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燃料電池担持触媒及びスーパーキャパシタ電極用の ナノ構造化材料の開発

Development of Nanostructured Materials for Fuel Cells Electrocatalyst Support and Supercapacitor Electrode

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成 果 の 概 要

Fuel cells and supercapacitors emerge in the recent few years in response to the needs for clean and sustainable energy supplying devices. These two devices use carbon for their core components. In addition to its prominent electrical properties, carbon is economical and abundant in stock. It is therefore understandable that carbon is currently the most popular electrocatalyst support and super-

capacitors electrode material.

The popularity of carbon makes the development of carbon an old yet still hot research topic. Nowadays, it is focused on the nanostructuration and functionalization for a high performance electrochemical energy supplying devices. We were working on this particular subject, using spray pyrolysis to synthesize macroporous nitrogen-functionalized carbon particles from melamine resin.

Formation of the macropores relied on the utiliza-

Figure 1 SEM images of melamine-derived (a) dense carbon, (b) porous carbon using 170 nm PSL template, and (c) porous carbon using 270 nm PSL template.

tion of polystyrene latex (PSL) as the sacrificial template. PSL decomposed in the middle of the pyrolysis process, *i.e.* at approximately 400°C. Droplets were generated by ultrasonic nebulizer and nitrogen was used as carrier gas. Droplets containing melamine resin and PSL underwent thermal decomposition in a tubular furnace of which temperatures were divided into five stacks, *i.e.* 200, 400, 800, 1000, and 1000°C. The rapid thermal decomposition allowed preservation of the nitrogen in the precursor, that microporous carbon particles with a nitrogen content of 5.44% were obtained at the end of the synthesis. The pore size is controllable, depending on the size of PSL, as seen in Figure 1. The optimum porous structure was obtained using a PSL to melamine resin mass ratio of 1.6 : 1 using 270 nm PSL as template (Figure 1 (c)).

Although we have successfully synthesized nano-structured and functionalized carbon particles which are potential to be used as electrocatalyst support and supercapacitors electrode, we realized the cyclic stability issue when using carbon in some electrochemical devices. Based on this concern, another material intended as a replacement for carbon was further developed.

The material is called Magnéli phase TiO_x , or

simply TiO_x . This is a substoichiometric form of TiO_2 having a chemical formula of $\text{Ti}_n\text{O}_{2n-1}$. TiO_x basically has a similar structure with rutile TiO_2 . Due to the oxygen vacancies, the electrons of Ti atoms are shared in some places, forming a shear plane which acts as a good electron conductor. In short, TiO_x , especially Ti_4O_7 , has a high electron conductivity of which value is comparable to that carbon delivers.

In recent years, several efforts have been devoted to synthesizing Magnéli phase TiO_x , typically by the reduction of rutile titania (TiO_2) under high temperatures between 600 and 1000°C. However, the high reduction temperature promotes heavy sintering. In response to this problem, we employed plasma method to synthesize nano-sized TiO_x particles from TiO_2 , which we believe to be the first time in the world.

The rapid nucleation inside the plasma reactor induced the formation of small sized particles (approximately 20 nm). The electrical resistivity of the synthesized TiO_x could be as low as 0.04 $\Omega\cdot\text{cm}$. Electrochemical characterization of the nano-particles shows remarkable stability of TiO_x nano-particles in a strongly oxidizing environment (1 M HCl, oxygen saturated).

外部発表成果

論文発表

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