Laser-induced graphenization of poly(dimethylsiloxane)/poly(ethylene glycol) composite

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INTRODUCTION

With the accelerating development of wearable smart electronics, flexible strain sensors are in rising demand. Cost-effective, single-step preparation of laser-induced graphene (LIG) on polymeric surfaces has emerged as a highly promising technology for fabricating wearable LIG-based sensors [1]. The reason for that are remarkable properties of LIG such as good flexibility, piezoresistive properties, high mechanical stability, good electrical conductivity, low cost and ease of preparation [2]. However, the single-step fabrication of LIG/polymer composites that are both biocompatible and conductive, as well as stretchable, remains a significant challenge [3]. Poly(dimethylsiloxane) represents biocompatible and stretchable polymer being the most popular elastomer because of its great mechanical properties [4]. Because of its lack of aromatic structure and low carbon content, pure PDMS is not suitable for LIG so our study addresses preparation of laser induced graphene on a novel biocompatible poly(dimethylsiloxane)/poly(ethylene glycol) (PDMS/PEG) materials using optimal processing conditions.

METHODS AND MATERIALS

Poly(dimethylsiloxane) (Dow Corning, Sylgard 184) and poly(ethylene glycol) (Sigma Aldrich, Mn=400 g/mol) were used. Five sets of PDMS samples were synthesized with different weight concentrations of PEG (10-50 wt.%). The CO_2 laser used to produce LIG was a DBK FL-350. FTIR spectra of PDMS/PEG and LIG were recorded with a Thermo Fisher Scientific, Waltham, MA, USA spectrometer, in transmission mode on a KBr substrate. Raman spectra of the samples were recorded with a DXR Raman microscope (Thermo Fisher Scientific, Waltham, MA, USA). SEM imaging with EDX was done at magnifications 400x, 1000x, 2000x, 5000x and 10000x with a PhenomProX scanning electron microscope (Phenom, Thermo Fisher Scientific, Waltham, MA, USA).

RESULTS

Illustration of laser induction on PDMS/PEG composite is shown in Figure 1. SEM image of the surface of LIG on PDMS with 40 wt.% of PEG is presented on Figure 2. Raman spectra of LIG on PDMS/40%PEG is presented in Figure 3. Graph I_D/I_G and I_{2D}/I_G as a function of percentage of PEG in PDMS is presented on Figure 4. FTIR spectra of LIG on PDMS with 10 and 40 wt.% are presented on Figure 5 and band assignation in Table 1.

Figure 1. Illustration of laser induction on PDMS/PEG

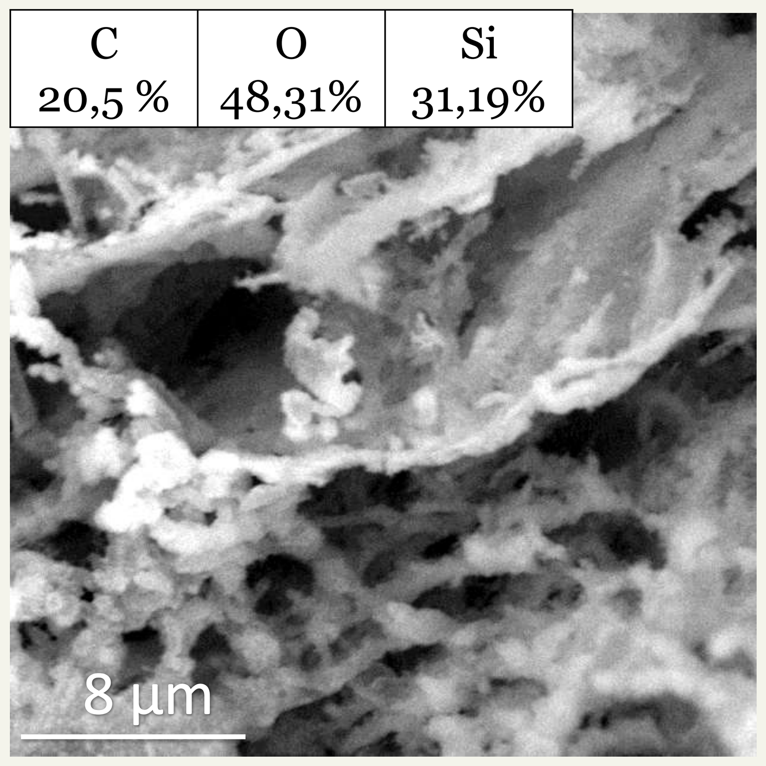

Figure 2. SEM micrograph with EDX analysis of LIG on PDMS with 40 wt.% PEG with 10 000x magnification

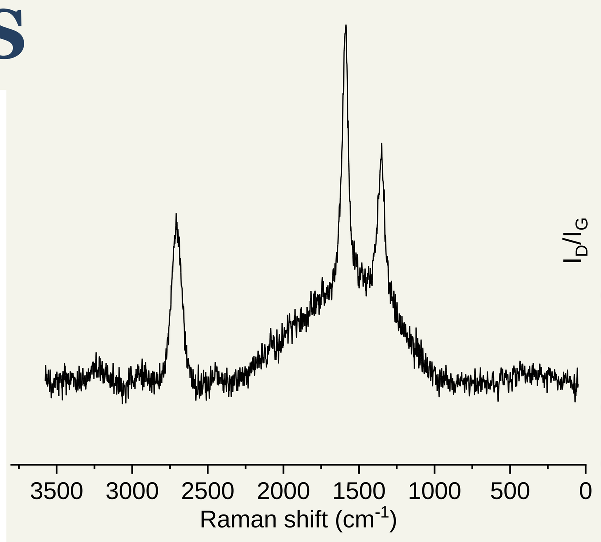

Figure 3. Raman spectrum of LIG on PDMS with 40 wt.% PEG

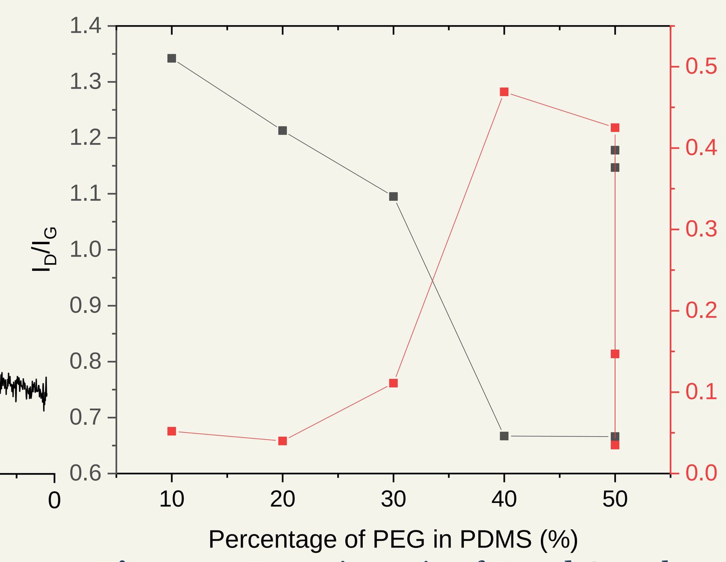

Figure 4. Intensity ratio of D and G peaks and 2D and G peaks for different percentages of PEG

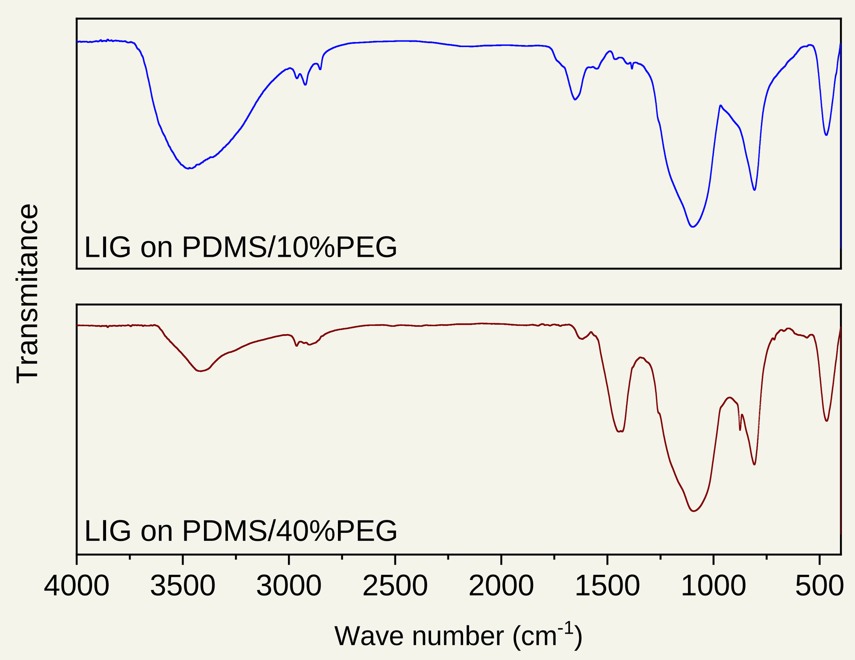

Figure 5. FTIR spectra of LIG on PDMS/10%PEG and LIG on PDMS/40%PEG

Table 1. Band assignment of LIG on PDMS with 10 wt.% PEG and LIG on PDMS with 40 wt.% PEG

	ν(O-H) (cm^{-1})	$\nu(CH)_{as}$ (cm^{-1})	$\nu(CH)_s$ (cm^{-1})	ν(C=C) (cm^{-1})	$\delta(C\text{-}H)_s$ (cm^{-1})	SiO_2 nanoparticles + ν(C-O) (cm^{-1})	Si-C ili C-H rocking (cm^{-1})	δ(C-C) (cm^{-1})
PDMS/ 10%PEG	3331	2962	2866	1629	/	1075	801	/
PDMS/ 40%PEG	3313	2962	/	1618	1259	1073	800	461

DISCUSSION

The results revealed that adding PEG to PDMS is favorable for induction of graphene. Methods of characterization have confirmed the formation of graphene on the surface of PDMS/PEG. SEM micrographs (Figure 2) showed expected 3D porous structure of LIG. FTIR and SEM/EDX analyses also indicated the presence of SiO_2 nanoparticles, attributed to the thermal degradation of the PDMS matrix under CO2 laser treatment. The study of Raman spectra (Figure 3) show three prominent peaks that are typical features of graphene: strong G band shown at ~1585 cm^{-1} originating from a first order zone-boundary phonons and presence of sp_2 carbon bonds, D band at ~1348 cm^{-1} induced by defects and vacancies and 2D band at ~2700 cm^{-1} that originates from second order zone-boundary phonons [2]. The analysis of the intensity ratio of the D and G peaks and 2D and G peaks was performed (Figure 4) and the lowest intensity ratio was obtained for LIG on PDMS with 40 wt.% of PEG indicating bigger crystal domains in graphene. Two more measurements of I_D/I_G and I_{2D}/I_G were picked to represent the instability of the sample with 50 wt.% of PEG in PDMS.

CONCLUSIONS

- Graphene can be induced by laser irradiation of PDMS/PEG composites
- The resultant graphene is characterized with FTIR, SEM/EDX and Raman spectroscopy
- 40 wt.% PEG concentration is found to be optimal for induction of graphene, similar to what was observed earlier with PEEK/PDMS composites [5]
- The materials also contains SiO2 and SiC similar to what was observed earlier with PEEK/PDMS composites [5].

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