Water splitting by photocatalysts with intermetallic compounds $Mg_{1-x}Al_xB_2$ as cocatalysts

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Abstract: There are few reports that used intermetallic compounds as the cocatalysts. Here we report the properties of $Mg_{1-x}Al_xB_2$ ($0 \leq x \leq 1$) as cocatalyst for water splitting photocatalysis. The electronic structure such Fermi level or work function of $Mg_{1-x}Al_xB_2$ is controllable with the Al content x. The roles of the cocatalyst could be controlled by changing as the cocatalyst's composition x.

Keywords: Intermetallic compound, sacrificial agent, half reaction.

1. Introduction

For increasing demand for renewable energy, photocatalysts for water splitting have been more extensively studied for recent years. Cocatalysts, such as Ni/NiO[1], are often combined with the semiconducting photocatalysts to improve the activity for water splitting reaction. Precious metals, transition metals, and their simple oxides have been frequently used as the cocatalysts. On the other hand, there are only a few reports that used intermetallic compounds as the cocatalysts. MgB_2, AlB_2 and their solid solution $Mg_{1-x}Al_xB_2$ [2,3] are intermetallic compounds with a layered structure. Fermi level of $Mg_{1-x}Al_xB_2$ is controllable with the Al content x. Thus, the behaviors of $Mg_{1-x}Al_xB_2$ as cocatalysts are of great interest and importance from both scientific and technological aspects. Here we report the properties of $Mg_{1-x}Al_xB_2$ ($0 \leq x \leq 1$) as cocatalyst for water splitting photocatalysis.

2. Experimental

We used $KCaSrTa_5O_{15}$ developed by Kudo et al [4] as the semiconducting photocatalyst. The cocatalyst was mixed with $KCaSrTa_5O_{15}$ and small amount of ethanol in a mortar and the mixture was heated at 573 K *in vacuo* to obtain the cocatalyst-loaded photocatalysts. The loading amount of the cocatalyst was 10 wt%. The photocatalytic water splitting experiments were carried out with flow system. Photocatalysts were dispersed in 700 mL of water and photo-irradiated by 350 W high pressure Hg lamp from the inside of a quartz-made photocatalytic reactor. The outlet gas was analyzed with an on-line GC equipped with a BID detector.

3. Results and discussion

Figure 1 illustrates crystal structure of MgB_2. Table 1 summarizes the results of photocatalysis tests. MgB_2 / $KCaSrTa_5O_{15}$ showed the activity improved about 3 times higher compared to pristine $KCaSrTa_5O_{15}$.[5,6]

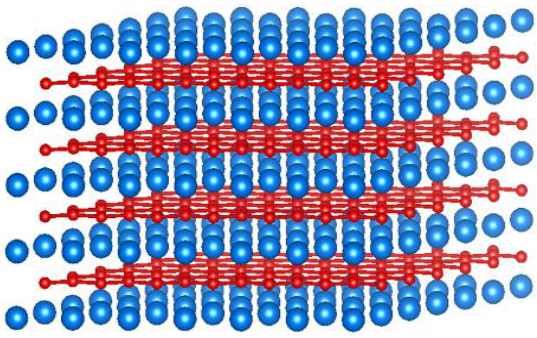

Figure 1. Crystal structure of MgB_2.

For MgB_2 / $KCaSrTa_5O_{15}$, we examined half reaction rates of H_2 and O_2 evolutions using the sacrificial agents CH_3OH and $AgNO_3$, respectively. From these results, it was concluded that MgB_2 acted as a cocatalysts contributing to the oxidation reaction. Furthermore, TEM observations of photocatalysts on which Pt and PbO_2 were photo-deposited gave more detailed information about the roles of the cocatalysts in the water splitting reaction, and it was found that the Al content x had great influence on the role of the cocatalysts.

Table 1. Results of photocatalytic water splitting.

photocatalyst	solvent	product amount for 7h / μmol	
		H_2	O_2
$KCaSrTa_5O_{15}$	water	131	63
MgB_2/ $KCaSrTa_5O_{15}$	water	399	199
$Mg_{0.75}Al_{0.25}B_2$/ $KCaSrTa_5O_{15}$	water	277	109
$Mg_{0.5}Al_{0.5}B_2$/ $KCaSrTa_5O_{15}$	water	252	120
$Mg_{0.25}Al_{0.75}B_2$/ $KCaSrTa_5O_{15}$	water	147	58
AlB_2/ $KCaSrTa_5O_{15}$	water	191	14

4. Conclusions

MgB_2 was found to act as a useful cocatalyst for photocatalytic overall water splitting. It was found that controlling the electronic structure of $Mg_{1-x}Al_xB_2$ by changing the composition x had great influence on the role of the cocatalysts.

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