

Supplementary information:

1. XPS analysis (*This content of XPS analysis has already published in Carbon as shown below¹.*)

The XPS spectra of the reduced GO are shown in Figure S1. Figure S1(a) shows the GO C1s core level spectrum clearly indicating a considerable degree of oxidation. The functional groups and composing structure include aromatic C=C and aliphatic C-C; hydroxyl carbon C-O; epoxy carbon C-O-C; carbonyl carbon C=O; carboxylate carbon O-C=O²⁻⁴. Figure 1a shows that the percentage of sp³ carbon (30.1%) was higher than that of sp² carbon (25.4%), indicating a typical C1s spectrum of oxygenated carbon. Figure S1(a) confirms that epoxy functional groups are most common on basal GO plane. The majority of oxygen species contained carbonyl moieties. Another oxidation species such as C-O and O-C=O are present in lower quantity. The C=O compounds mainly due to single ketones and quinines⁵ which are generally located at the edges of GO sheets, but may also be bound to the basal plane as carbonyl groups^{5,6}. The C-O (6.5%) is composed by hydroxyl groups; the O-C=O species are present primarily at the edges of GO sheets⁶⁻⁸. Figure S1(b) shows XPS spectrum indicating the percentages of carbon and oxygen after NaBH₄ reduction, there was a large reduction in oxygen content, and this is associated with a decrease in sheet resistance. The XPS C1s spectrum of N-GNS following the first reduction step

using NaBH_4 indicates that sp^2 carbon atoms increased at the consumption of sp^3 carbon, making the structure more graphene-like compared to GO. However, the carbonyl and carboxyl groups were converted to hydroxyl, indeed, all that remained were hydroxyl (C-OH) groups. This result was expected, since NaBH_4 is not reactive with this functionality as described by previous researches^{2,9}. Then, for increasing the fraction of sp^2 carbon and decreasing oxygen concentration, N-GNS was reduced by EG again at second step.

Figure S1(c) shows the XPS spectrum of N-GNS following the second reduction step, using EG. The spectrum clearly indicates a graphene-like structure for NE-GNS, with lower oxygen content and greater sp^2 hybridization, following EG reduction. Not only the peaks of the carbonyl and carboxyl groups almost disappear but also the amount of epoxy and hydroxyl groups are reduced by using EG. It exhibits that EG can reduce all kind of oxygen containing functional groups¹⁰.

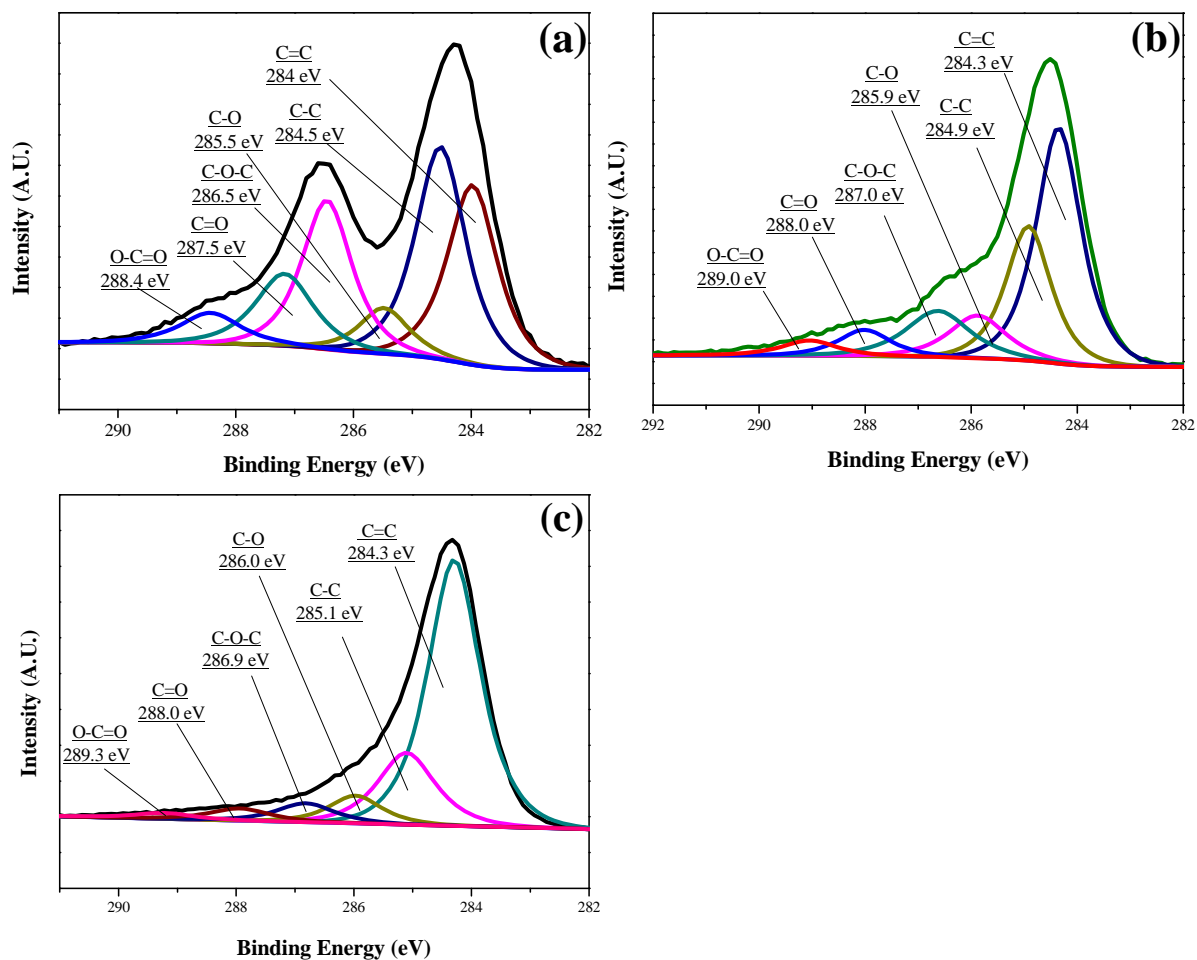


Figure S1. The C1s peak in the XPS spectrum of (a) GO, (b) N-GNS, (c) NE-GNS.

2. TGA analysis

This work used thermogravimetric analysis (TGA) to determine the quantity of organic substances grafted on graphene surface. All free and un-grafted molecules on the graphene surface were washed before TGA analysis.

Figure S2(a) shows that the NE-GNS exhibits a high thermal stability. The weight loss of 2.7 wt% below 700 °C illustrates residual oxygen-containing functional

groups on graphene. All organic substances were assumed to decompose below 500°C so that the quantity of grafted organic molecule could be measured by the weight retention at this temperature. Figures S2(b) and S2(c) show the weight retentions of polymer chains grafted on graphene surface at 500°C were 81.2 wt% and 76.4 wt%, respectively. Hence, it can be estimated that the quantities of PAA and PMA grafted on graphene are 18.8 wt% and 23.6 wt%. Figure S2(c) also indicates that NE-PMA-GNS starts to degrade at 250 °C which may be attributed to the decomposition of the surface-grafted acryl amide. The existence of acryl amide may cause that NE-PMA-GNS possessed higher amount of grafted polymer chains than that of NE-PAA-GNS.

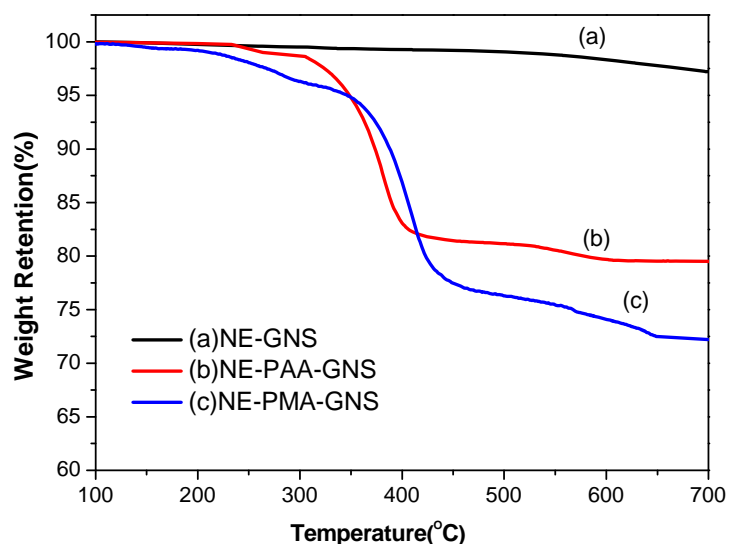


Figure S2. The TGA curves of (a) NE-GNS, (b)NE-PAA-GNS, and (c)NE-PMA-GNS

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