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Polymers for Reversible Hydrogen Storage Inspired by Electrode-active Materials in Organic Batteries

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Redox-active polymers with electrochemical reversibility and rapid electrode reaction rates are employed to develop organic electrode-active materials employed in organic batteries, based on their self-exchange reactions in polymer layers. Negative charging of the electroneutral redox polymers results in a significant increase in basicity to allow protonation of each redox-active site in the polymer. Since most of the hydrogenated products are no longer redox-active, aprotic battery electrolytes are employed to avoid the hydrogenation in organic batteries. On the other hand, organic compounds that undergo reversible hydrogenation, such as toluene to yield methylcyclohexane, have been studied as hydrogen storage materials. However, the hydrogenation with hydrogen gas usually proceeds via a highly energy consuming process. We anticipated that electrolytic hydrogenation of the redox-active molecules would provide a much simpler process. We have found that ketone-containing polymers stored hydrogen via the electrolytic process in the presence of water at room temperature. The resulting alcohol polymer evolved hydrogen gas by warming under mild conditions with an iridium catalyst. The hydrogenation/dehydrogenation cycle was accomplished throughout the polymer layer, meaning that all of the ketone groups in the polymer were equilibrated with the hydrogen gas according to $>C=O+H_2 \rightleftarrows >CH\text{-}OH$ in the presence of the iridium catalyst. The reversible hydrogenation/dehydrogenation was extended to various types of organic groups in the polymer, providing many types of the hydrogen carrier polymers as a new class of energy-related functional polymers. The easy handling and moldable nature of the organic polymers indicate the feasibility of applying them as pocketable hydrogen carriers.

Keywords : Organic battery, Hydrogen carrier, Energy storage