Graphene Derivatives for Catalysis and Energy Storage

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Covalent functionalization of graphene leads to graphene derivatives with significantly modulated electronic, magnetic and surface properties with respect to pristine graphene. The graphene derivatives can be applied in various sensing, energy storage and catalytic applications. A wide range of various approaches have been developed for covalent graphene functionalization so far. Despite the progress in direct covalent functionalization of graphene, this approach suffers from a low reactivity of graphene. Recently, we developed alternative route toward graphene derivatives based on chemistry of fluorographene (FG). FG is a stoichiometric graphene derivative (having C_1F_1 composition), which can be prepared by chemical delamination of graphite fluoride in a large scale. FG undergoes various chemical reactions at rather mild conditions [1], which lead to graphene derivatives. FG is susceptible for reductive defluorination, nucleophilic attack, Grignard [2], Bingel-Hirsch [3], photo Diels-Alder [4] and Sonogashira [5] reactions. The reactions result in homogeneously and densely surface functionalized graphene derivatives. Such materials can be utilized in a broad spectrum of applications. Hydroxyfluorographenes bear room-temperature antiferromagnetic or ferromagnetic ordering based on their composition [6, 7]. Cyanographene, i.e., graphene functionalized by nitrile groups, and graphene acid bearing carboxyl groups are well biocompatible materials suitable for further functionalization [8]. Conjugating graphene acid with redox active centers, e.g., ferrocene, leads to redox active heterogenous catalyst for arene CH insertion [9]. Pd nanoparticles with controllable size can be grown on graphene acid. The prepared nanohybrids were highly active catalysts in the Suzuki–Miyaura cross coupling reaction [10]. Anchoring Cu ions to cyanographene resulted in a mixed valence single-atom catalyst (SAC) very active in oxidative amine coupling reactions [11]. Graphene acid was covalently conjugated with dehydrogenase enzymes to a nano-bio catalyst exhibiting good performance in electrocatalytic reduction of CO_2 [12], also due to conductivity of graphene acid. It is worth noting that graphene acid shows metal free catalysis for alcohol oxidation, posing a new limit in carbocatalysis [13]. The high-conductivity and water dispersibility predispose graphene derivatives for electrode materials in supercapacitors [3, 14].

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