X-ray absorption spectroscopic characterization of Pt-Ru bimetallic nanoparticles

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X-ray absorption spectroscopy was employed to characterize two carbon-supported Pt-Ru catalysts, which are commercially available to be utilized as the anode of proton-exchange-membrane fuel cells, and one unsupported Pt-Ru black. On all these samples, both Pt and Ru were partially oxidized in the as-received form. Upon exposure to hydrogen at room temperature, Pt-Ru nanoparticles were fully reduced to the metallic state. The average size of bimetallic nanoparticles on each sample was around 2 nm. Detailed EXAFS data analysis revealed that both Pt and Ru atoms segregated to some extent, as evidenced by the higher preference for homometallic bonding than for heterometallic bonding. Particularly, $N_{Pt\text{-}Pt}$ is always larger than $N_{Ru\text{-}Ru}$, indicating the formation of a core-shell structure with Pt enriched in core and Ru enriched in shell. Such a core-shell structure retained even at an elevated reduction temperature of 473 K. Among three samples studied in this work, unsupported Pt-Ru black has the most uniform atomic distribution (the highest degree of alloying). The variation in surface composition among these three Pt-Ru bimetallic samples can account for the different electrochemical performance.