



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI  
SHORT ABSTRACT OF THESIS

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**SHORT ABSTRACT**

Graphene, on behalf of its unique physical properties, has been considered as an ideal material for energy storage applications like supercapacitor or hydrogen generation. However, their intrinsic face-to-face restacking tendency greatly restricts their practical adoptability. In particular, high area and mass specific energy density with high rate performance is very tough to attain in supercapacitors. On the other hand, requirement of high overpotential for anodic oxygen evolution reaction (OER) is the main hurdle for hydrogen generation by catalytic water splitting. The present thesis work addresses these challenges through systematically developing high performing graphene hydrogel based diverse nano-hybrids via scalable synthesis processes at room-temperature. For instance, the co-assembly of graphene and polyaniline (PANI) nanowires resulted in a porous and restacking controlled hydrogel-hybrid which exhibited a maximum areal capacitance of  $2.2 \text{ F cm}^{-2}$ . Further, a compressed gel hybrid obtained by controlling the hydration level of the hybrid hydrogel resulted in an excellent volumetric capacitance of  $560 \text{ F cm}^{-3}$ , while retaining high rate performances ( $81.3\%$  at  $20 \text{ mA cm}^{-2}$ ). Importantly, by down-sizing PANI nanostructure ( $<50 \text{ nm}$ ) via bio-mimicking “graphene hydrogel-organic”-interfacial surface polymerization process, high specific capacitance ( $503 \text{ F g}^{-1}$ ) and excellent rate performance ( $88.6\%$  at  $30 \text{ A g}^{-1}$ ) could be obtained even at commercial level of mass loading. The issue of low energy density were further addressed by developing a graphene-MXene hydrogel-hybrid. An asymmetric supercapacitor consisting of graphene-MXene-hydrogel as cathode and a graphene-PANI-hydrogel as anode resulted in a large cell-voltage of  $1.4 \text{ V}$  and an ultra-high energy density of  $30.3 \text{ Wh kg}^{-1}$ . The excellent performance of all these hydrogel hybrids can be associated with the uniform hybridization and the presence of porous conducting graphene framework. Furthermore, the low OER activity of the electrocatalysts was addressed by developing size and shape tuned versatile MOF-graphene heterostructures by adopting “graphene hydrogel-organic”-interfacial reaction. As-developed rod-like nickel-cobalt-iron tri-metallic MOF-graphene hybrid exhibited a remarkably low overpotential (at  $10 \text{ mA cm}^{-2}$ ) of  $255 \text{ mV}$  and a Tafel slope of  $44.3 \text{ mV dec}^{-1}$  surpassing the performance of other MOF based OER catalysts. The excellent OER activity of the MOF-graphene hybrid was attributed to the presence of conducting graphene backbone and the high surface area with abundant exposed active sites due the morphology tuning of the MOF nanostructure. We believe, the present thesis work will provide a guideline to develop versatile graphene based functional nano hybrids via large scale facile processing, and will find widespread applications not only in energy storage but in other fields namely oxygen reduction reaction, gas storage, oil adsorption, or adsorption of contaminants from water.