Promising anode materials for Ni-MH batteries and alkaline fuel cells

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Modern metal hydride power supplies are considered reliable and safe in operation, with relatively high energy efficiency and low cost manufacturing. Nickel-metal hydride (Ni-MH) batteries are widely used in portable electronic devices due to their high energy storage density, overcharging resistance and good environmental compatibility. Alkaline metal hydride fuel cells can also operate at near normal temperatures and do not require expensive catalysts.

Various intermetallic compounds (IMC) of the AB_5, $AB_{3\text{-}3.5}$, and AB_2 types are widely used as working materials for metal hydride power sources [1]. AB_5 type compounds have high catalytic activity and cyclic stability, but their electrochemical capacity is limited. AB_2-type IMC have higher capacitive characteristics compared to traditional AB_5-type IMC, $AB_{3\text{-}3.5}$ also show a higher electrochemical capacitance, but their cyclic stability is greatly reduced during oxidation and corrosion in an alkaline electrolyte.

The use of new Mg-containing alloys $(La,Mg)Ni_3$ (AB_3-type) and $(La,Mg)_2Ni_7$ (A_2B_7-type) with a high capacity instead of traditional $(La,Mm)Ni_{5-x}Ti_x$ (AB_5-type) served as a significant incentive for the next wave of research development. Cheaper manufacturing of carbon structures (graphene, carbon nanotubes and nanofibers) contributed to the creation of a large range of new composite materials with high performance characteristics. Work on the formation of new alloys, composites and technologies for their processing is carried out all over the world, and the number of publications is increasing exponentially. In addition, the increase in the cost of raw materials, the deterioration of the environmental situation in the world, the rise in the cost manufacturing technologies and the tightening of safety requirements make it possible to consider metal hydride power sources as an important alternative to lithium-ion sources.

The staff of the complex of laboratories for hydrogen materials science of the FRC PCP MC RAS is actively investigating the hydrogen sorption and electrochemical characteristics of new promising composite materials for reversible hydrogen storage and metal hydride power sources [2–4]. In the course of the research, intermetallic compounds of the AB_5, $AB_{3–3.5}$ and AB_2 types were studied. It has been shown that AB_5 intermetallic compounds based on lanthanum are relatively easy to activate, they have high kinetic characteristics and good cyclic stability. Partial replacement of La by lighter Mg, as well as by other rare earth elements in $(La,Nd,Mg)Ni_3$ intermetallic compounds with the $PuNi_3$ structure, leads to an increase in hydrogen and electrochemical capacity by more than 20% compared to $LnNi_5$. The capacity of electrodes using $La_{1.5}Nd_{0.5}MgNi_9$ reached 400 mAh/g at a discharge current density of 100 mA/g. AB_2 type intermetallic compounds with the Laves phase structure demonstrate high performance characteristics and cyclic stability, which makes them promising materials for electrodes of metal hydride power sources. The electrodes based on the studied alloys are quickly activated and reach the maximum capacity (370 mAh/g at 100 mA/g) by the fourth charge-discharge cycle. To improve the electrical conductivity of electrode materials, primarily cathode materials, composite materials with additives of carbon nanostructures (nanotubes, nanofibers, graphene-like material) were obtained. It is shown that the electrical conductivity of $Ni(OH)_2$ with carbon nanostructures (3 wt %) is much higher than that of hydroxide with graphite. A technique for the formation of composites by synthesizing nickel hydroxide directly on the surface of carbon nanostructures by precipitation from an aqueous solution of nickel nitrate with ammonium hydroxide was developed. This method made it possible to obtain composites with electrical conductivity an order of magnitude higher than mechanical mixing, and the specific capacity of the electrodes was increased by more than 30% (265 mAh/g).

References

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