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Method for preventing hydrogen embrittlement using plasma process

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Hydrogen has attracted much attention as a clean, renewable, and sustainable source of secondary energy. However, to encourage the widespread use of hydrogen as an energy source, it is necessary to address issues such as hydrogen embrittlement. To solve this issue, stainless still (SUS316L) and/or aluminum alloy (A6061) have been used for high-pressure hydrogen gas tanks and pipes that are highly resistant to hydrogen embrittlement. However, as these materials are expensive, applications such as fuel cell for vehicles and/or home power supply. It is economical to apply a coating of A6061 on the inner surface of a tank or pipeline, which is composed of a low-cost material such as carbon steel. Many researchers studies about the coating, and they have shown the resistance of aluminum oxide films to hydrogen entry at a hydrogen gas pressure below 24MPa. In a hydrogen energy system, it is necessary to consider the design of components that can withstand high-pressure (100MPa) hydrogen gas. We have also prepared functional thin films under various deposition conditions, such as titanium dioxide (TiO_2) and zinc oxide (ZnO) using the plasma processing method, and all of them showed high quality, including high crystallinity and hardness without substrate heating. We also prepared A6061 thin films using a conventional magnetron sputtering method [1-2] on the small size of JIS S25C steel (hereinafter, S25C substrate) substrate. Experimental results suggest that A6061 film can prepared on the S25C substrate, and the ~40 μm thickness A6061 film is highly resistant to hydrogen entry into the material used in corrosive environments. To improve the properties of superhard material surfaces on long cylinder rods, hard materials such as tungsten, carbon, and titanium were prepared on a carbide steel cylinder rod by a new magnetron sputtering deposition method using a modulated magnetic field. During the deposition, plasma was generated between the cylinder rod anode substrate and the cylinder pipe targets, and a modulated magnetic field was used to improve the axial and radial uniformities of the film and deposition rate. Experimental results showed that the surface morphology of the film became smooth, and the surface roughness of the film decreased. Deposition rate and film uniformity increased with the use of a modulated magnetic field, and friction coefficient increased as a result of the film preparation used.

In this study, A6061 thin film is prepared inside surfaces of the cylinder pipes a new magnetron sputtering deposition method, and studies about the properties of the A6061 film. In addition, hydrogen entry prevention property by the film prepared using plasma process was investigate.

Film property of hydrogen entry prevention was investigated. The film was prepared by the conventional magnetron sputtering deposition method as mentioned above. To investigate the hydrogen entry prevention property, two S25C steel substrates were coated by the magnetron sputtering method. After the deposition, one of the substrate were immersed in 20 mass% ammonium thiocyanate aqueous solution at 313 K for 48 hour to charge hydrogen. And then, same bending stress of 875 MPa add to both substrates until the film fractured. Picture of substrates before coating (a), after film deposition (b), 2×10^4 times bending without hydrogen charge test (c) and 2×10^4 times bending with hydrogen charge test (d) were shown in Fig. 1. As the results, both of the thin film coated S25C steel substrates with and without hydrogen charged were fractured all of them were fractured at the 2×10^4 times bending. However, both of them were not fractured before 1×10^4 times bending, not shown here. In our previous work, S25C steel substrates with hydrogen charged were broken before 1×10^3 times. Therefore, the results suggest that the bending stress tolerance of the S25C steel substrates with A6061 coating after hydrogen charging is almost same of the S25C steel substrate without hydrogen charging. This may be due to plasma coating thin film effect for the resistant to hydrogen entry into the material used in corrosive environments.

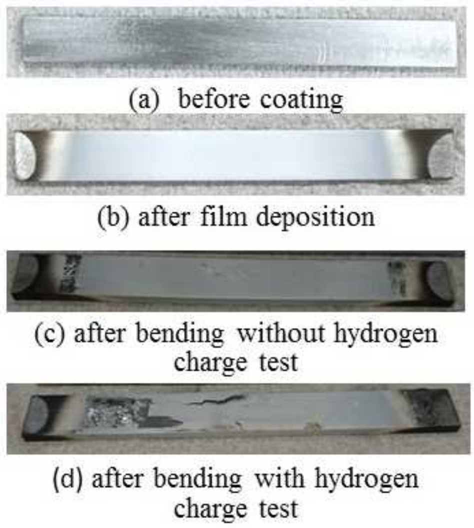

Fig. 1. Picture of substrates before coating (a), after film deposition (b), 2×10^4 times bending without hydrogen charge test (c) and 2×10^4 times bending with hydrogen charge test (d).

References
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