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Wafer-scale inspection of graphene conductivity by Terahertz near-field scanning: As-grown on sapphire and after transfer to SiO_2/Si

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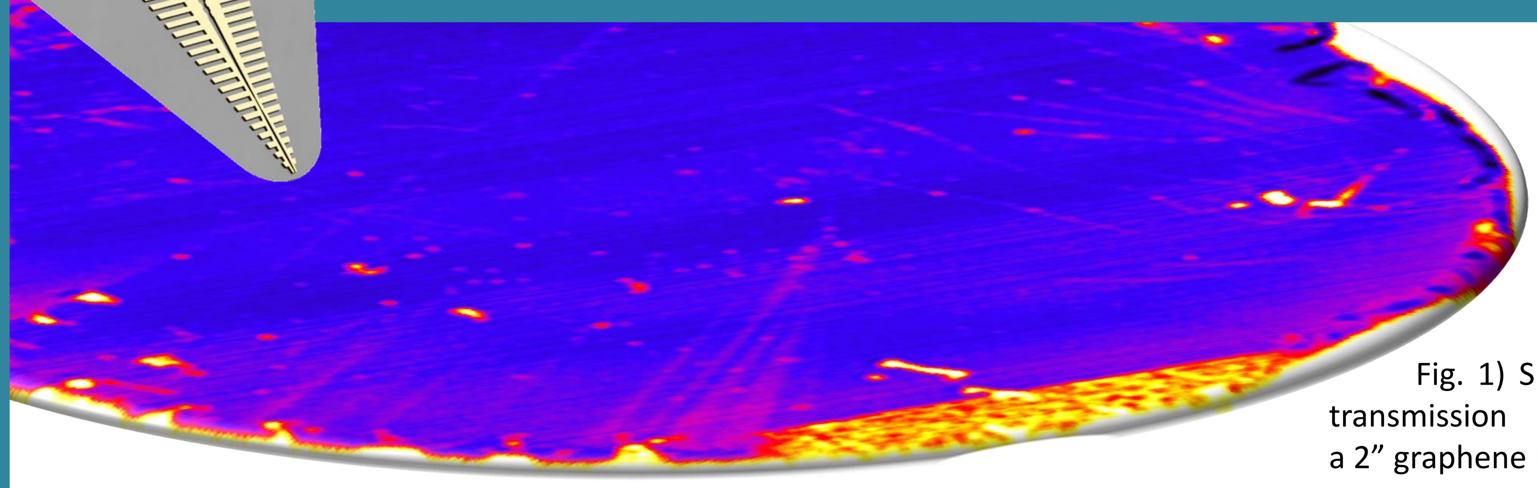


Fig. 1) Spatially resolved transmission amplitude across a 2" graphene layer on Si.

Motivation

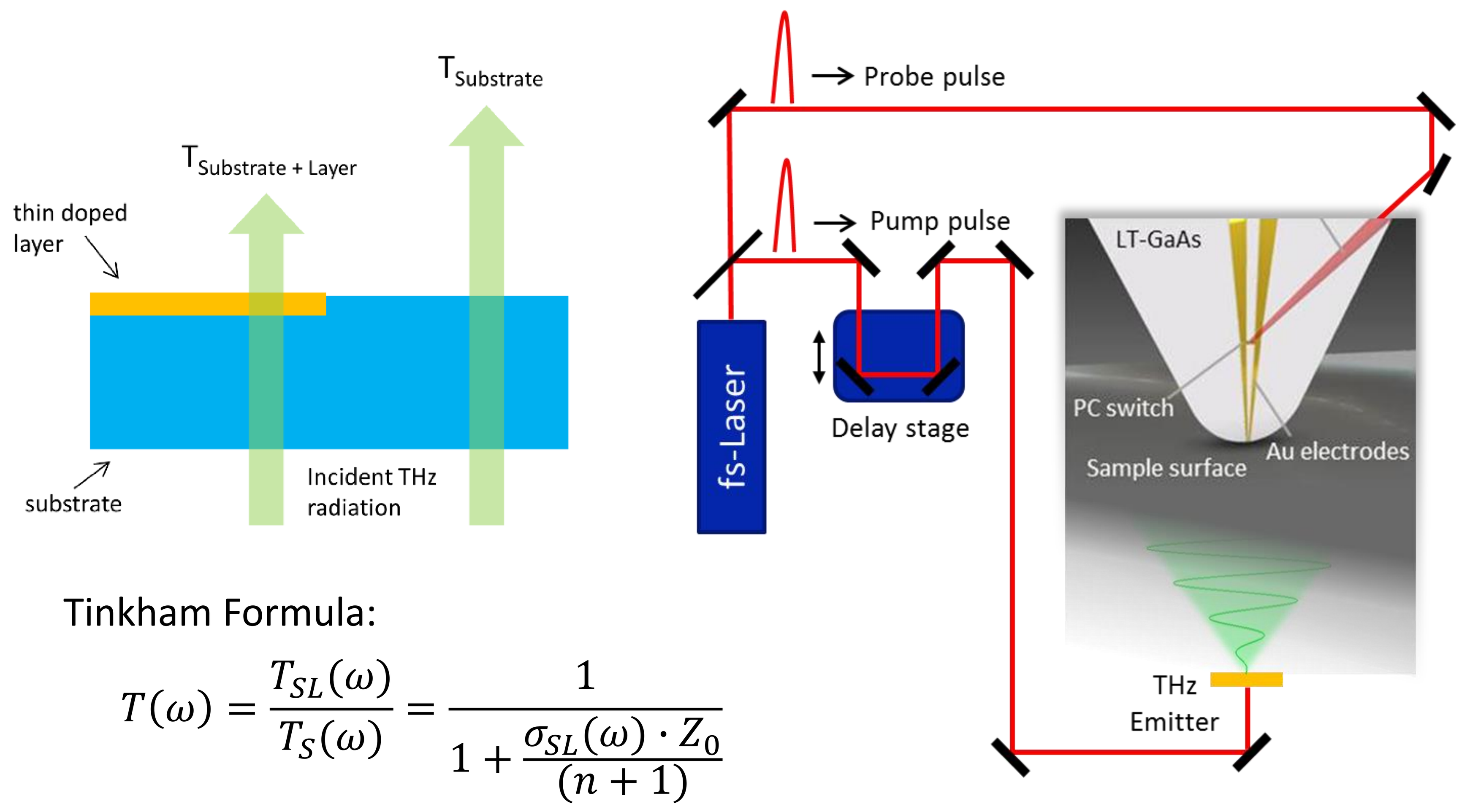
- **Terahertz (THz) spectroscopy** is one of the leading methods in terms of measurement speed and accuracy for **contact-free mapping of sheet resistance** and carrier mobility of large area graphene or other 2D materials [1].
- THz **near-field inspection** provides accurate measurements of graphene layers on various THz transparent substrates at **wafer-scale** with **µm spatial resolution**.
- Enables **graphene metrology** and **process surveillance** by inspection directly after manufacturing, as well as **quality inspection** right before further processing and device fabrication.

Results

- Spatially resolved **graphene sheet conductivity maps**, revealing graphene coverage and large-scale homogeneity as well as local variations and defects.
- Inspection of graphene on **Al_2O_3 growth substrate** (see Fig. 3a) provides knowledge about **quality on a single wafer** as well as **process variations** across multiple samples.
- Measurements after graphene transfer to **final SiO_2/Si wafers** (see Fig. 3b) shows additionally introduced **transfer-defects** and yields **local material properties** independent of involved device fabrication processing steps.

Method

- THz time-domain spectroscopy (**THz-TDS**) in **transmission** configuration based on an optical pump/probe scheme driven by an ultra short pulse laser as depicted in Fig. 2.
- THz **near-field detection** based on **photo-conductive micro-probes** provides high spatial resolution [2].
- Analytic description according to **Tinkham formula** and Drude-Model to extract **graphene sheet conductivity σ_{SL}** and carrier-mobility from THz data.



Tinkham Formula:

$$T(\omega) = \frac{T_{SL}(\omega)}{T_S(\omega)} = \frac{1}{1 + \frac{\sigma_{SL}(\omega) \cdot Z_0}{(n+1)}}$$

Fig. 2) Schematic of the THz near-field setup and the measurement scheme. Additional THz absorption by a graphene layer with conductivity σ_{SL} is measured as a reduction of the THz transmission amplitude T. A complete THz map is acquired by moving the sample laterally and recording THz data at each position.

Conclusion

- THz microprobe-based imaging systems enable the **non-destructive and contact-free** inspection of graphene for process monitoring and quality assurance.
- Near-field inspection achieves **micron-scale resolution on wafer-scale areas** at high measurement speeds.

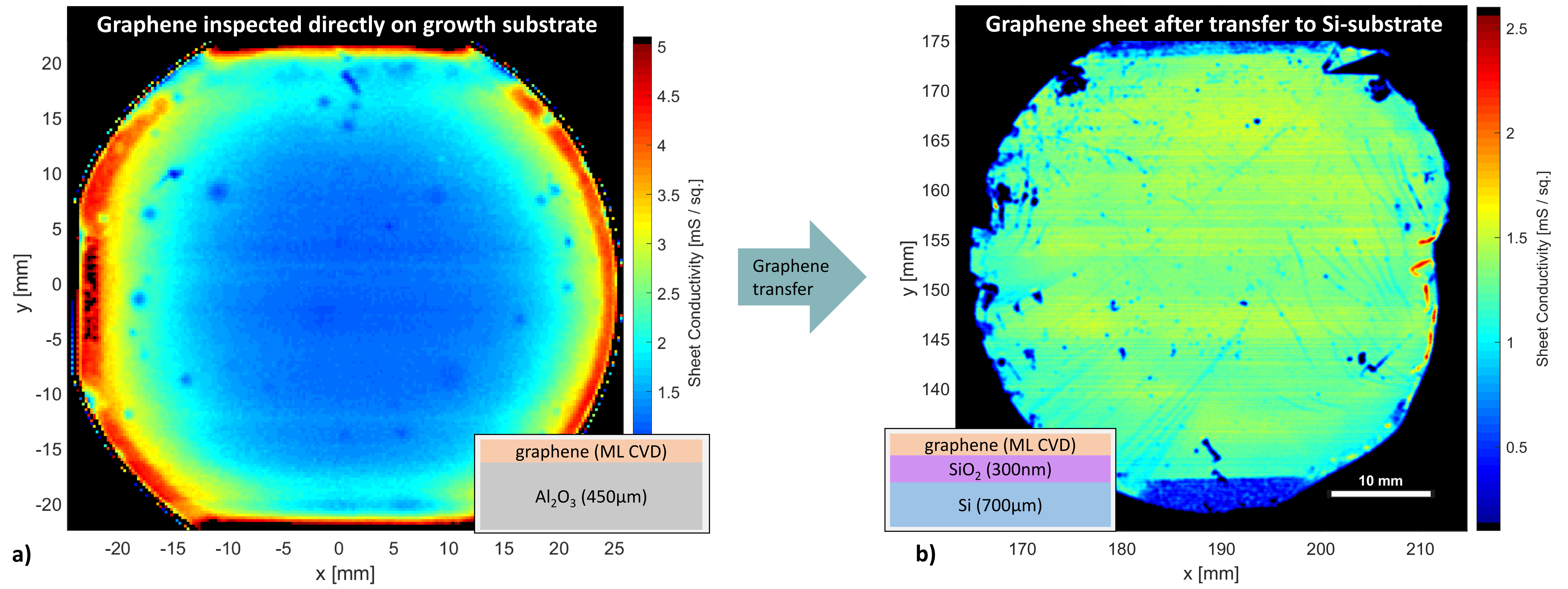


Fig. 3) Graphene sheet conductivity results obtained via high-resolution terahertz near-field transmission measurements. CVD-graphene directly after growth on sapphire substrate (a) and the same graphene sheet after transfer to a SiO_2/Si substrate (b). The central graphene area shows mostly homogeneous conductivity around 1.5mS/□, with just a few point defects before transfer and some transfer-typical additional defects like cracks and wrinkles after transfer onto the final substrate.

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