ABSTRACT

Graphene has been considered as a rising star of the two dimensional materials owing to its attractive physicochemical properties. However, the inert nature of a pure graphene greatly limits its catalytic properties in various applications. Therefore, functionalization of graphene is one of the best ways to explore the intrinsic properties out of graphene. In particular, the functionalization of graphene or reduced graphene oxide (rGO) with metals, metal-oxides and polymers nanocomposite have gained great interest in the field of energy and environmental aspects. In general, the highly conductive rGO sheet is utilized as a potential solid support for catalysts, which not only prevent the carrier recombination but also enhance the carrier mobility to drive various solar energy conversion applications. In the present study, the rGO based nanocomposites were synthesized and employed in several applications, such as photocatalalytic and sonophotocatalytic degradation of organic pollutants, photocatalytic water splitting, polymer solar cell and oxygen reduction reaction. The specific carrier transport role of rGO sheet along with the AgI-TiO\textsubscript{2} photocatalyst was investigated during the photodegradation of different organic pollutants [methyl orange (MO) and rhodamine B (RhB)]. It was found that the superoxide ($O_2$\textsuperscript{−•}) radicals and photogenerated holes ($h^+$) were the main reactive species for the degradation of MO and RhB, respectively. An excellent electron transport property of rGO sheets effectively produced a large amount of $O_2$\textsuperscript{−•} radicals and thereby showed a 60% enhancement in MO degradation. On the otherhand, only 12% increased RhB degradation was observed since the
RhB degradation was mainly depending on photogenerated $h^+$, where the role of rGO was almost negligible. Besides, the interfacial electron transport properties of rGO sheet was identified by placing it at the heterojunction of Cu$_2$O and C$_3$N$_4$ photocatalyst. Thus, an excellent electron transportation by the rGO sheet at the heterojunction significantly enhanced the photocatalytic 4-nitrophenol reduction performance of the resultant Cu$_2$O-rGO-C$_3$N$_4$ nanocomposite. The rGO supported CuO-TiO$_2$ photocatalysts were synthesized for the sonophotocatalytic degradation of organic pollutants using diffused sunlight as a source of irradiation. A maximum synergistic effect of ~10 fold was achieved for the first time with the combination of diffused sunlight, ultrasound and CuO-TiO$_2$/rGO nanocomposite. Similarly, the electron storing and shuttling properties of rGO sheet supported Cu$_2$O-TiO$_2$ photocatalyst was also evaluated for the photocatalytic water splitting to produce H$_2$. The presence of rGO sheet at the heterojunction of $p$-$n$ junction formed Cu$_2$O-TiO$_2$ photocatalyst showed ~7 fold increased H$_2$ production rate ($110968 \mu$mol h$^{-1}$ g$_{cat}^{-1}$) than the Cu$_2$O-TiO$_2$ photocatalyst ($16656 \mu$mol h$^{-1}$ g$_{cat}^{-1}$) without rGO support. This is the highest H$_2$ production rate achieved in graphene based photocatalysts. Furthermore, the rGO was covalently grafted with pyridyl benzimidazole based Ru complex decorated polyaniline assembly (PANI-Ru) and employed as an electron donor in bulk heterojunction based polymer solar cell. As a result, the ultrafast excited state charge separation and electron transfer role of rGO sheet significantly accelerated the open circuit potential ($V_{oc}$) of the device made using rGO/PANI-Ru nanocomposite. Apart from that, nitrogen doped graphene quantum dots decorated 3D MoS$_2$-rGO nanohybrid were designed and demonstrated as an efficient electrocatalyst for oxygen reduction reaction. The resultant 3D
nanohybrid not only exhibited a superior oxygen reduction reaction (ORR) performance but also showed a better methanol tolerance property.