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PAPER

Supporting Information

Patterned liquid metal contacts for high density, stick-and-peel 2D material device arrays

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Characterization of liquid metal residue after filling

EDX was employed to determine if liquid metal was deposited on the porous membrane after application of a vacuum. As shown in Suppl. Figure S1 no evidence for indium or gallium, the components of the liquid metal, could be observed. Instead, carbon and oxygen were the only components that originate from the filter paper while residue of platinum originates from the conductive film that was deposited for improved SEM.

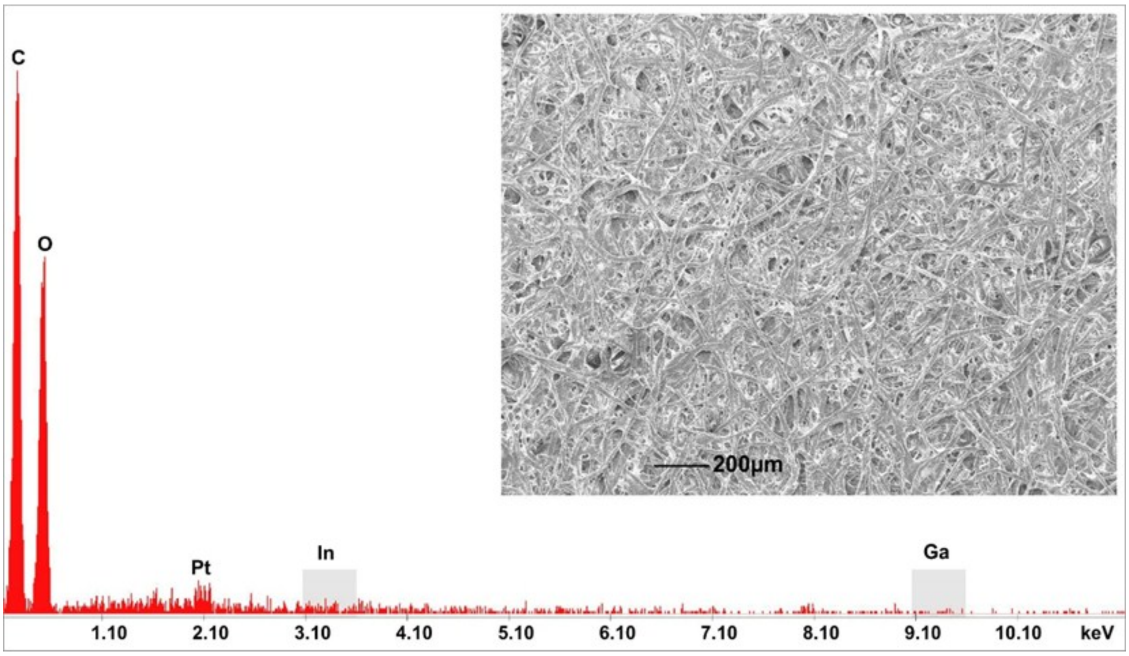

Figure S1. EDX characterization of filter paper, (inset) SEM image of filter paper.

Quality of features

A 500um PDMS cylindrical channel in contact with a filter paper was filled with liquid metal. SEM images were taken at the surface of the channel opening after filling (Figure S2). It is shown that the resulting liquid metal pattern is circular in shape and follows the PDMS opening exactly without evidence for smearing of the feature.

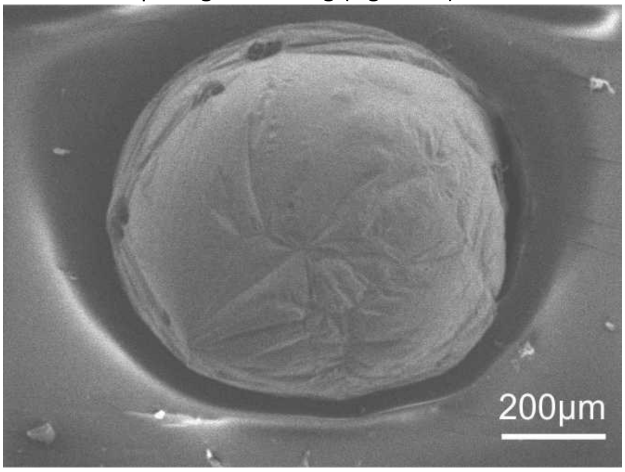

Figure S2. SEM image of liquid metal pattern.

Contact resistance of liquid metal electrodes

To extract the contact resistance of our liquid metal electrodes we produced contacts with different spacing. We observe a linear trend with a positive offset as expected from transmission line modeling. The contact resistance was extracted to be 11Ω which indicates that high quality contacts can be made using liquid metal contacts.

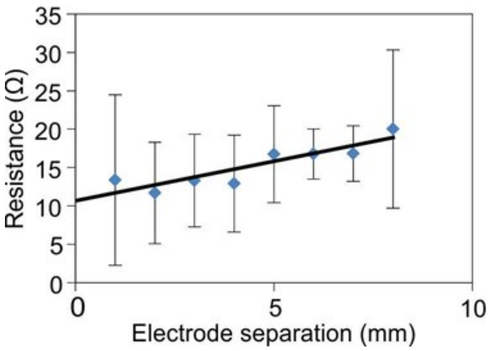

Figure S3. Resistance of liquid metal contacted Au film with fit to transmission line model

Lithographically patterned graphene FETs

Microscopic graphene FETs were produced by a multistep lithography process. Au/Cr contacts were thermally evaporated and a top-gate contact was aligned on top of a 30nm Al_2O_3 gate dielectric.

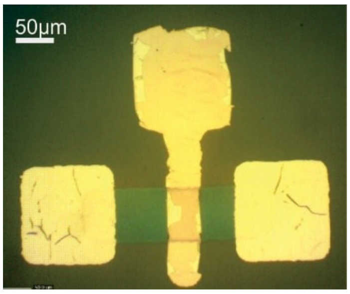

Figure S4. Optical micrograph of lithographically patterned graphene FET

Resistance measurements under deformation

To test the tolerance to dynamic deformation, we adhered the soft contact array to a 25µm thick copper foil and adjusted the uniaxial strain by bending the assembly. Supplementary Figure S4 shows a low resistance value that confirms the high quality of the contact. Moreover, the resistance is not increasing with strain which indicates that the contacts can sustain significant mechanical strain.

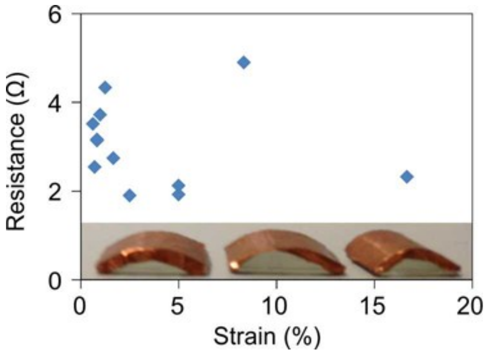

Figure S5. Resistance versus bending strain measured by soft contact device on copper foil, (inset) photographs of samples under various strain

Oxidation resistance

A liquid metal contacted Au film was exposed to UV-generated ozone for extended periods and no increase of the device resistance was observed.

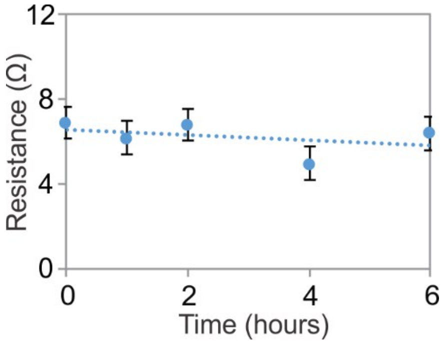

Figure S6. Resistance versus exposure duration to UV-generated ozone

Temperature resistance

Variable temperature measurements were conducted on a liquid-metal contacted Au film and no systematic change in the device resistance was observed within a large temperature window

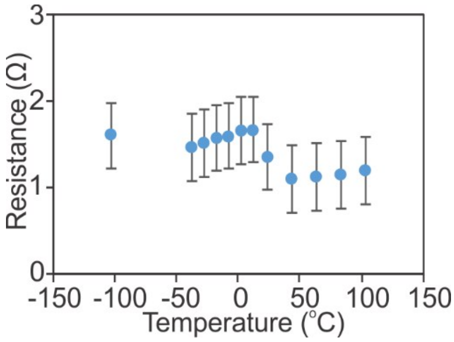

Figure S7. Resistance versus temperature

Application to other 2D materials

Besides graphene, liquid metal is shown to make good contact with other 2D materials. We applied liquid metal contacts to CVD grown MoS_2 films[1] and observed an improvement in the contact resistance compared to silver paint contacts.

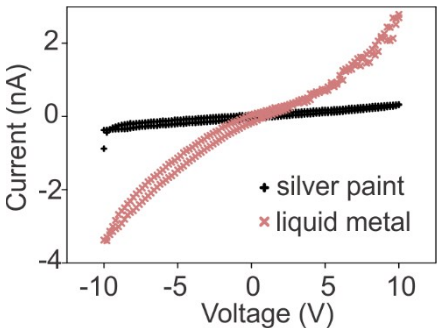

Figure S8. Current-voltage characteristics for MoS2 contacted by liquid metal and silver paint.

References

1 J. Wang, L. Chen, W. Lu, M. Zeng, L. Tan, F. Ren, C. Jiang and L. Fu, *RSC Adv.*, 2015, **5**, 4364-4367.