

## Galvanostatic Pulse Plating of PtRu Nanoparticles for Direct Methanol Fuel Cells

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### Introduction

Nanoparticulate PtRu has attracted considerable attention as an anode electrocatalyst for direct methanol fuel cells. The objective for PtRu research activity is the synthesis of PtRu with desirable atomic distributions in both bulk compositions and surface arrangements. Conventional synthetic route involves chemical reduction method which unfortunately requires post-treatments to remove surfactants and reaction products, not to mention the challenges in composition control [1,2]. In contrast, electrodeposition is able to form PtRu directly, albeit with a reduced coulombic efficiency [3-5]. In this work, we adopted the pulse galvanostatic deposition to prepare PtRu nanoparticles on carbon clothes and evaluated their methanol oxidation abilities by cyclic voltammetry (CV). Composition and phase analysis were conducted using TEM, ICP-MS, and XPS.

### Experimental

The electrolyte contained 5 mM of  $\text{H}_2\text{PtCl}_6$  and ruthenium precursors in 0.25 M  $\text{H}_2\text{SO}_4$  aqueous solution. The PtRu nanoparticles were deposited on the pretreated carbon cloth. By adjusting variables including  $T_{\text{on}}$ ,  $T_{\text{off}}$ , as well as values for current density, we obtained PtRu in distinct sizes and distributions.

### Results and discussion

Fig. 1 presents the results of CV analysis from samples with different  $T_{\text{off}}$ , which indicated substantial differences in current responses. It was shown that 400 ms of  $T_{\text{off}}$  revealed the highest catalytic behavior. Since the concentrations of Pt and Ru precursors were minute, we rationalized that local depletion of depositing ions was likely to occur during pulse deposition. Therefore, sufficient  $T_{\text{off}}$  is necessary for mass transport in order to grow PtRu in successive pulses. Correspondingly, we observed smaller and fewer PtRu nanoparticles when the  $T_{\text{off}}$  was reduced gradually. In contrast, as the  $T_{\text{off}}$  was too large, the PtRu particles became aggregated and their catalytic ability was not improved further. Table 1 lists the characteristics of PtRu, showing an increase of  $T_{\text{off}}$  leads to reducing Ru amount. Fig. 2 provides the typical TEM images of PtRu nanoparticles from  $T_{\text{off}}$  of 200 ms

and 400 ms, respectively.

### Conclusions

We have successfully deposited PtRu nanoparticles using pulse galvanostatic electrodepositions for desirable composition control to obtain enhanced CV performances.

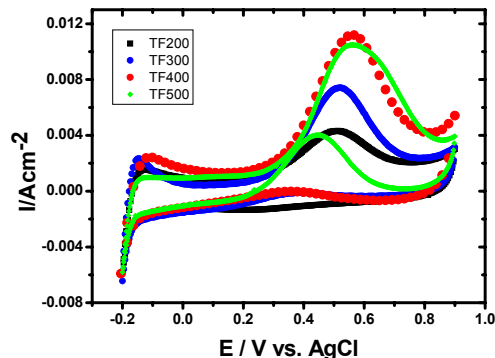


Fig. 1: CV responses of deposited PtRu nanoparticles with different  $T_{\text{off}}$ .

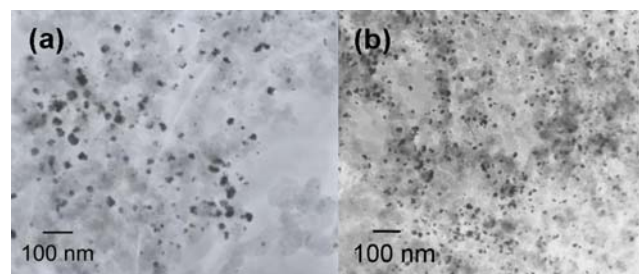


Fig. 2. TEM image of PtRu prepared with (a)  $T_{\text{off}} = 200$  ms. (b)  $T_{\text{off}} = 400$  ms.

Table 1. Characterization of pulse plating PtRu

	Pt atomic%	Ru atomic%	Total weight ( $\text{mgcm}^{-2}$ )
TF200	54.6	45.4	0.129
TF300	61.2	38.8	0.085
TF400	64.1	35.9	0.068
TF500	77.9	22.1	0.091

### References

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