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Supplement

# Silicon nitride waveguide-integrated chemical vapor deposited graphene photodetector with 38 GHz bandwidth: supplementary material

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This document provides supplementary information to "Silicon nitride waveguide-integrated chemical vapor deposited graphene photodetector with 38 GHz bandwidth". It contains information of the device fabrication and the carrier mobility of a graphene-on-silicon nitride waveguide.

## 1. Device Fabrication

The device fabrication involves three steps of electron-beam lithography (EBL). The first EBL step defined the pattern of the grating couplers and rib waveguides, which was transferred to the $Si_3N_4$ layer by reactive-ion etching. After that, the second EBL step defined the pattern of the metal contacts, followed by thermal evaporation (Cr/Au of 5 nm/60 nm) and lift-off processing. Next, a graphene monolayer with PMMA resist atop was wet transferred onto the chip. After the sample was dried in the ambient conditions, it was baked to strengthen the adhesion between the graphene and the waveguide. The last EBL step defined the pattern of the covering graphene, followed by oxygen plasma etching where needed, during which critical alignment was not necessary. Lastly, the resist on the graphene surface was removed by rinsing in acetone, isopropyl alcohol (IPA) and deionized water.

## 2. Device Mobility

A graphene-based field-effect transistor (FET) was used for characterizing the electrical properties of graphene reported in our manuscript. Photolithography and sputtering were used to define the contact electrodes (Cr/Au: 5 nm/50 nm) on a silicon oxide/silicon substrate. Afterwards, the graphene was transferred onto the devices and a drop of ionic liquid was used to form the top gate. The schematic of the FET for electrical characterization is shown in Fig. S1(a).

The electrical transport measurement was conducted in the ambient conditions at room temperature using Keithley 4200 Characterization System. At a fixed source-drain voltage $V_{DS}$ of 0.5 V, the source-drain current $I_{DS}$ was measured against the gate voltage $V_{GS}$ from 0 to 3 V. According to the transfer characteristics of the graphene FET shown in Fig. S2(b), the charge neutrality point ($V_{Dirac}$) is around 2.45 V. We can obtain the carrier mobility, $\mu$, based on the graphene FET model[1]:

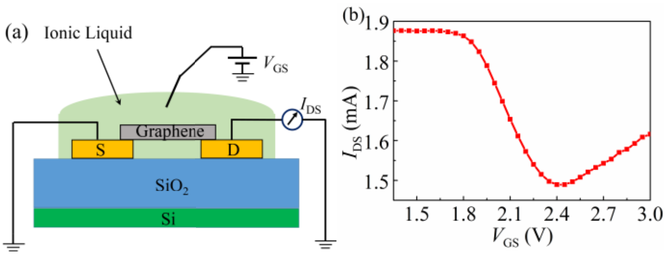


**Fig. S1** (a) Schematic of the graphene FET for electrical characterization; (b) the transfer characteristics of the graphene FET.

$$\mu = \frac{L}{WC_g V_{DS}} \frac{dI_{DS}}{dV_{GS}}, \quad \text{(S1)}$$

where $L$ is the length of channel, $W$ is the width of channel, and $C_g$ is the gate capacitance per unit area of the ionic liquid. In the design, $L/W$ is 1 and $C_g$ is about 0.68 $\mu$F/cm$^2$. The mobilities of holes and electrons are estimated to be ~2,440 and ~1,110 cm$^2$V$^{-1}$s$^{-1}$, respectively. The difference in electron and hole mobilities was also reported in previous works [2-5].

## References

1. F. Schwierz, *Nat. Nanotechnol.*, 2010, **5**, 487–496.
2. S. Wang, P. K. Ang, Z. Wang, A. L. L. Tang, J. T. L. Thong and K. P. Loh, *Nano Lett.*, 2010, **10**, 92–98.
3. V. E. Dorgan, M.-H. Bae and E. Pop, *Appl. Phys. Lett.*, 2010, **97**, 082112.
4. W. Zhu, V. Perebeinos, M. Freitag and P. Avouris, *Phys. Rev. B*, 2009, **80**, 235402.
5. H. Zhong, Z. Zhang, H. Xu, C. Qiu and L.-M. Peng, *AIP Adv.*, 2015, **5**, 057136.