Improving the drug delivery characteristics of graphene oxide based polymer nanocomposites through the “one-pot” synthetic approach of single-electron-transfer living radical polymerization

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Abstract

Graphene oxide (GO) based polymer nanocomposites have attracted extensive research interest recently for their outstanding physicochemical properties and potential applications. However, surface modification of GO with synthetic polymers has demonstrated to be trouble for most polymerization procedures are occurred under non-aqueous solution, which will in turn lead to the restacking of GO. In this work, a facile and efficient “one-pot” strategy has been developed for surface modification of GO with synthetic polymers through single-electron-transfer living radical polymerization (SET-LRP). The GO based polymer nanocomposites were obtained via SET-LRP in aqueous solution using poly(ethylene glycol) methyl ether methacrylate (PEGMA) as the monomer and 11-bromoundecanoic acid as the initiator, which could be effectively adsorbed on GO through hydrophobic interaction. The successful preparation of GO based polymer nanocomposites was confirmed by a series of characterization techniques such as ^1H nuclear magnetic resonance, Fourier transform infrared spectroscopy, thermogravimetric analysis, transmission electron microscopy and X-ray photoelectron spectroscopy. The resultant products exhibit high water disperisibility, excellent biocompatibility and high efficient drug loading capability, making these PEGylated GO nanocomposites promising candidates for biomedical applications.

Key words: Graphene oxide, surface modification, single-electron-transfer living radical polymerization, polymer nanocomposites, drug delivery

1. Introduction

Graphene, a carbon nanomaterial, was first reported by Novoselov et al in 2005.[1] It is a kind of single atom thick layer of carbon materials with a large specific surface area, remarkable mechanical, electrical and optical properties, which raised increasing interest in both physics and material fields.[2-6] However, unilaminar graphene sheets tended to aggregate into three-dimensional (3D) graphite by prominent π - π interaction at high concentrations or temperature, such drawback has impacted the performance of graphene and limited its potential. Graphene oxide (GO), a quasi two-dimensional (2D) layer structure, can be regarded as graphene sheets, which connected with some hydroxyl, epoxy and carboxyl groups on its surface.[7] It can be mainly prepared through oxidizing graphite powders with some strong oxidants to get the single layer or few layer GO sheets.[8] Because the distance between GO layers is greater than that of graphene sheets and the oxygen-containing functional groups are in favor of forming hydrogen bonds in the aqueous solution. Therefore the GO sheets showed much better dispersity as compared with graphene sheets. However, such advantage is still not enough to obviously improve the performance of GO related materials. Therefore great effort has been devoted to the preparation of different GO based nanocomposites included GO composited with metal nanoparticles, semiconductor nanoparticles, metal oxide nanoparticles and polymers.[9-17] Among them, the GO based polymer nanocomposites should be the most important ones due to the combination advantages of both GO and polymers.[17-29]

Previously, fabrication of GO based polymer nanocomposites through controlled living radical polymerization methods such as reversible addition fragmentation chain transfer (RAFT) polymerization, atom transfer radical polymerization (ATRP) and single-electrical transfer living radical polymerization (SET-LRP) has been developed.[29-32] These GO based polymer nanocomposites have demonstrated to be promising candidates for different applications.[33] For example, Rouff *et al* have reported the surface modification of GO with polymers through surface-initiated ATRP. In this work, the polymerization initiator (Bromoisobutryl bromide) should

be first covalently immobilized on the surface of GO for polymer brush growth.[31] However, the water should be first removed from GO for immobilization of the initiator, that will in turn result in the restacking of GO sheets. The preparation of thermosensitive GO-polymer composites through RAFT polymerization was also demonstrated by Liu *et al.*[32] In Liu's work, the chain transfer agent (CTA) was first conjugated with perylene, and then the thermal response polymer brushes (PNIPAM) terminated with perylene were synthesized via RAFT polymerization. These perylene terminated polymer brushes can attach onto GO sheets through hydrophobic interaction. In our former report, a novel approach combines mussel inspired chemistry and free radical polymerization was carried out.[28] We demonstrated that GO can be functionalized with various polymers for different applications.[33] Nevertheless, most of these modification strategies are not easily to realize because immobilization of initiators and polymerization procedures are required under non-aqueous solvents. The complete removal of water from GO is a rather complex procedure and will lead to restacking of GO sheets into graphite oxides. Therefore, the development of novel, effective and simple surface modification strategies for preparation of GO based polymer nanocomposites is still highly desirable. SET-LRP is a novel emerged controlled living polymerization method with good controllability and high polymerization rate, that can be used for growth of polymer brushes under room temperature, air atmosphere and aqueous solution within short time.[34-41] More importantly, a large number of monomers such as poly(ethylene glycol) methyl ether methacrylate (PEGMA), N-isopropylacrylamide (NIPAM) and styrene sulfonic acid can be polymerized using SET-LRP.[30, 37, 42, 43] These features make SET-LRP very suitable for preparation of various homopolymers or copolymers in aqueous solution, low temperature and air atmosphere.

We present a facile and effective strategy for fabrication of GO based polymer nanocomposites through "one-pot" SET-LRP in aqueous solution (**Scheme 1**). The water soluble and biocompatible PEGMA was selected as the monomer. 11-Bromoundecanoic acid was employed as the initiator, which initiated the polymerization of PEGMA to generate PPEGMA brushes via SET-LRP. The

PPEGMA brushes can strongly attach to GO sheets in aqueous solution due to the hydrophobic interaction between GO sheets and alkyl chain of 11-Bromoundecanoic acid. The biomedical application potential of resultant products GO-PPEGMA was also examined.

Scheme 1 Schematic representation for the surface modification of GO with PPEGMA through a one-pot SET-LRP.

2. Experiments

2.1 Materials and Characterization

Graphite powders were purchased from Sinopharm Chemical Reagent Co., Ltd (Shanghai, China). PEGMA (MW: 950 Da, 98%) was obtained from Aladdin (Shanghai, China). Cuprous bromide (CuBr) and tris[2-(dimethylamino) ethyl] amine (Me_6TREN) as a catalytic system was supplied by Heowns (Tianjin, China). Dialysis membranes ($\text{MWCO} \geq 3500$ Da) were obtained from Viskase (America). The other chemical reagents mentioned in this experiment were got from Aladdin (Shanghai, China) of analytical grade and used directly without further purification. The synthetic materials were characterized by Fourier transform infrared (FT-IR) spectroscopy using KBr pellets. FT-IR spectra were obtained on a Nicolet 5700 FT-IR spectrometer (Thermo Nicolet Corporation) with a resolution of 4 cm^{-1} . The thermogravimetry

(TGA) was carried out on a TA instrument Q50 with a heating rate of $10\text{ }^{\circ}\text{C min}^{-1}$ using crucibles of aluminum. Samples weighing between 10 and 20 mg were heated from 30 to $600\text{ }^{\circ}\text{C}$ with N_2 as the carrier gas (40 mL min^{-1}). X-ray photoelectron spectroscopy (XPS) spectra were measured on a VGESCALAB 220-IXL spectrometer using an Al $\text{K}\alpha$ X-ray source (1486.6 eV). Transmission electron microscopy (TEM) images were recorded on a Hitachi 7650B microscope operated at 80 kV. The TEM specimens were obtained by placing a drop of a nanoparticle ethanol suspension on a carbon-coated copper grid. ^1H NMR spectra were recorded on Bruker Avance-400 spectrometer with CDCl_3 as the solvent.

2.2 Preparation of GO

The GO was prepared via a modified Hummers' method.[8] Briefly, 1 g graphite powder, 0.5 g NaNO_3 and 6 g KMnO_4 were added into a 500 mL conical flask. The container was next put in an ice-water bath. Then 46 mL concentrated sulfuric acid was added into the flask slowly. After that, 92 mL deionized water was dropwise added into the flask with stirring for 30 min at $90\text{ }^{\circ}\text{C}$. Then, 10 mL H_2O_2 and 100 mL H_2O was added slowly. The mixture was maintained the solution at room temperature for 30 min with ultrasonication. Finally, the mixture was centrifuged and washed with HCl (aq) for three times. And then the sediment was dialysed in deionized water for three days before GO was collected for further modification.

2.3 Preparation of GO-PPEGMA

The polymerization was carried out via SET-LRP using $\text{CuBr/Me}_6\text{TREN}$ as catalytic/ligand system in the presence of water. Briefly, 0.5 g GO, 0.13 g 11-Bromoundecanoic acid, 5.7 g PEGMA, 50 mL H_2O and 80 mg CuBr were added into a polymerization bottle. The reaction system was exhausted the air under a vacuum pump and filled with nitrogen for three times. After 10 min ultrasonic vibration the solution of 0.1 mL Me_6TREN in 3 mL CH_3CN was added into the polymerization bottle via injection. The polymerization bottle was immersed in an oil bath at $40\text{ }^{\circ}\text{C}$ and stirring for 2 h. Then reaction mixture was collected via repeated centrifugation and washing procedures for three times. The final products were dried

in vacuum at 40 °C.

2.4 Biocompatibility of GO-PPEGMA

Cell viability of GO-PPEGMA on A549 cells was determined by CCK-8 assay according to our previous reports.[44-49] Briefly, cells were seeded in 96-well microplates at a density of 5×10^4 cells mL^{-1} in 160 μL of respective media containing 10% FBS. After 24 h of cell attachment, the cells were incubated with 10, 20, 40, 80, 120 $\mu\text{g mL}^{-1}$ GO-PPEGMA for 12 and 24 h. Then nanoparticles were removed and cells were washed with PBS for three times. 10 μL of CCK-8 dye and 100 μL of DMEM cell culture media were added to each well and incubated for 2 h at 37 °C. Plates were then analyzed with a microplate reader (VictorIII, Perkin-Elmer). Measurements of dye absorbance were carried out at 450 nm, with the reference wavelength at 620 nm. The values were proportional to the number of live cells. The percent reduction of CCK-8 dye was compared to controls (cells not exposed to nanoparticles), which represented 100% WST reduction. Three replicate wells were used for each control and test concentrations per microplate, and the experiment was repeated three times. Cell survival was expressed as absorbance relative to that of untreated controls. Results are presented as mean $\pm$ standard deviation (SD)

2.5 DOX loading onto GO-PPEGMA

The loading of DOX onto GO-PPEGMA was performed by simple mixing GO-PPEGMA with DOX. In brief, 100 mL of GO-PPEGMA (0.2 mg mL^{-1}) and DOX (0.2 mg mL^{-1}) dispersed in PBS were thoroughly mixed and stirred at room temperature. After 24 h, the mixture was taken and centrifuged at 8000 rpm for 10 min. Then absorbance of DOX in the supernatant was determined using UV-Visible spectrometer with the wavelength at 490 nm and the concentration was calculated by a standard DOX concentration curve generated from a series of DOX solutions with various concentrations. The drug loading efficiency (DLE) was calculated from the following formula:

$$\text{DLE (w/w \%)} = (\text{weight of loaded drug/weight of CNT nanoparticles}) \times 100\%$$

2.6 Release behavior of DOX from GO-PPEGMA

The release behavior of DOX from the GO-PPEGMA was carried out at room temperature in PBS at pH values of 7.4 and 5.5. In brief, 10 mg GO-PPEGMA-DOX complexes were placed into a dialysis tube, which was dialyzed against 100 mL of PBS (release reservoir). The release reservoir was placed in a shaking bed at 37 °C with a rotation speed at 100 rpm, and 2.0 mL of release media in the reservoir was taken out at desired time interval.

3. Results and discussion

In this study, we demonstrated an efficient and economical method for preparing high water dispersible GO based polymer composites through a “one-pot” SET-LRP strategy. The initiator with a long alkyl chain could be easily adsorbed onto the surface of GO through hydrophobic interaction. And the synthetic polymers can be grown from the initiator through in situ polymerization. Compared with other modification strategies, this method is much more facile for “one-pot” SET-LRP method could successfully avoid the undesirable multiple steps like dewatering or immobilizing the initiators onto the surface of GO by employing highly active initiators. Thus we are secured that the strategy reported here is potentially used for mass production of GO based polymer nanocomposites. The resultant materials were characterized with a series of typical analysis methods including TGA, FT-IR, TEM, XPS and ^1H NMR.

The ^1H NMR spectroscopy was employed to characterize the GO-PPEGMA nanocomposites (**Fig. 1**). It was run in CDCl_3 to prove the occurrence of the in situ polymerization and attachment to the GO sheets. The signal peaks at 0.89, 1.29 and 1.99 ppm are ascribed to the protons of CCH_3 and CH_2 from PPEGMA and undecanoate, a strong peak at 3.66 ppm is corresponded to the four protons of $\text{OCH}_2\text{CH}_2\text{O}$ from PPEGMA chains while another strong signal peak at 2.70 ppm was ascribed to the H_2O of the sample. The peak at 3.40 ppm is mainly from the protons of OCH_3 of each PEGMA chain. The peak at 1.98 ppm can be ascribed to the CCH_2 of each PPEGMA. The peak at 4.19 ppm is corresponded to the COOCH_2 of the

polymer brushes. The information proves the successful modification of GO via “one-pot” SET-LRP.

Fig. 1 The ^1H NMR spectrum of modified GO-PPEGMA in CDCl_3 .

The GO and GO-PPEGMA were analyzed by TGA. As shown in **Fig. 2**, GO and GO-PPEGMA display the mass weight loss of 11.5 wt% and 5 wt%, respectively below 100 °C. The weight loss of these materials could be regarded as the water adsorbed on GO samples. Another obvious weight loss was occurred at 160-210 °C, this part of weight loss can be attributed to the decomposition of oxygen containing functional groups on the GO samples. The particular evident weight loss of GO-PPEGMA near 360 °C is largely corresponded to the dissociation of the organic polymer brushes that could convince the functional polymer brushes had been grafted onto the GO sheets. The weight loss of GO become much slow at the temperature above 230 °C, while significant weight loss was observed at about 360 °C (**Fig. 2A**). And the weight loss of GO and GO-PPEGMA from 100-600 °C are 38.5 wt% and 56.5 wt%, respectively. Therefore, we can draw a conclusion that there are about 28 wt% polymer was grafted onto GO sheets. On the other hand, the DTA curves of GO and GO-PPEGMA were displayed in **Fig. 2B**. As compared with GO, an sharp endothermic peak was observed in the DTA curve of GO-PPEGMA. The endothermic peak indicated that polymer brushes on GO were decomposed at this temperature.

Fig. 2 TGA (A) and DTA curves (B) of GO and GO-PPEGMA. As compared with GO, the weight loss of GO-PPEGMA is obviously greater than that of GO. On the other hand, a strong endothermic peak at 360 °C was found in the sample of GO-PPEGMA. These results confirmed that PPEGMA polymer brushes were indeed attached on the surface of GO.

FT-IR spectroscopy was also employed to characterize these two samples. As shown in **Fig. 3**, it is obvious that the modified GO has a series of novel peaks in 750-1750 and 2700-3050 cm^{-1} . The signal peak near 1100 cm^{-1} was ascribed to the C-O-C stretching vibration from PEGMA, suggesting that the polymer brushes are immobilized on the GO sheets. Another signal peak near 2860 cm^{-1} can be ascribed to the $-\text{CH}_2-$ and $-\text{CH}_3$ from PEG and 11-Bromoundecanoic acid. The signal at 1720 cm^{-1} from stretching vibration of C=O, suggesting that polymer brushes have been grafted onto the surface of GO sheets. The signal peak at 1550 cm^{-1} was ascribed to the C-C stretching vibration from PPEGMA and undecanoic acid. FT-IR spectra further supported that GO-PPEGMA nanocomposites have been successfully fabricated via “one-pot” SET-LRP.

Fig. 3 FT-IR spectra of GO and GO-PPEGMA. As compared with GO, Two peaks located at 2860 and 1550 cm⁻¹ were significantly enhanced, that can be ascribed to the alkyl chain of PEGMA and 11-Bromoundecanoic acid. On the other hand, the stretching vibration of C-O and C=O groups was observed at 1100 and 1720 cm⁻¹, respectively. All of these results confirmed that the successful formation of GO-PPEGMA composites.

The size and morphology of GO and GO-PPEGMA was observed by TEM images. As shown in **Fig. 4**, thin and highly wrinkled sheets were observed in the sample of GO, implied that graphite powders were successfully peeled into GO sheets. As compared with GO sheets, the thickness GO-PPEGMA sheets was increased to some extent. This further implied the polymer brushes have been successfully grafted onto the GO sheets through hydrophobic interaction. **Fig. 4D** is the diffraction rings of modified GO, it suggests that the sandwich was single graphene generated from the reduction of GO in a slightly alkaline solution.

Fig. 4 (A) TEM image of GO observed at low magnification; (B) and (C) TEM images of GO-PPEGMA, revealing that the polymer brushes had been grafted onto the GO sheets; (D) diffraction pattern of modified GO.

The chemical information of GO and GO-PPEGMA was defined by XPS. As shown in **Fig. 5**, we can find out that the elements such as C, N, O and S were existed in both GO and GO-PPEGMA. While C and O are the main elements, the O is mainly generated from the oxidation reaction which majorly formed epoxy, hydroxyl and carboxyl groups. The elements of N and S from GO are mainly induced by the complex oxidation reaction from H_2SO_4 and NaNO_3 . Furthermore, another part of O was contributed by the H_2O , which was adsorbed on GO and GO-PPEGMA. And the H_2O molecules are difficult to be completely removed from GO samples. The adsorption of H_2O on GO samples was also confirmed by other characterization techniques such as TGA, FT-IR and ^1H NMR. More importantly, the successful modification of GO with PPEGMA was also confirmed by the Br3d spectra. As shown in **Fig. S1**, almost no peak between 66-71 eV of Br3d was found in GO. After surface modified with polymer, an obvious peak at this region was emerged. The appearance of Br3d signal clearly indicated that the initiator (11-Bromoundecanoic acid) was contained in the sample of GO-PPEGMA. Furthermore, we can also

conclude that PPEGMA brushes were attached onto GO sheets through hydrophobic interaction based on the XPS spectra and other characterization results.

Fig. 5 The XPS spectra of GO and GO-PPEGMA. The elements of C, N, O and S were observed in both of the two samples.

The detailed C1s spectra of these two samples were also investigated. As shown in **Fig. S2A** and **Fig. S2B**, the C1s signal peak of GO could be divided into five peaks that were located at 284.1, 284.7, 285, 286.68 and 288.12 eV, respectively. The peaks at 284.1, 284.7 and 285 eV are mainly associated with the sp^2 carbon bonds of GO. The positional difference between these peaks is mostly caused by the different oxidation degree of GO samples. The peak at 286.8 eV is corresponded to the C=O from -COOH and the peak at 288.12 eV associated with C-O from the epoxy and carboxyl group of GO. The C1s peak of GO-PPEGMA can be divided into five main sub-peaks located at 283.1, 283.5, 284.6, 285 and 285.5eV, respectively. As compared with the spectra of GO, the new signal peaks are mostly from PPEGMA, and the decreased peaks are likely caused by the increasing thickness.

Fig. 6 XPS C1s peak deconvolution of GO (E); XPS C1s peak deconvolution of GO-PPEGMA.

The percentages of different elements in GO samples were compared based on the XPS analysis. As displayed in **Table 1**, the element percentages of GO are 67.9%, 2.74%, 27.35% and 2.01% for C1s, N1s, O1s, S2p, respectively. No Br3d was detected in GO. After surface modification with PPEGMA, the element percentages were changed to 62.57%, 0.67%, 35.88%, 0.3% for C1s, N1s, O1s, S2p, respectively. Furthermore, the element Br was emerged in the sample of GO-PPEGMA with percentage of 0.58%. The appearance of Br, increase of O content and decrease of C, N, S content further indicated that GO sheets were successfully modified with PPEGMA.

Table 1 Element content (%) of GO and GO-PPEGMA based on the XPS analysis

Samples	C1s	N1s	O1s	S2p	Br3d
GO	67.9%	2.74%	27.35%	2.01%	0
GO-PPEGMA	62.57%	0.67%	35.88%	0.3%	0.58%

The dispersion of the original GO and GO-PPEGMA in different organic solvents and aqueous solution was also investigated. As shown in **Fig. S3**, GO-PPEGMA exhibit excellent dispersibility in a number of organic solvents except from n-heptan (**Fig. S3A**). The water stability of GO and GO-PPEGMA was shown in **Fig. S3B**. It can be seen that most of GO was deposited in the bottom of bottles after 6 h, while the GO-PPEGMA can still be well dispersed in water over 6 h. The different dispersibility of GO and GO-PPEGMA implied that GO was successfully modified by PPEGMA. To evaluate the potential biomedical applications of GO-PPEGMA, cytocompatibility of GO-PPEGMA nanocomposites toward A549 cells was determined using CCK-8 assay. It can be seen that the cell viability of GO-PPEGMA

was gradually decreased as the concentrations of GO-PPEGMA increased from 10 to 120 $\mu\text{g mL}^{-1}$. However, the cell viability value is still greater than 80% when the concentration is as high as 120 $\mu\text{g mL}^{-1}$ (**Fig. 7**). The cell viability results suggested that GO-PPEGMA nanocomposites possess considerable biocompatibility for biomedical applications. The biocompatibility as well as the possible toxic mechanism of GO has intensively investigated.[50, 51] Previous results suggested that the toxicity of GO is largely dependent on the surface properties of GO.[52-55] For example, Wei et al have demonstrated that the unmodified GO was mainly accumulated in the lung, liver and spleen after intravenous injection and high dosage of GO will also induce toxicity toward the accumulation organs.[35, 56] We have recently compared with the cell uptake behavior and cytotoxicity of different carbon nanomaterials such as carbon nanotubes, GO and nanodiamond.[57] Results suggested that ND displayed the highest cell uptake efficiency and lowest cytotoxicity. However, many other reports also suggested that the surface modification with polymers such as PEG could significantly change their biodistribution behavior and improve their biocompatibility.[53] This provide the possibility to prepare water soluble and biocompatibility GO based materials with better performance for biomedical applications.

Fig. 7 Cell viability evaluation of GO-PPEGMA to A549 cells. The concentrations of GO-PPEGMA were ranged from 0-120 $\mu\text{g mL}^{-1}$.

Because of the desirable biocompatibility of GO-PPEGMA, the drug loading and release behaviors of GO-PPEGMA were subsequently investigated. It has been demonstrated that GO possess a high specific surface area, which is promising for carrying a number of anticancer drugs such as paclitaxel, cisplatin and DOX etc.[33, 52, 58] Apart from loading of drugs through adsorption, the drug molecules could also be carried by GO based materials through covalent conjugation and coordination interaction.[33] Doxorubicin hydrochloride (DOX-HCl) was used to treat a number of cancers, it has good solubility in physical solution, but its application was limited by the serious influence to normal cells which severely limited its applications, and thus development of novel controlled drug release systems is urgently required. To date, many drug delivery systems were realized by bonding the aim drugs with the carriers through different covalent bonds, however, this may potentially cause some other problems like reduce their curative effect et al. Therefore the drug delivery systems constructed via a noncovalent method is more desired. It was demonstrated that DOX could easily adsorb onto GO sheets via hydrophobic interaction, π - π stacking, hydrogen bonding and their combined action. Herein we employed DOX as the model drug to evaluate the ability of GO-PPEGMA on loading drugs and their release character. The drug loading efficiency of GO-PPEGMA was evaluated by UV-Vis spectrometer. We demonstrated that the maximum loading percentage of DOX onto GO-PPEGMA is 84.8 % (0.848 mg DOX per gram of GO-PPEGMA). On the other hand, the release behavior of DOX from GO-PPEGMA-DOX nanocomposites in pH = 7.4 and 5.5 was also determined. As shown in **Fig. 8**, we can clearly find out that the maximum release rates of DOX at pH = 5.5 is much higher than that at pH = 7.4. Because the lysosomes are usually acidic, it is therefore GO-PPEGMA can be used for controlled drug delivery application. Although the GO sheets prepared in this work may be too large for intracellular delivery of drugs for cancer treatment. Previously reports have demonstrated the size of GO sheets can be adjusted via using

different oxidation conditions or separation of GO sheets with different size.[55]

Fig. 8 Release profiles of DOX from GO-PPEGMA at pH = 7.4 and pH = 5.5.

Conclusion

In summary, we have successfully demonstrated an environmental friendly, facile and efficient method for preparing GO based polymer composites through a “one-pot” SET-LRP route. As compared with other polymerization methods such as ATRP and RAFT polymerization, SET-LRP should be another important controlled living polymerization for its advantages. For example, the SET-LRP can be occurred at room temperature in aqueous solution under air atmosphere with high polymerization rate. On the other hand, Bromoundecanoic acid contained the long alkyl chain and bromine, that can act as the initiator and linker simultaneously. It can therefore be utilized for preparation of various GO based polymer nanocomposites in aqueous solution and air atmosphere. As compared with other noncovalent strategies,[58] the polymers’ properties are expected to be largely adjusted for the well applicability of SET-LRP towards various monomers. Finally, GO-PPEGMA nanocomposites exhibited high water dispersibility, desirable biocompatibility, high drug loading capability and pH responsive drug release behavior. Therefore, combination of the advantages of GO and SET-LRP, the resultant GO-PPEGMA should be promising

candidates for various biomedical applications.

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The PEGylated graphene oxides with high water dispersibility, good biocompatibility as well as high drug loading capability were fabricated via “one-pot” SET-LRP