X-ray Absorption Spectroscopic Characterization of Pt-Ru Nanoparticles Reduced in Hydrogen and Carbon Monoxide

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Pt-Ru bimetallic nanoparticles attracted broad interest in recent years due to their extensive applications in proton-exchange-membrane fuel cells as the anode for electro-oxidation of methanol or hydrogen. However, the atomic distribution and the degree of alloying in Pt-Ru nanoparticles significantly influence their catalytic properties. In the present study, X-ray absorption spectroscopy was employed to investigate the reducibility of Pt and Ru atoms in different atmospheres (such as 10% H_2 in He or 20% CO in N_2) at 100°C. It is expected that the reducibility of Pt and Ru atoms depends on the structural details of Pt-Ru bimetallic nanoparticles. For comparison, two commercial samples were studied. The Pt-Ru/C catalyst, with a nominal loading of 20 wt% Pt and 10 wt% Ru (in an atomic ratio of 1:1), was obtained from E-TEK Inc. (labeled as E-T sample). The other unsupported Pt-Ru (1:1) black was supplied by Johnson Matthey Co. (the J-M sample).

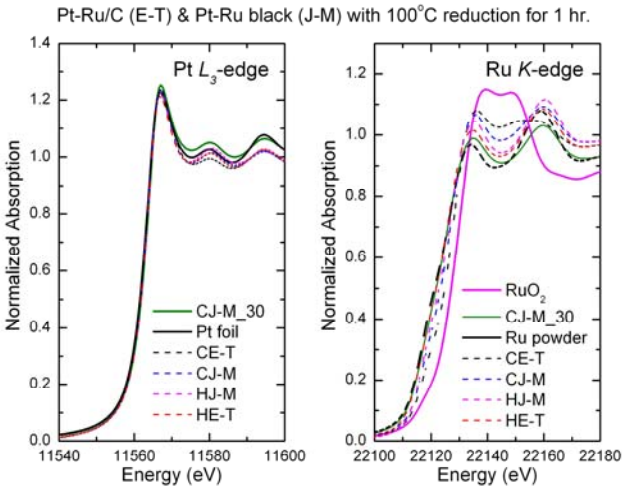

Figure 1. XANES spectra of E-T and J-M samples after being reduced by H_2 or CO at 100°C. Some reference compounds and the J-M sample reduced by CO at 30°C are also included for comparison.

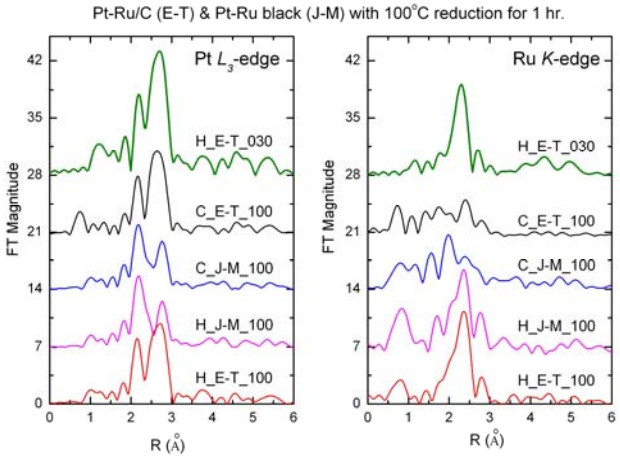

Figure 2. Fourier transform of k^3-weighted EXAFS data of E-T and J-M samples after being reduced by H_2 or CO at 100°C. The E-T sample reduced by H_2 at 30°C is also included for comparison.

The XANES spectra and radial distribution function (Fourier transformed EXAFS spectra) are shown in Figures 1 and 2, respectively. It is clear to note that Pt can be reduced to metallic state by either 10% H_2 or 20% CO. In contrast, the reducibility of Ru in 20% CO is quite low even at 100°C. Nevertheless, the degree of reduction of Ru in the J-M sample is slightly higher than that of E-T sample. Since Pt is easier to be reduced than Ru, the presence of Pt atoms can usually promote the reduction of neighboring Ru atoms. As a result, Ru can be partially reduced by 20% CO on the J-M sample, which has a higher degree of alloying between Pt and Ru than does the E-T sample. Such a promotional effect becomes very weak for the E-T sample even though it possesses a surface composition enriched in Ru (according to previous studies).