Carbon-Based Composites

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Carbon-based composites are materials in which a primary component in the form of a carbon structure or structures (graphene, carbon nanotubes, mesoporous carbon, etc.) and usually an inorganic phase or phases are combined into one system. Such a material is expected to exhibit additive or synergetic interfacial effects resulting in enhanced properties, such as reactivity in catalytic or electrocatalytic reactions.

water electrolysis hydrogen production energy conversion carbon composites

1. Introduction

Compared with traditional carbon materials, nanocarbons always exhibit higher electrical conductivity, larger surface area, tunable structural hierarchy, ultra-thin graphitic layer, and low dimensional properties. These unique features endow nanocarbons with multifunctionalities to strongly couple with other catalytically active components, resulting in significantly enhanced performances. In recent years, transition metal/carbon (TM/C) composites have surfaced as a new class of effective catalysts for electrochemical oxygen and hydrogen evolution reactions. These composites usually exhibit the reactivity characteristics of their components (metal compound or carbon); however, the synergetic and interfacial effects are sought for and designed to endorse the material with enhanced electrocatalytic activities. A combination of cheap components, i.e., carbon and Fe-, Co-, Ni-phases and promising reactivities render them perfect candidates for the replacement of precious metal-based electrodes. Thus, new material formulations of the TM/C type, such as hierarchically porous carbon-supported TMs, carbon network supported TMs or carbon encapsulated TMs, are being developed to explore the possibility of deriving new functionalities. Parallel to developing new carbon morphologies, carbon doping, especially with S and N, is used to obtain enhanced properties of the hybrid materials.[1]

2. Synthesis of Carbon-Based Nanocomposites

The preparation of the composites starts with the surface functionalization of carbon components to increase their reactivity. The great abundance of the hydroxide/oxide carbon materials results from the relative ease of the preparation of the structured catalysts. The synthesis procedures usually do not require high temperature treatments and a variety of precursors can be used. Among the reported synthesis methods, by far the most popular is the hydrothermal treatment of pretreated carbon with metal salt in the Teflon-lined autoclave placed in a conventional oven/dryer. Although from a thermodynamical point of view, metal sulfides are less stable than metal oxides under oxidizing potentials and metal nitrides and phosphides are less stable than sulfides and so on, an abundance of such electrocatalytic systems has been reported in recent years also for the OER. It can thus be anticipated that metal chalcogenides, nitrides, and phosphides would be readily oxidized, at least on the surface, to the respective metal oxides/hydroxides in the strongly oxidative environments of OER. Therefore, care must be taken when characterizing such systems and particular attention should be paid to the spent catalysts. Carbon composite materials with metal phosphides can be obtained by a procedure involving a direct combination of components, e.g., ultrasonication of $Ni_{12}P_5$ and oxidized MWCNTs. However, most of the described methods to synthesize carbon-nitrides and -phosphides involve the preparation of a precursor that is subsequently high-temperature treated to obtain the final material.[1]

References

1. Paweł Stelmachowski; Joanna Duch; David Sebastián; María Jesús Lázaro; Andrzej Kotarba; Carbon-Based Composites as Electrocatalysts for Oxygen Evolution Reaction in Alkaline Media. *Materials* **2021**, *14*, 4984, 10.3390/ma14174984.