Photo-generated cathodic protection of mild carbon steel using electrophoretically deposited layers of TiO_2 nanoparticles

Ji Hoon Park[1], Jong Myung Park[2]

[1]*Technical Research Laboratories, POSCO, Gwangyang 545-875, Republic of Korea*
[2] *Graduate Institute of Ferrous Technology, Pohang University of Science and Technology (POSTECH), Pohang 790-784, Republic of Korea*
jihun@posco.com

Carbon steel suffers from corrosion when exposed to the atmosphere. Various methods have been employed to prevent corrosion, such as alloying with elements more noble than base metal, using protective coatings and providing cathodic protection. Sacrificial cathodic protection is one of the methods used, and it is a versatile and powerful approach for preventing the corrosion of carbon steel. Zinc is one of the most commonly used coatings for sacrificial cathodic protection, which provides superior corrosion resistance for carbon steel [1, 2]. The zinc coating provides corrosion protection by being sacrificially dissolved. This occurs because the electrochemical potential of zinc is more negative than that of steel. The zinc coating provides protection while it is dissolving itself, but the duration of protection is limited by the amount of zinc in the coating. A newly introduced approach instead uses photocatalytic TiO_2 as an anti-corrosion coating material, which is non-sacrificial [3-7]. A TiO_2 coating is a good insulation layer because of its electrochemical stability, and it can be used as a photo-generated anode for non-sacrificial protection due to its photocatalytic activity. Under solar illumination, a TiO_2 coating can shift the electrochemical potential of a steel substrate toward values lower than the corrosion potential of steel. In the present work, we evaluated the photo-generated cathodic protection provided by TiO_2 coatings on the mild carbon steel. There have been many attempts to deposit nano-sized materials onto steel, such as physical vapor deposition, chemical vapor deposition, electrochemical vapor deposition and deposition by plasma technologies [10-14]. Deposition processes that can take place at room temperature and ambient pressure should be advantageous in many ways compared to the aforementioned methods, which require high temperatures and a vacuum environment [15]. The colloidal deposition route is a typical example of an ambient pressure, room temperature process. Colloidal deposition methods include electrophoretic deposition, which can be used to deposit nano-sized functional materials on a solid substrate. EPD has recently been attracting attention as a powerful method for the fabrication of nano-structured, thin ceramic composite films on conductive substrates. It can be used for a variety of applications, and it is simple and cost effective [16-19]. In the present work, we used electrophoretic deposition (EPD) to deposit TiO_2 photo-catalysts onto carbon steel to fabricate a corrosion protection layer. The corrosion protection performance of the EPD layer was evaluated in terms of photo-generated cathodic protection. In order to compare the photo-generated cathodic protection behaviors of the EPD layers on carbon steel, we also deposited a TiO_2 EPD layer onto ITO (Indium Tin Oxide) glass and AISI Type 304 stainless steel and used those as reference specimens.The surface morphology of the deposited sample was observed by scanning electron microscopy (SEM). The composition of the EPD layer and the degree of reduction were determined by X-ray diffraction (XRD) with CuKa radiation. The optical properties of the electrodes were also characterized with a UV–Vis diffuse reflectance spectrophotometer. Furthermore, the anti-corrosion performance was evaluated by using various electrochemical testing techniques. Open circuit potential (OCP) measurements and the potentiodynamic polarization test were conducted on EPD samples using a Gamry Reference 600 with a PCI4 Controller. The same tests were carried out under the same conditions with UV irradiation to evaluate photo-generated cathodic protection. A 200 W mercury-xenon lamp was used as an ultraviolet (UV) light source. The coated specimen, saturated calomel electrode (SCE) and graphite rod counter electrode were immersed in 3.5% NaCl. In some cases, the electrochemical corrosion test was carried out at different pH levels..

References:
[1] J. C. Hudson, J. F. Stanner, *J. Iron Steel Inst*. 175 (1953) 381.
[2] J. E. M. Mayne, *Br. Corros. J*. 5 (1970) 106.
[3] T. Imokawa, R. Fujisawa, A. Suda, S. Tsujikawa, Zairyo-to-Kankyo 43 (1994) 482.
[4] T. Konishi, S. Tsujikawa, *Zairyo-to-Kankyo* 46 (1997) 709.
[5] J. Huang, T. Shinohara, S. Tsujikawa, *Zairyo-to-Kankyo* 48 (1999) 575.
[6] Y. Ohko, S. Saitoh, T. Tatsuma, R. Fujisawa, *J. Electrochem. Soc.* 148 (2001) B24.
[7] G. X. Shen, Y. C. Chen, J. Li, *Thin Solid Films* 489 (2005) 130.
[8] X. B. Chen, S. S. Mao, *Chem. Rev.* 107 (2007) 2891
[9] P. D. Cozzoli, M. L. Curri, A. Agostiano, *Chem. Commun.* (2005) 3186.
[10] M. Jakob, H. Lebanon, P.V.J. Kamat, *Am. Chem. Soc.*126 (2004) 4943.
[11] S. H. Elder, F. M. Cot, Y. Su., S. M. Heald, A. M. Tyrysgkin, M. K. Bowman, Y. Gao, A. G. Joly, M. L. Balmer, A. C. Kolwaite, K. A. Magrini, D. M. Blake, *J. Am. Chem. Soc.* 122 (2000) 5138.
[12] H. Tada, A. Hattori, Y. Tokihisa, K. Imai, N. Tohge, S. J. Ito, *Phys. Chem. B* 104 (2000) 4585.
[13] T. Tatsuma, S. Saitoh, P. Ngaotrakanwiwat, Y. Ohko, A. Fujishima, *Langmuir*, 18 (2002) 7777.
[14] P. F. Fu, Y. Luan, X. G Dai, *J. Mol. Catal. A: Chem.* 221 (2004) 81.
[15] A. K. Geim, K. S. Novoselov, *Nat. Mater.* 6 (2007) 183.
[16] A. K. Geim, *Science 324* (2009) 1530.
[17] M. D. Stoller, S. J. Park, Y. W. Zhu, J. H. An, R. S. Ruoff, *Nano Lett. 8* (2008) 3498.
[18] S. Stankovich, D. A. Dikin, G. H. B. Dommett, K. M. Kohlhaas, E. J. Zimney, E. A. Stach, R. D. Piner, S. T. Nguyen, R. S. Ruoff, *Nature* 442 (2006) 282.
[19] X. L. Li, X. R. Wang, L. Zhang, S. W. Lee, H. J. Dai, *Science* 319 (2008) 1229.