



## Journal Name

### ARTICLE

Electronic Supplementary Information

#### **Thermal-needle-triggered cascade reduction of graphene oxide for controllable moving trajectory into conductive pattern**

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## **Materials**

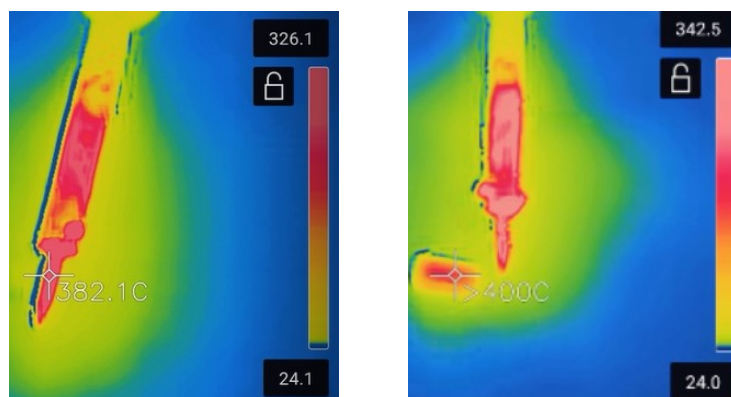
The raw material graphite was (purity:  $\geq 99\%$ , 180 mesh) provided by Huatai Lubricant Sealing S&T Co. Ltd (Qingdao, China). Sodium dodecyl sulfate (SDS purity:  $\geq 99\%$ ), vitamin C (purity:  $\geq 99\%$ ), polyethylene glycol (average Mn: 4000), hexachlorocyclotriphosphazene (purity: 98%), and polyvinyl alcohol (alcoholysis degree: 92-94 mol%) were obtained from Aladdin Biochemical Technology Co., Ltd (Shanghai, China). Potassium permanganate (purity:  $\geq 99\%$ ) and potassium hydroxide (KOH, purity: 85%) was supplied by Sinocharm Chemical Reagent Co., Ltd. GO were synthesized following our modified Hummers' method.<sup>1,2</sup> GO with different O/C ratios could be controlled by dosage of potassium permanganate or controlling the reaction times.

## ***Cascade reduction reaction of GO aerogels and films***

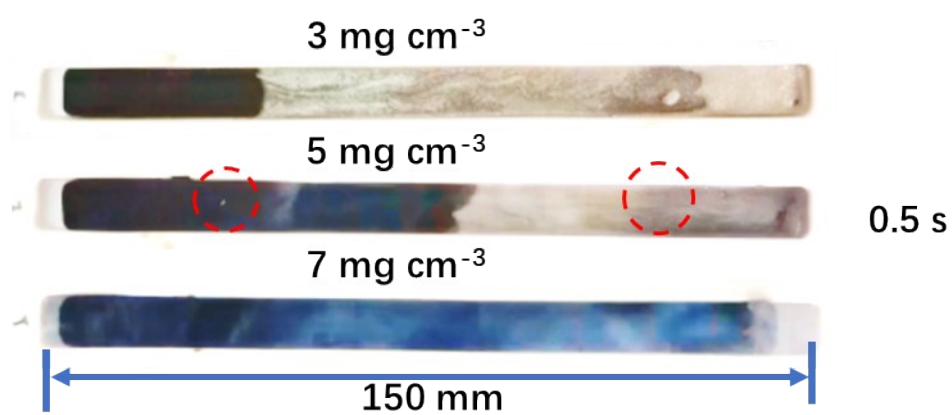
GO films with different thicknesses were fabricated by casting the GO dispersion with different volumes into a container followed by air-drying. GO aerogels were produced with a typical freeze-drying process from the GO solutions (3-9 g/ml). A metal needle (tip area: 0.78 mm<sup>2</sup>) with a pre-determined temperature of 190~400 °C was used to trigger the reduction reaction under the atmosphere of air, nitrogen, or vacuum. For patterning, water or polymer solutions was used to infiltrate the GO film and aerogels via writing or mask-wetting.

## **Characterization**

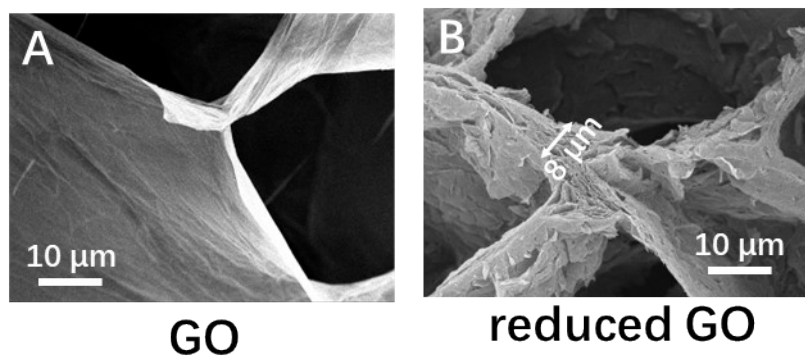
Scanning electron microscope (SEM) images were collected from a Field Emission Scanning Electron Microscope (Hitachi S4800, Japan) with an operating voltage of 5 kV. In-situ wide-angle X-ray Scattering (WAXS) curves were obtained from Xeuss 2.0 (Xenocs corporation, France). Raman spectra were acquired from Renishaw inVia (Renishaw, England) with 532 nm wavelength incident laser light. Compressive measurement of GO and cascade reduced GO aerogels was performed on a Instron 5900 (America) with a rate of 50 mm min<sup>-1</sup>. The electronic conductivity of the color film was performed on an electrochemical workstation (CH660, Shanghai Chenhua instrument company) with potential ranging from -2 to 2 V. X-ray photoelectron spectra (XPS) were recorded on an ESCALAB 250Xi (Thermo Scientific). The IR images were obtained with a Flir One Pro IR camera.



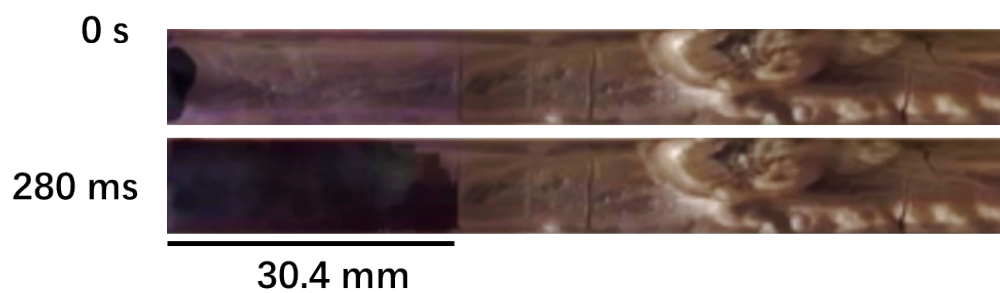
**Fig. S1.** Infrared images of triggering the cascade reaction with a hot needle (left) and the captured Infrared image of the reducing GO aerogel sample.



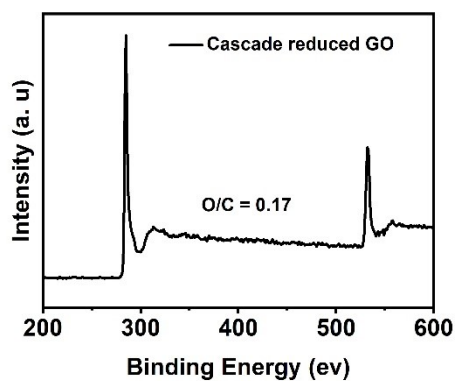
**Fig. S2.** The captured digital pictures of GO aerogels with different densities at the cascade reduction of 0.5s (in air).



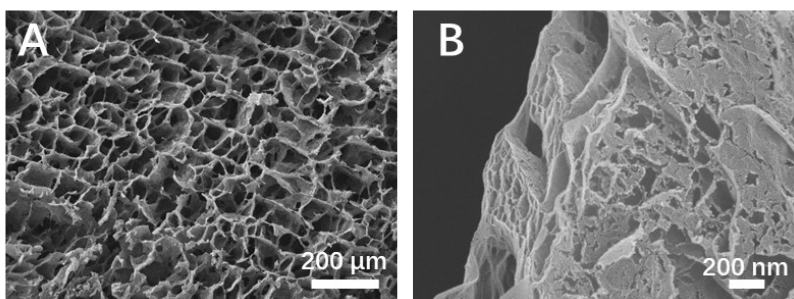
**Fig. S3.** SEM images of GO (A) and reduced GO (B).



**Fig. S4.** The captured digital pictures of GO aerogel with lateral size of  $\sim 35 \mu\text{m}$  at the cascade reduction of 280 ms (in air, density:  $7\text{mg cm}^{-3}$ ).



**Fig. S5.** XPS wide scan spectra of cascade reduced GO.



**Fig. S6.** SEM images of rGO aerogels to show the porous morphology.

**Table S1.** Density, speed and conductivity property of GO aerogels and cascade reduced GO aerogels.

		Density / mg.cm <sup>-3</sup>	Speed / mm.s <sup>-1</sup>	Conductivity / S.m <sup>-1</sup>
Sample 1	GO aerogel	3	133	4.8*10 <sup>-6</sup>
	Cascade reduced GO	1.7	No	4.1*10 <sup>-3</sup>
Sample 2	GO aerogel	5	200	1.3*10 <sup>-5</sup>
	Cascade reduced GO	2.8	No	7.8*10 <sup>-3</sup>
Sample 3	GO aerogel	7	320	5.9*10 <sup>-5</sup>
	Cascade reduced GO	4.2	No	2.4*10 <sup>-2</sup>

**Notes and references**

1. X. F. Zhang, T. P. Zhang, Z. Wang, Z. J. Ren, S. K. Yan, Y. X. Duan and J. M. Zhang, *ACS Appl. Mater. Interfaces*, 2019, **11**, 1303-1310.
2. H. Yang, Z. Li, B. Lu, J. Gao, X. Jin, G. Sun, G. Zhang, P. Zhang and L. Qu, *ACS Nano*, 2018, **12**, 11407-11416.