Supporting information for

Mobile microplasma synthesis of silver nanoparticles/graphene nanocomposites for flexible strain sensors

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1. Experimental

2.1 Materials

Silver nitrate (AgNO$_3$, ≥99.8%) was purchased from Sinopharm Chemical Reagent Co., Ltd. Monolayer graphene (≥99.5%) was purchased from Shenzhen Suoheng Technology Co., Ltd. Argon gas (99.999%) was purchased from Wuxi Taihu Gas Co., Ltd. PDMS and the PDMS curing agent were purchased from Shenzhen Songsen New Material Technology Co., Ltd.

2.2 Mobile microplasma jet system for the preparation of Ag/Gr nanocomposites and sensors

2.2.1 Mobile microplasma fabrication of Ag/Gr nanocomposites

Ag/Gr nanocomposites were fabricated using a mobile microplasma jet system, the detailed configuration of which was reported in our previous work[1]. Briefly, a stainless-steel capillary (1/16″ O.D., 0.02″ thru hole) as the cathode was mounted onto the gantry of a commercial 3D printer (Leader 3D). Its motion path was digitally designed using a computer prior to plasma nanofabrication. Meanwhile, a grounded aluminum plate was used as the anode, on which a copper film (4 cm × 1 cm) was placed for the deposition of Ag/Gr nanocomposites. Both electrodes were energized by a DC high-voltage power supply (AU-10R30, Matsusada Precision Inc.). With the supply of high voltage to the electrodes, microplasma jet was formed within the electrodes gap. This setup enabled precise, computer-controlled movement of the plasma jet along the X and Y axes, allowing for localized and selective deposition.

In a typical procedure, a specific amount of AgNO$_3$ was mixed with 10 mg of graphene solution to achieve the target concentration. The solution was then delivered to a Tee junction by a syringe pump (Fusion 200, Chemxy, Inc.), and mixed with an argon flow (20 sccm) to form a biphasic gas-

liquid stream. As the stream entered the plasma zone, Ag^+ ions were immediately reduced by plasma to generate AgNPs, and deposited on the graphene to form Ag/Gr nanocomposites. Meanwhile, experimental values of the plasma current and voltage were recorded using an oscilloscope (TBS1102, Tektronix). After plasma processing, square nanocomposites with a thickness of approximately 50 μm was formed. In this work, Ag/Gr nanocomposites of diverse silver contents were produced by adjusting the $AgNO_3$ concentration. Four variations (Ag/Gr-6.4%, 11.9%, 16.9%, and 21.4%) were produced by adjusting the mass fraction of the silver precursor. The silver content refers to the theoretical mass percentage of Ag relative to the total solid content, calculated based on the initial $AgNO_3$ and graphene amounts.

2.2.2 Construction of Ag/Gr-based strain sensors

To fabricate the Ag/Gr-based strain sensors, a 10:1 mixture of PDMS and its curing agent was uniformly coated onto the nanocomposite-loaded copper films. The samples were then placed in a vacuum chamber for 0.5 h to eliminate air bubbles, followed by thermal curing in an oven at 80°C for 0.5 h. Subsequently, the copper film was peeled off, and the degassing and curing steps were repeated to create the second PDMS layer, forming a sandwich structure (PDMS-Ag/Gr-PDMS).

2.2.3 Sensing performance evaluation

To evaluate the performance of the Ag/Gr-based sensor, the as-prepared PDMS-Ag/Gr-PDMS structure was integrated into a circuit via copper foils, and connected to a benchtop digital multimeter to monitor resistance changes during physical movement. Sensors were secured to the subjects' cheeks, fingers, elbows, and knees using insulating tape. Resistance variations were induced by applying tension or bending to these body parts. Each sample group underwent ten measurement

cycles with a 10-second interval between tests. Digital signals were processed using MIKD software to evaluate the sensor's performance.

2.3 Characterization

Plasma emission was characterized using an ER4000-EX optical emission spectrometer (OES, Shanghai Chen Chang Inc.). The morphology of the Ag/Gr nanocomposites was examined by a S-4800 field emission scanning electron microscope (Hitachi Ltd., Japan), equipped with an energy-dispersive X-ray spectroscopy (EDX) detector to analyze elemental composition and distribution. The shape and microstructure of the nanocomposites were examined by a JEM-2100plus transmission electron microscopy (JEOL Ltd., Japan) at a 200 kV accelerating voltage. Raman spectra were acquired by a confocal Raman spectrometer (Renishaw, UK). The crystal structure was determined by a D8 Advance X-ray diffractometer (Bruker AXS GmbH, Germany). The sensing performance was evaluated using a DMM6500 benchtop digital multimeter (Keithley Instruments, USA).
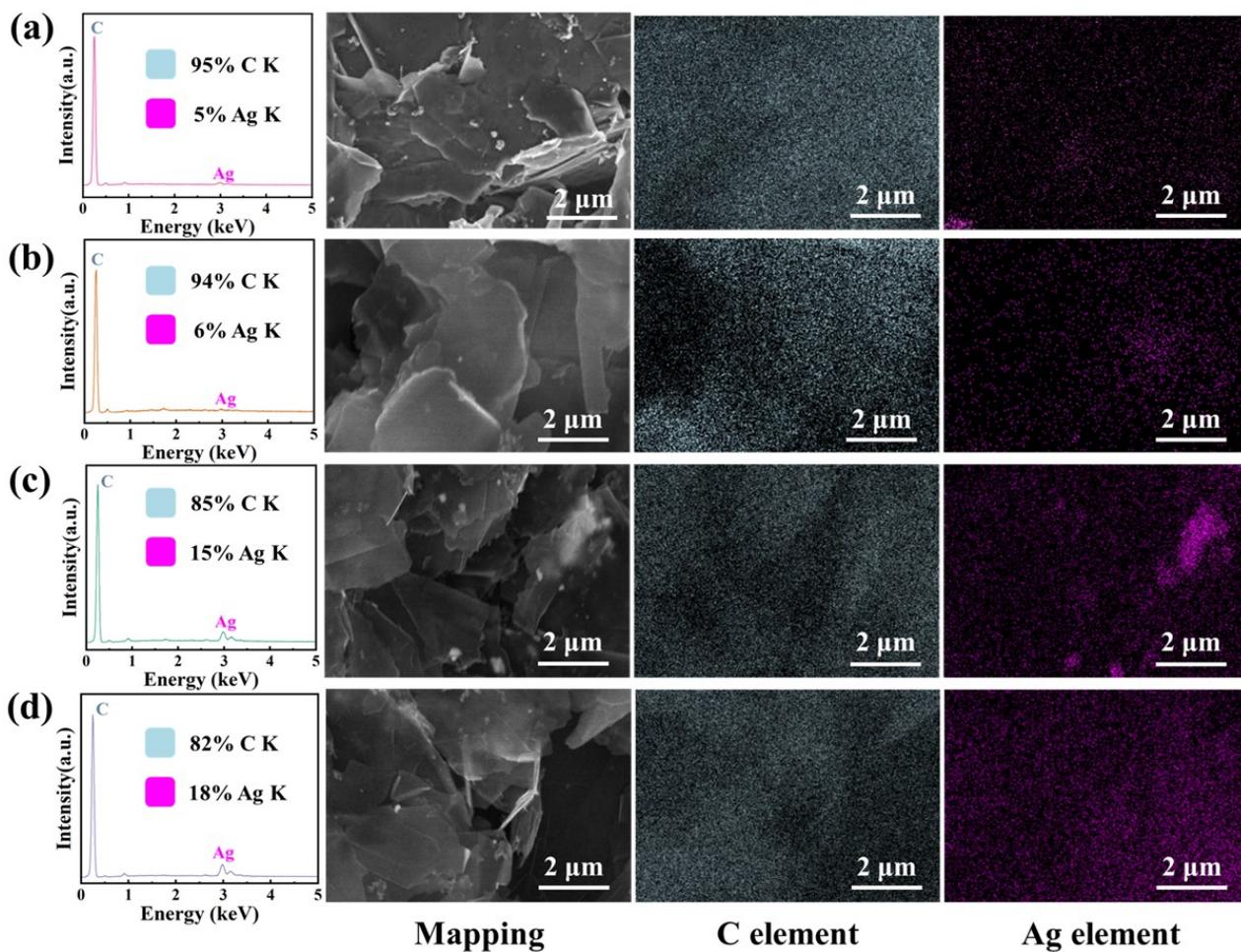
Fig. S1. EDX spectra and elemental distribution images of Ag/Gr nanocomposites with different Ag contents: (a) 6.4 wt%; (b) 11.9 wt%; (c) 16.9 wt%; (d) 21.4 wt%.
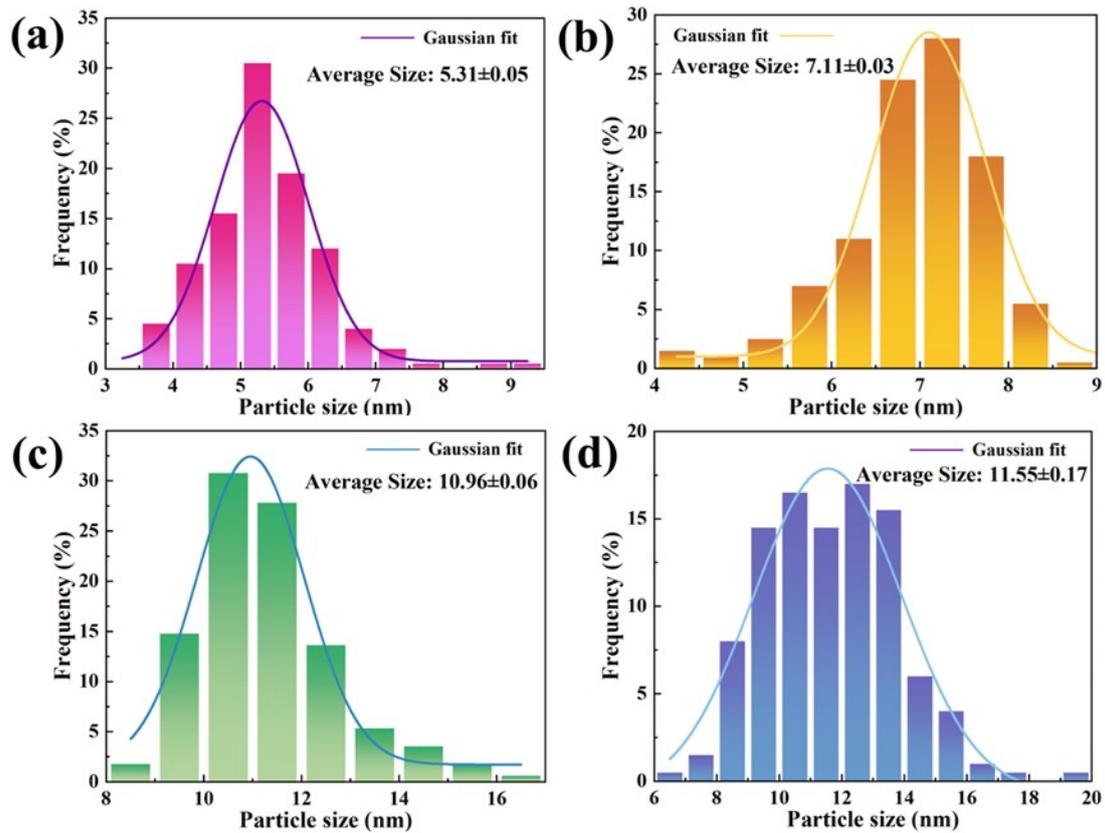
Fig. S2. The corresponding size distribution histograms of Ag/Gr nanocomposites with different Ag contents: (a) 6.4 wt%; (b) 11.9 wt%; (c) 16.9 wt%; (d) 21.4 wt%.

Tab. S1. Typical operation parameters of the mobile microplasma system.

Operation parameter	Value
Precision	0.05 mm
Electrode distance	2-4 mm
Moving speed	20 mm/s
X-axis accuracy	0.0011 mm
Y-axis accuracy	0.0011 mm
X-axis width of the platform	10 mm
Y-axis width of the platform	10 mm
Operation temperature	Room temperature
Pressure	Atmospheric pressure

Tab. S2. A comparison of existing techniques for the preparation of Ag/Gr-based strain sensors.

Materials	Method	Max strain	Sensitivity metric reported	Durability/stability	Ref.
AgNPs, graphene, PDMS	Mobile microplasma jet	200%	$\triangle R/Ro \approx 500\%$ (finger) $\triangle R/Ro \approx 470\text{-}1000\%$ (knee)	800 cycles at 200% strain	This work
AgNPs, rGO, PDMS	3D foam	50%	GF = 1588 (50% strain)	500 cycles at 30% strain	2
AgNPs, graphene, polyimide	UV laser patterning	16%	GF up to 492.95 (at 16% strain)	1000 cycles at 3-5% strain	3
AgNP, graphene, PDMS	Laser-induced method	70%	GF = 17.7 (5%), GF = 26.7(70%)	Stable under cyclic loading	4
Metal NPs, graphene, PDMS	Electron beam evaporation	40%	GF=136 (5% strain)	4000 cycles	5
AgNPs, graphene, polyimide	Nano-silver-modified LIG	/	Sensitivity 426.8	Stable up to 8000 s	6

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