Light-induced Preparation of Multi-component Cocatalyst for Photocatalytic Water Splitting

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INTRODUCTION

Deposition of cocatalyst, which is typically in the form of nanoparticles of metals or metal oxides, on the surface of semiconductor photocatalyst is one of the useful strategies to enhance the photocatalytic activity[1)]. Photodeposition method is widely applied for the deposition of cocatalyst. This method is based on photochemical reaction. Exited electrons and holes are generated in a semiconductor photocatalyst by irradiation of light, which has larger energy than the band gap of the semiconductor, and reduce or oxidize metal precursors. As the result, metal or metal oxide nanoparticles are loaded on the semiconductor surface.

In recent study, multi-component cocatalysts, which consisted of more than two metal species, have been reported to show more efficient promotional effect for photocatalytic water splitting than single-component one[2)]. However, in most cases, such light-induced method has been applied to single-component cocatalysts, while there have been few reports on nanoparticles which consist more than two metal species.

Our group has developed a new light-induced method (simultaneous photodeposition, SPD) to prepare multi-component nanoparticles, aiming to improve the activity for photocatalytic water splitting. We have reported that composites containing Rh and Cr with different electronic states and morphological characters can be introduced simultaneously on various semiconductors by light irradiation[2)].

In this study, we applied a SPD method to photochemically prepare multi-component nanoparticles on the $SrTiO_3$ surface[3)]. We chose Cr as the paired metal, and combined various transition metals and Cr to create photocatalytic H_2 evolution promoters.

EXPERIMENTAL

$SrTiO_3$ powder was dispersed in 10 vol.% methanol aqueous solution containing various amounts of K_2CrO_4 and a transition metal precursor. A SPD method was carried out in a top-irradiation type reaction cell connected to a closed gas circulation system. The solution was completely degassed and irradiated for 5 h (Xe lamp, $\lambda \geq 300$ nm). Water splitting reactions were conducted under same condition but in pure water.

RESULT & DISCUSSION

Photocatalytic water splitting activities of $SrTiO_3$ modified with various transition metals loaded with or without Cr are shown in Table 1. In most cases, the activity was decreased by co-existence of Cr. On the other hand, with co-deposition of Cr, a distinct promotional effect was observed in the combinations of Au-Cr and Pd-Cr, in terms of the generation of O_2, which was not observed without Cr. This result indicates that the SPD method is stable for the combinations of Pd-Cr and Au-Cr to introduce effective multi-component cocatalyst for water splitting. Moreover, in the Pd-Cr system, not only morphology and electronic state of Pd-Cr nanoparticles but also cocatalyst effect for water splitting varied with the concentration of Cr.

Table 1. Overall water splitting on various Metal and Cr nanoparticles loaded $SrTiO_3$ under UV irradiation[a]

Entry	Metal	Activity / μmol h^{-1}			
		without Cr		With 0.1 wt% Cr	
		H_2	O_2	H_2	O_2
1	None	< 0.1	N.D.	< 0.1	N.D.
2	Pt	5.3	2.1	4.6	2.3
3	Cu	0.1	1.2	0.3	0.9
4[b]	Au	0.3	< 0.1	1.0	0.5
5	Ag	0.2	N.D.	0.1	N.D.
6	Ir	0.7	0.3	0.1	0.3
7	Pd	0.8	< 0.1	1.7	0.5
8	Rh	5.3	1.9	5.3	2.2

[a]Catalyst: 100 mg, [b]200 mg; Pure water 100 mL; 300 W Xe lamp (λ > 300 nm); top irradiation cell

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