Solution gate field-effect transistor based on aminated graphene /graphene composite for Alzheimer's disease biomarker p-tau217 detection

Yu-Xiu Lin[1], Chi-Hsien Huang[1*]
Sung-Tao Shih[2], Chun-Hung Li[2], Kai-Hsiang Huang[2]

[1]*Department of Materials Engineering, Ming Chi University of Technology, New Taipei City, Taiwan, 24303*

Abstract

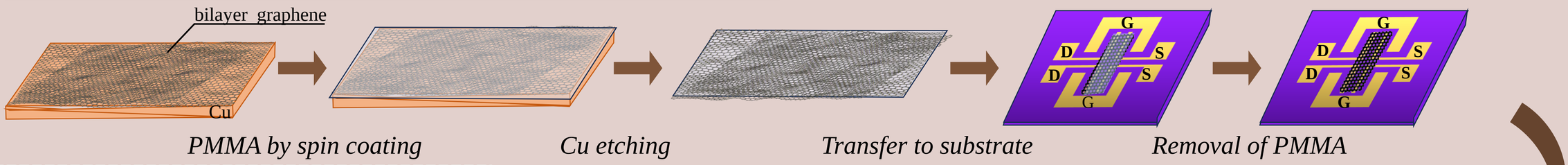
In this study developed an aminated graphene/graphene composite with an atomic-layered structure as the channel material in a solution-gated graphene field-effect transistor (SGGT) for the high sensitivity detection of the Alzheimer's disease biomarker p-tau217.

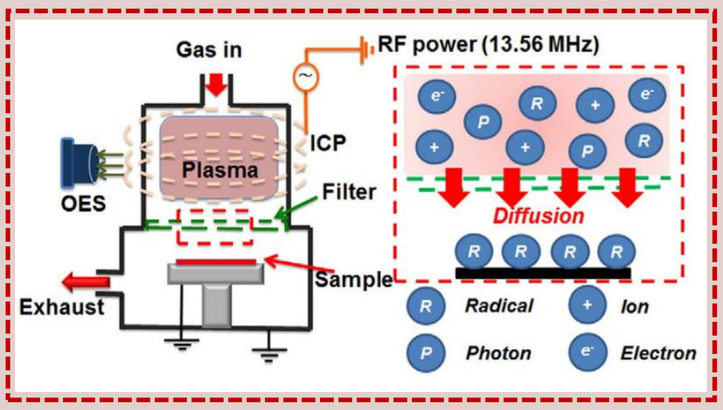
Bilayer graphene was synthesized via low-pressure chemical vapor deposition (LPCVD) and transferred onto a SiO_2 substrate with pre-patterned transistor electrode using a wet transfer technique.

The top graphene layer was modified through a low-damage plasma treatment(LDPT) to introduce amine and pyrrolic N functional groups, forming aminated graphene. These functional groups enable binding with the carboxyl groups at the antibody's terminal, allowing antibodies to be immobilized in a vertically oriented configuration, thereby significantly enhancing antigen capture efficiency.

Meanwhile, the bottom graphene layer retains its intrinsic high electron mobility and conductivity, ensuring stable electrical performance and efficient signal transduction of the device.

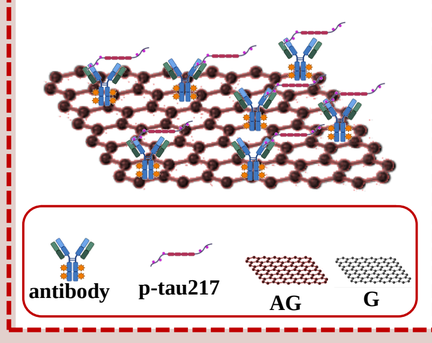
Experiment



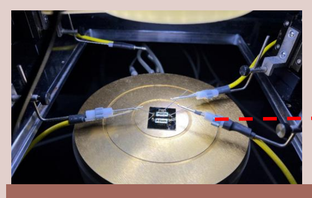


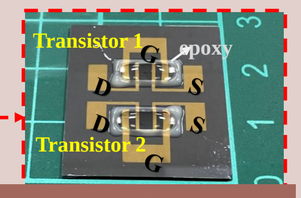
H.-E. Cheng, et al., Surf. Coat. Technol. (2016), http://dx.doi.org/10.1016/j.surfcoat.2016.03.028

Low Damage Plasma Treatment (LDPT)



p-tau217 protein bind with antibody immobilized on AG/G

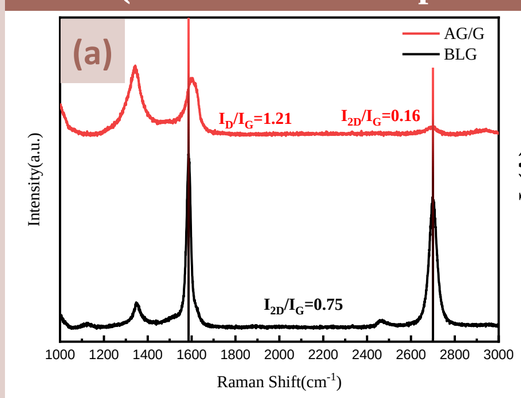


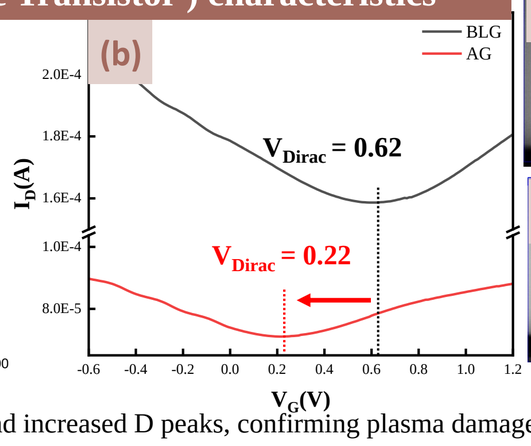


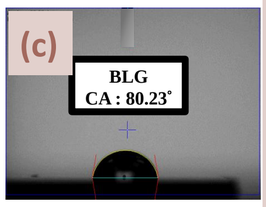
Photos of measurement setup and SGGT

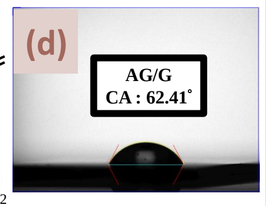
Results and Discussion

SGGT(Solution Gate Graphene Transistor) characteristics







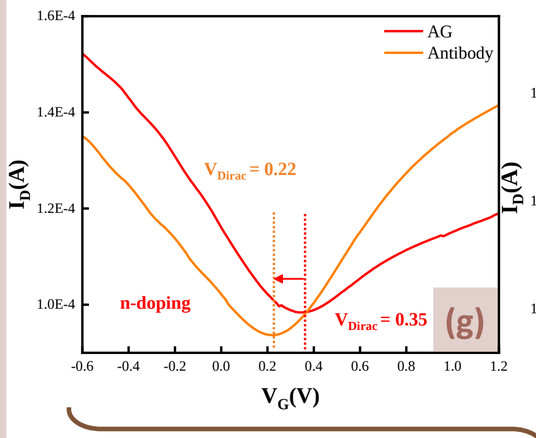


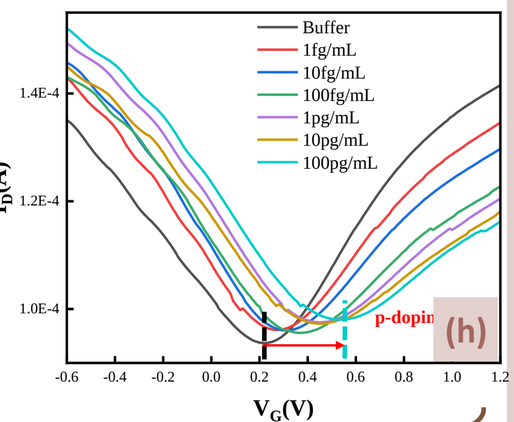
(a) Raman analysis shows decreased 2D and increased D peaks, confirming plasma damage in graphene.

(b) I–V curve shows a left-shifted Dirac point, indicating hole doping of graphene by amine functional groups.

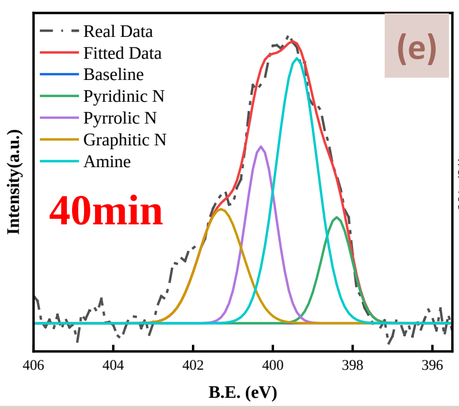
(c)~(d) The reduced contact angle after plasma modification indicates enhanced surface hydrophilicity from amine functionalization.

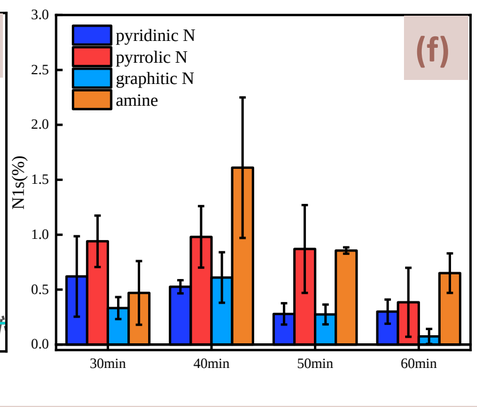
Hysteresis and sensitivity analysis after antibody immobilization with different antigen concentrations



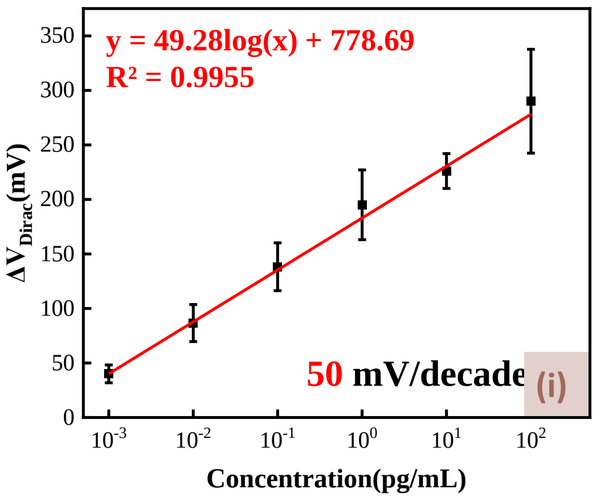


Variation of amine groups with plasma parameters





(e)~(f) XPS analysis shows the highest amine functional group content after 40 min of plasma treatment.



(g) antibody binding causes a leftward shift of the Dirac point

(h) Increasing antigen concentrations result in a right shift of the Dirac point.

(i) Response trend across concentrations from 1 fg/mL to 100 pg/mL

Conclusion

1. The I–V curve reveals the characteristic bipolarity of graphene.
2. After low-damage plasma treatment, the bipolar behavior is retained, and the Dirac point shifts due to amine groups doping.
3. Amine groups enhance antibody attachment and sensing, enabling future applications.
4. The sensor detects p-tau217 across a concentration range of 1 fg/mL to 100 pg/mL, with a high sensitivity of 50 mV/decade, excellent regression (R^2 = 0.9955), and a low detection limit of 1 fg/mL, demonstrating strong potential for biosensing applications.