

Activities of Pseudomorphic Pt Layers Electrochemically Prepared on Au(111) for Various Electrocatalytic Reactions

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Introduction. Ultra-thin metal layers on the foreign metal substrates have been attracting interests because of their unique physical and chemical properties, particularly their high electro-catalytic activities. Such special catalytic activity is due to their unique surface atomic arrangements and their induced surface electronic energy.

Because Pt is one of the best catalysts for various chemical reactions, Pt is one of the most precious and expensive metals, and Pt resources are limited, it is greatly expected that catalytic activity of Pt becomes higher and that loading amount of Pt becomes less. Recently, we succeeded in electrochemically constructing a pseudomorphic Pt monolayer on a single crystal Au(111) surface and its atomic arrangement was precisely confirmed to be pseudomorphic by resonance surface X-ray scattering (RSXS) measurements [1,2]. In this report, electrocatalytic activity of the electrochemically prepared pseudomorphic Pt monolayers on the Au(111) surface for oxygen reduction reaction (ORR) and hydrogen oxidation reaction (HOR) was investigated using rotating ring-disk electrode (RRDE) system [3].

Experimentals. Pt monolayer on Au(111) (Pt/Au(111)) was electrochemically deposited by the procedures as previously reported [1,2]. Using the RRDE system, ORR measurements were performed in an oxygen saturated 0.1 M HClO₄ with a scan rate of 10 mV s⁻¹ from 0.15 V to 1.05 V (vs. RHE) with several rotating rates. HOR measurements were performed in a hydrogen saturated 0.1 M HClO₄ with a scan rate of 10 mV s⁻¹ from -0.15 V to 0.50 V (vs. RHE) with several rotating rates. Electrocatalytic activities of ORR and HOR were analyzed based on the Koutecky-Levich and Butler-Volmer equations, respectively.

Results and Discussion. Figure 1a shows a set of linear sweep voltammograms (LSVs) for ORR of the Pt/Au(111) disk-Pt ring electrode. Based on the results of LSVs, Figure 1b shows the Koutecky-Levich plots whose linearity and parallelism suggest first-order kinetics with respect to molecular oxygen. From the slope and intercept of this plot, number of electrons and kinetic current density, J_k , for ORR were obtained to be 3.8 and 0.81 mA cm⁻² (at 0.90 V vs. RHE), respectively. These values

indicated that the product of ORR is water and that the electrocatalytic activity of Pt/Au(111) is higher than that of Pt(111).

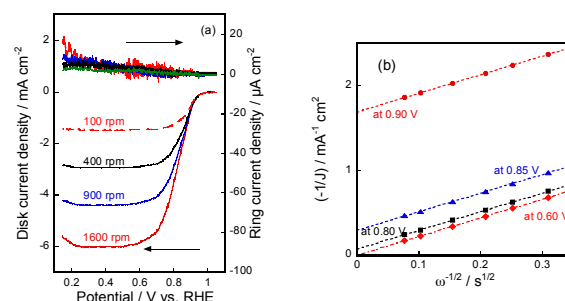


Figure 1 (a) LSVs for ORR of Pt/Au(111) electrode with various rotation rates. (b) Koutecky-Levich plots of Pt/Au(111) electrode.

Figure 2a shows a set of LSVs for HOR of the Pt/Au(111) electrode. Figure 2b shows the expansion of Figure 2a in the potential region between -0.006 V and +0.006 V. From the slope of Fig. 2(b), the exchange current density, J_0 , for HOR was obtained 1.253 mA cm⁻² whose value was larger than Pt(111), indicating that the electrocatalytic activity of Pt/Au(111) is higher than that of Pt(111).

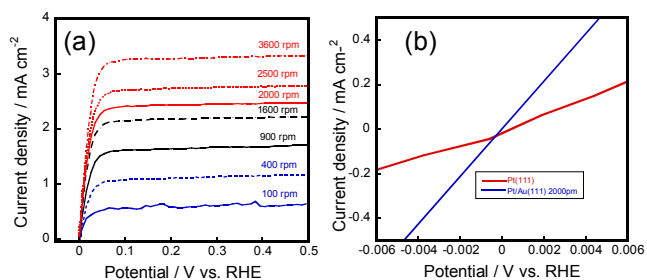


Figure 2 (a) LSVs for HOR of Pt/Au(111) electrode with various rotation rates. (b) LSVs for HOR of Pt/Au(111) electrode with 2000 rpm in the potential region between -0.006 V and +0.006 V.

Thus, we can conclude that the electrocatalytic activity of the pseudomorphic Pt monolayer on Au(111) for both ORR and HOR is higher than that of Pt(111). We are now investigating the dependence of the thickness of the pseudomorphic Pt layers on the electrocatalytic activity.

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References.

- [1] T. Kondo et al., *Electrochim. Acta*, 55, 8302 (2010).
- [2] M. Shibata et al., *J. Phys. Chem. C*, 116, 26464 (2012).
- [3] T. Kondo et al., *Chem. Lett.*, 40, 1235 (2011).