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Mesoporous $NiCo_2S_4$ nanostructures grown on 3D graphene-nickel foam for supercapacitor applications

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Electrical energy storage and conversion systems play a vital role in the efficient and cost-effective utilization of clean energy from renewable sources [1]. In particular, electrochemical energy storage and conversion devices such as batteries, fuel cells, and supercapacitors are considered the most promising candidate for portable and mobile applications. Among them, supercapacitors have advantages due to their long-term cycling stability, safety operation mode and high power output [2]. The energy storage properties of the supercapacitors mainly depend on electrode materials, electrolytes and separators [3]. Improvement in electrode materials have been affected the electrochemical performance of supercapacitors positively. Nano-sized (0D, 1D, 2D and 3D) electrode materials not only increase the surface area but also increase the active sites between the electrode material and the electrolyte solution and shortens the ionic diffusion paths during the reaction [1,4,5]. Recently, 3D architecture substrates (nickel foam, graphene foam) with numerous pores have been widely investigated for supercapacitor electrodes. Among these substrates, 3D graphene skeleton possesses excellent cycling stability and high power density due to electrochemical double-layer capacitor performance of graphene [5]. Graphene has been used as ideal matrix to anchor electroactive pseudocapacitive ternary metal sulfide composites to improve the performance of supercapacitors [6,7]. The excellent synergistic effect between the graphene layers and ternary metal composites leads to improved specific capacitance, rate capability and cycling stability [6]**.** Therefore, in this study $NiCo_2S_4$ nanostructures were synthesized on 3D-graphene nickel foam substrate by two step processes, namely, CVD (chemical vapor deposition) method and hydrothermal reaction to produce graphene and $NiCo_2S_4$ nanostructures respectively and used it as electrode for supercapacitors.

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