

High Speed Mask-less Laser Controlled Precision Deposition of Metals

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1. Introduction

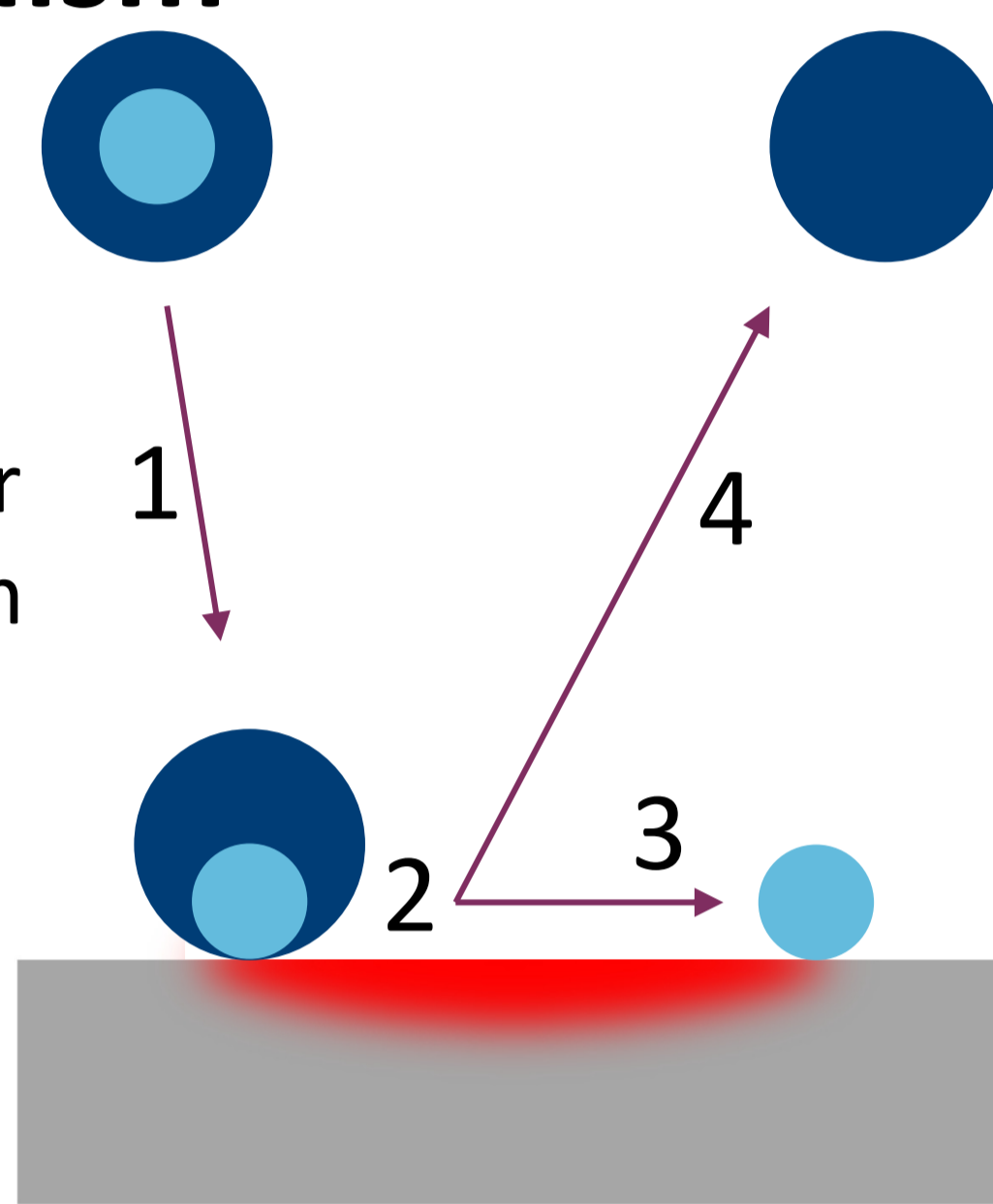
Laser chemical vapour deposition (LCVD) deposits material via dissociation of organic precursors at locations defined by a laser spot without a mask. With LCVD, a range of metals can be deposited e.g. tungsten, copper and silver; in a freeform pattern, defined by the laser; on substrates such as oxide coated silicon wafers, fused silica and metal substrates [1].

2. Research motivation

Lithography involves the use of chemical masks that may contaminate sensitive substrates such as graphene. Electron and focused ion beam deposition techniques do not require masks but the deposition rate is very slow. When writing conductive tracks on graphene based devices, using the LCVD technique, a conductive deposit needs to be chosen which has a deposition temperature below the damage threshold of graphene.

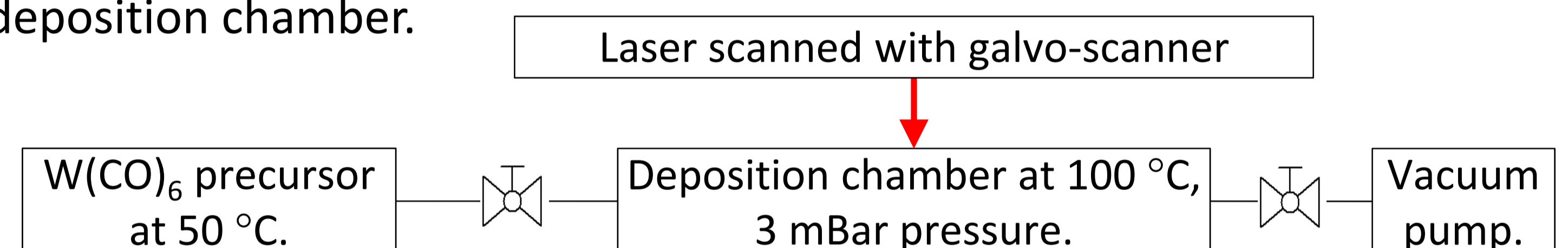
3. Deposition mechanism

1. Precursor vapour adsorbs onto the surface of the substrate.
2. On the surface, the precursor receives thermal energy from the laser and dissociates.
3. Deposition atoms remain on surface.
4. Volatile by-products desorb from the substrate surface.



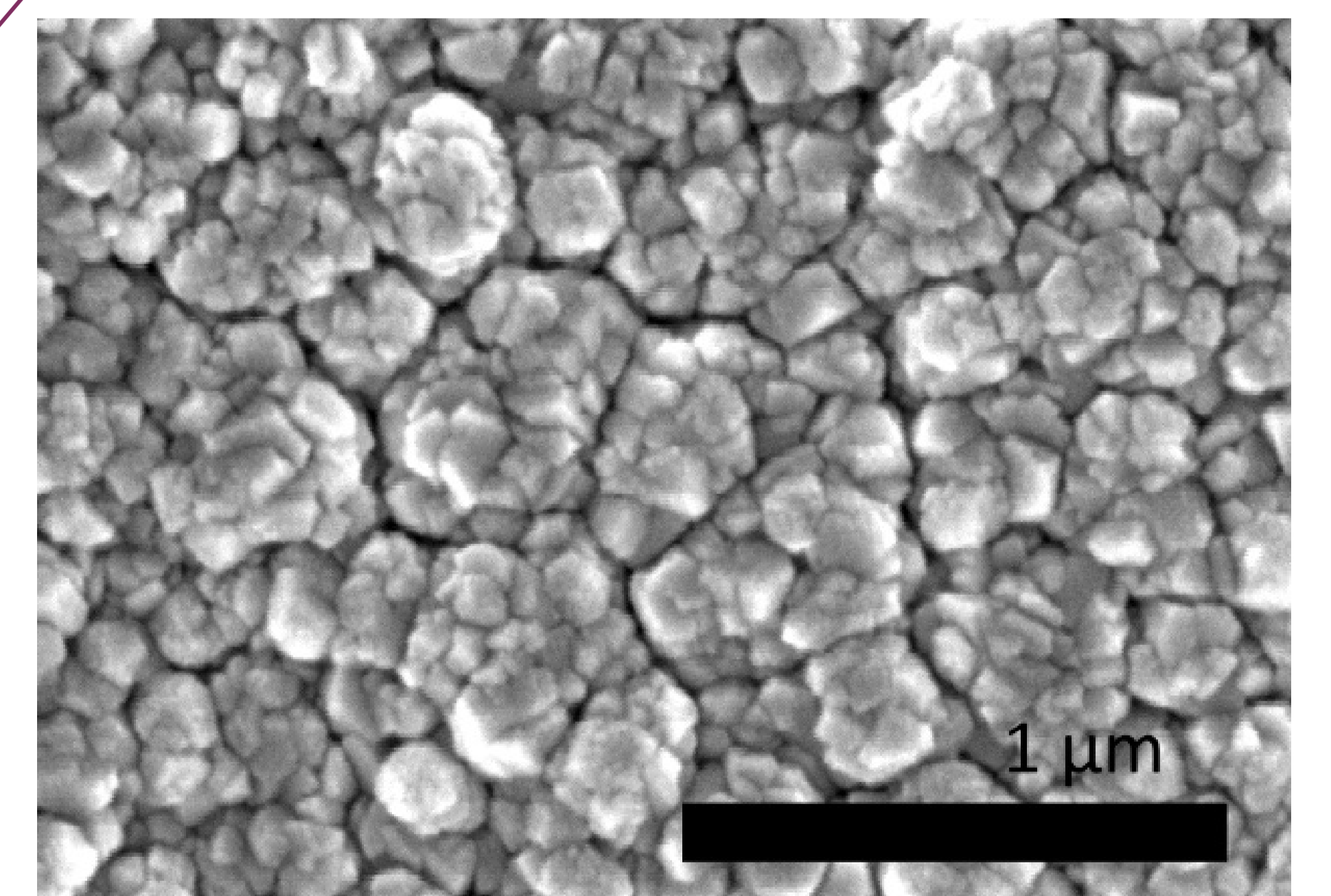
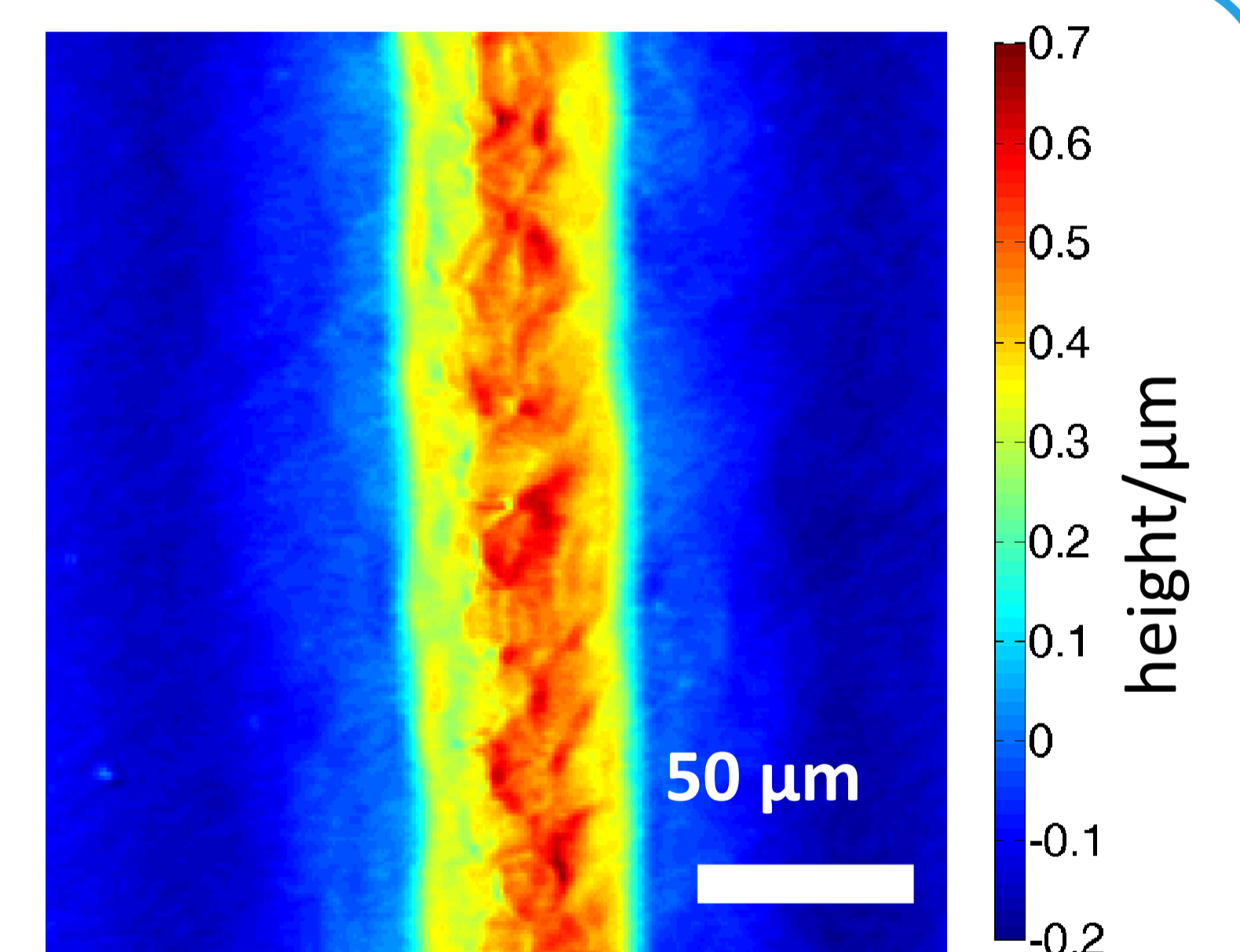
4. Experiment set-up

An SPI G3 1064 nm 20 W fibre laser is scanned using a Nutfield XLR8 galvo-scanner with a Jenoptik JENar 125 mm focal length f-theta lens. This laser is scanned through an AR coated fused silica window onto the substrate in the deposition chamber with walls heated at 100 °C. This temperature is above the precursor temperature of 50 °C to prevent condensation of the precursor in the chamber. A vacuum pump is used to achieve 3 mBar of pressure in the deposition chamber.



5. Results and analysis

- The deposition of W from $W(CO)_6$ is chosen because W has a low contact resistance with carbon-based materials [2] and the deposition temperature in CVD at 375 °C [3] is lower than the damage threshold of graphene on Si substrates at around 500 °C [4].
- W has been deposited from $W(CO)_6$ when a 40 μm diameter laser beam is scanned on SS304 and Si substrates at powers of 2-4 W with scan speed of 0.1-0.2 mm/s.
- The deposition temperature has been measured to be 210 °C using a FLIR A615 infrared thermal camera. This temperature is lower than the damage threshold of graphene on Si substrates [4].
- The resistivity of the W track deposited on Si substrates was measured to be 31 $\mu\Omega\text{ cm}$ which is around 5.5 times the bulk resistivity of W. This is acceptable for conductive track applications because W has a low contact resistance with carbon-based materials [2].
- A continuous track is formed at a deposition rate of up to 3600 $\mu\text{m}^3/\text{s}$, based on scanning speed and average profile measured using a Veeco Wyko NT3300 white light interferometer. This is around two orders of magnitude higher than EFIB techniques [5].
- The microstructure of the deposit is quite similar to the β -W polycrystalline film grown in CVD using the same precursor [3], it is likely because the dissociation, nucleation and growth processes in LCVD and CVD are similar.
- Analysis using an Oxford Instruments X-Max^N 80 energy dispersive X-ray spectroscopy of the deposits reveals that they consist of above 84 % of W on both SS and Si substrates. This is comparable to the composition in CVD [3] and higher than in EFIB techniques at 60 % [5].



6. Conclusion

An apparatus has been made that is capable of depositing W from $W(CO)_6$ precursor on locations defined by a laser. The deposits have a resistivity of only 5.5 times bulk and are deposited at a temperature of 210 °C. This temperature is lower than the thermal damage threshold of graphene. The deposition has been demonstrated on materials commonly used as graphene device substrates such as Si.

References

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