Pore Structure Controllable Holey-graphene for High-Performance Energy Storage

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Recently, there have been great interests in developing porous carbonaceous for energy storage devices, such as battery and supercapacitor. Graphene is an ideal electrode material in this regard due to high electrical conductivity, high surface area, and chemical stability. However, the re-stacking of graphene flakes significantly lower the volume capacitance.[1-2] The previously reported works on preparing porous graphene are considered as an effective method to address this issue.[3] Nevertheless, most reports suffer from the uncontrollable pore structure, including pore size, homogeneity, density, and edge state, making it unable to apply as active materials in energy storage.

Here, we report a novel methodology of creating size and shape controlled holes on graphene by catalytic etching through copper nanoparticles under a hydrogen atmosphere. The homogenous and hierarchical pore structures on graphene were controlled through the rapid and gradual thermal annealing, respectively. The hierarchical multimodal pores(via HRTEM and BET) starting from macro(85 nm) and meso(10nm) to micro(0.6 nm) pores. As for the homogenous hole-graphene, the ultra-high pore densities of up to $1x10^3$/ μm2 with uniform pores of ~20 nm was achieved, which is the highest among the reported data on holey-graphene. In electrochemical supercapacitor, the holey graphene shows one order higher capacitance than that of the non-holey reduced graphene(Figure 1). The diffusion coefficient values which is not only one order higher than non-holey graphene but shows an order increase with 15 times increase in mass loading. The energy density is 120% increase than non-holy graphene. This pore-size and shape-controlled holey-graphene may pave the way for advanced energy storage devices with high energy density.

Figures

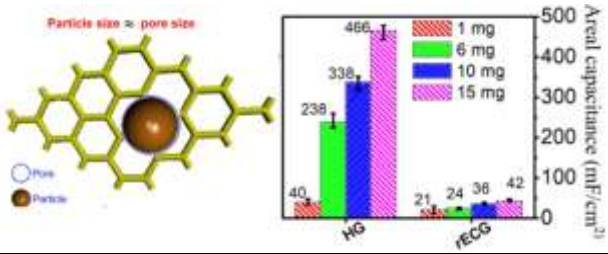

Figure 1: The pore structure controllable holey-graphene, by a nano-catalytic etching procedure, significantly enhance the electrochemical capacitance more than one orders. The performance continues to increase with mass loading from 1~15 mg.

Reference

[1] C. H. Chen, S. W Yang, M. C. Chuang, W. Y. Woon and C. Y. Su, (2015), Nanoscale, 7, 15362.
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[3] J. H. Chang, Y. H. Hung, X. F. Luo, C. H. Huang, S. Jung, J. K., Chang, J. K. and C. Y. Su, (2016), RSC Advances, 6, 8384.