour at the weld zone was attributed to the presence of nickel. The degree of corrosion with respect to microstructure varied as follows: HAZ > BM >WZ.

1.2. Research Article: "Effect of Rare-Earth Elements on the Corrosion Resistance of Flux-Cored Arc-Welded Metal with 10CrNi3MoV Steel". In this research work, the flux-cored arc-welding (FCAW) process was used for welding. It involves the fusion of a flux-cored wire metal with a base metal and is a widely used semiautomatic/automatic process. 10CrNi3MoV steel is a high-strength low-alloy steel (HSLA) widely used in shipbuilding industry. In this work, the composition of the flux-cored wires was modified with varying amount of rare-earth element (cerium rich ferro silicon). The rare-earth element modified wire was used to weld the steel. The microstructural, mechanical, and electrochemical properties of the weldment were reported highlighting the effect of the rare-earth elements on the weld properties. The addition of rare-earth elements up to 0.3 wt.% resulted in refining the second phase particles and acicular ferrite structure of the base metal. Further, charge-transfer channel effect of the second phase particles was reduced by the addition of rare-earth elements. At the optimum composition of 0.3% rare-earth element addition, both mechanical properties and corrosion resistance of the weldment improved.

1.3. Research Article: "The Analysis of the Influence of Various Factors on the Development of Stress Corrosion Defects in the Main Gas Pipeline Walls in the Conditions of the European Part of the Russian Federation". In this research article, investigation of the stress corrosion cracking of gas pipelines has been reported. The surveyed gas pipeline was made of large diameter rolled steel pipes (mostly produced by Khartsyzsk Pipe Plant, KhPP). In this paper, the influencing factors of stress corrosion defect formation and growth are reported, which were detected during the inspection and overhaul of the main gas pipeline section. Mechanical tests by cyclic loading of samples containing cracks (field testing) showed no crack growth in the absence of corrosive medium. Mechanism of development of SCC crack was proposed. It is reported that there was a consistent pattern between the width of the opening and the length of the crack. The appearance of cracks was found to be influenced by various factors during different stages of life cycle, such as (i) presence of harmful impurities that contaminate the metal pipe and (ii) presence of residual stresses in the pipe wall during manufacturing.

1.4. Research Article: "Pitting Corrosion of the Resistance Welding Joints of Stainless Steel Ventilation Grille Operated in Swimming Pool Environment". The pitting corrosion resistance of a stainless steel ventilation grill welded joint in a swimming pool environment is reported in this article. In swimming pools, in addition to plastics, stainless steel is used for structures/equipment such as ladders, ventilation systems, barriers, and drainage grills. Ventilation grills are usually welded using resistance welding. Corrosion behaviour of the welded joint showed pitting corrosion. The heat affected zone in the weldment showed severity of corrosion when compared to that of the base metal. The poor corrosion resistance of the weldment was attributed to the low quality finish of the weldment, which resulted in unstable weld microstructure that resulted in acceleration of pitting corrosion due to ease of migration of chloride ions.

2. Corrosion of Solders

2.1. Research Article: "Corrosion and Leaching Behaviours of Sn-0.7Cu-0.05Ni Lead-Free Solder in 3.5 wt.% NaCl Solution". In this research article, a new lead-free solder alloy with composition Sn-0.7Cu-0.05Ni was investigated for its corrosion and leaching behaviour in 3.5 wt.% NaCl solution. The highest corrosion rate was observed in the alloy when compared to Sn-Cu and Sn-Ag-Cu alloys, from potentiodynamic polarization measurements. In contrast, 30-day leaching measurements showed reduction in leaching rate in the developed Sn-Cu-Ni alloy solder joint when compared to that of the Sn-Cu and Sn-Ag-Cu joints. This was attributed to the formation of thin passivation film after 15 days. The joint showed higher leaching rate when compared to the alloy due to galvanic corrosion at the surface, which was confirmed by the presence of tin oxides on the surface.

3. Nanocrystalline Ni-Surface Coatings

3.1. Research Article: "Improvement of Corrosion Behavior of Nanostructured Ni Coating by Jet Electrodeposition and Laser Remelting". In this research article, an effective method to improve the corrosion resistance of Ni coating predeposited on 304 stainless steel (1Cr18Ni9) by jet electrodeposition has been reported. The Ni coating was treated by laser remelting so as to improve the coating microstructure and interfacial properties. Corrosion experiments revealed that the as-coated Ni surface had optimal corrosion resistance due to fine grains and dense microstructure when compared to the uncoated substrate. After laser remelting, the corrosion rate decreased significantly owing to the modification in microstructure and enhanced bonding between the coating and substrate. It was identified that the corrosion behaviour of Ni coating on steel substrate can be greatly enhanced by employing laser remelting of the coating.

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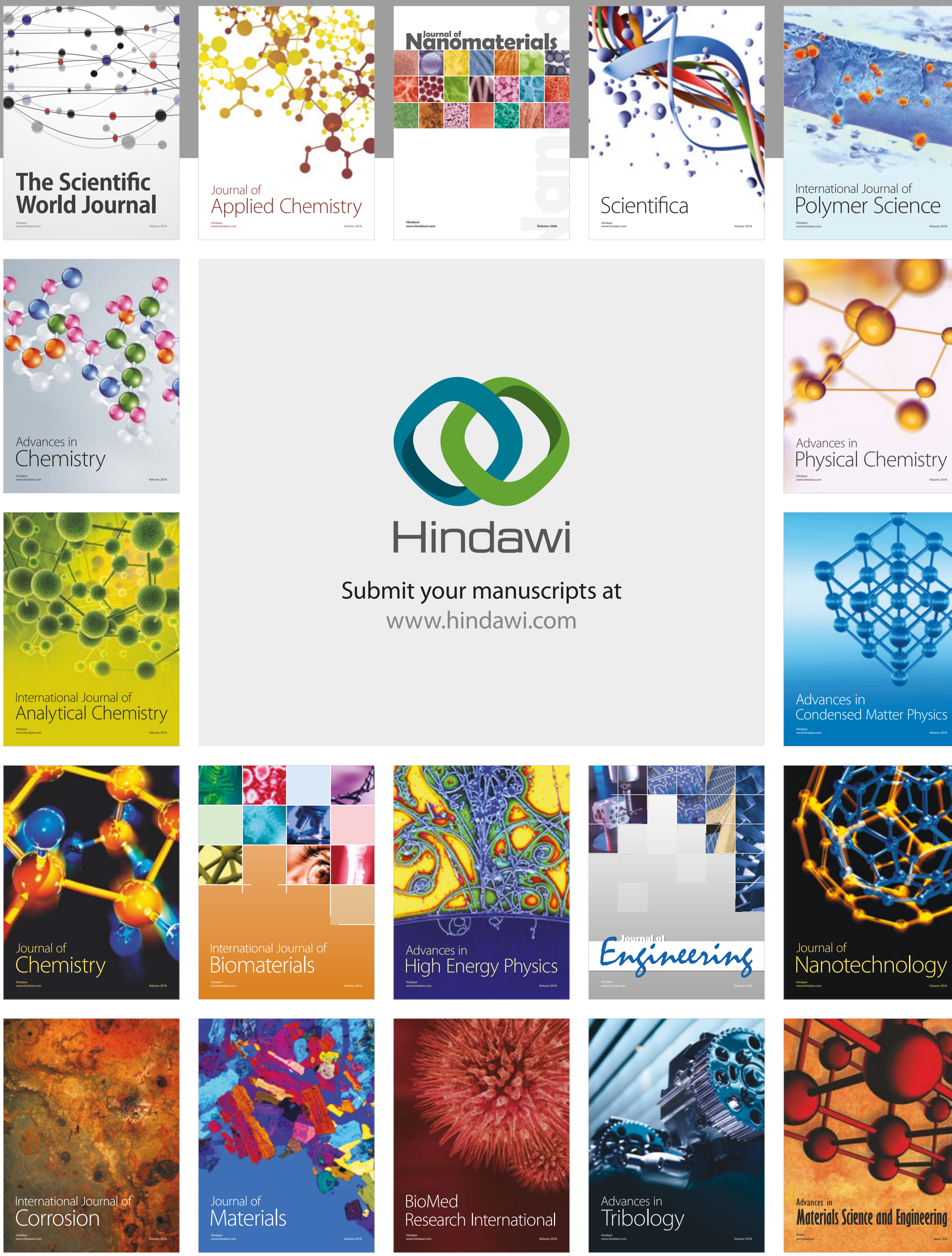
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