Mechanoelectrochemical Catalysis of the Effect of Elastic Strain on a Platinum Nanofilm for the ORR Exerted by a Shape Memory Alloy Substrate

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Abstract

In this research, a novel way to examine the elastic strain effect on a platinum catalysis surface during oxygen reduction reaction (ORR) has been developed. A NiTi shape memory alloy was selected as substrate to provide both tensile and compressive strain by using the nature of two-way shape memory effect for the first time. The experimental results clearly show that the compressive strain can enhance the ORR activity, while the tensile strain has the opposite effect during ORR.

Keywords: ORR, platinum thin film, elastic strain effect, catalysis

A recent paper published in *Journal of the American Chemical Society* by M. Du, *et al*. introduced a novel and convincing way to examine the effect of elastic strain on catalysis surfaces during oxygen reduction reaction (ORR). According the d-band theory, the elastic strain on a metal catalysis surface can influence the electro-catalytic behavior of the metal. However, there are few effective ways to separate this "strain effect" with the "ligand effect", which can also affect the electro-catalytic reactivity in thin film or nano-particle catalysis systems. This article published by M. Du, *et al*. successfully separates the "strain effect" from "ligand effect" by cleverly choosing NiTi shape memory alloy as substrate to introduce both tensile and compressive elastic strain.

The polycrystalline 10nm and 5nm Pt films were deposited at room temperature onto a pre-deformed NiTi substrate using direct current magnetron sputtering. By changing the temperature to according phase transformation temperature, the shape memory alloy substrate can either expand 4% or contract 7.5% strain. Thus, the NiTi substrate can provide both tensile and compressive strain to the Pt film deposited on its surface without any chemical/composition change of film surface.

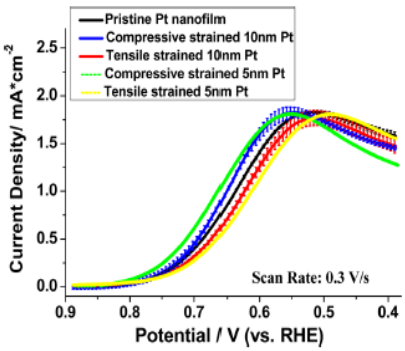

Figure 1. Polarization surves of the ORR of 10 and 5nm Pt nanofilm under different strain states at a scan rate of 0.3V/s. The data of 10 nm Pt nanofilm are shown with strandard deviation. [1]

The researchers then examined the catalytic behavior of the Pt thin films at different elastic strain levels. As shown in Figure 1, the compressive strain improves the Pt thin film ORR activity,

while the tensile strain reduces it. More specifically, the 5 nm Pt film at compressive strain reflects a 52% enhancement of the kinetic rate constant and a 27 mV positive shift of the half-wave potential compare with strain-free Pt film. In contrast, a 35% decrease of the rate constant and a 26 mV negative shift of the half-wave potential have been observed for the 5 nm Pt at tensile strain.

This work clearly shows the elastic strain on the catalysis surface can indeed shift its catalytic activity. These experimental results demonstrate that it is possible to precisely manually control the catalysis reaction rates. It is very important to modify the existing fuel cell systems to further increase their efficiency.

Reference

[1] M. Du, *et al*., *JACS*, 2015, doi: 10.102/jacs.5b03034.