Graphene-based thin-films for flexible applications inspected by high-resolution Terahertz near-field microscopy

Simon Sawallich[1,2], Burkay Uzlu[2,3], Martin R. Lohe[4], Jimin Lee[1,2], Alexander Michalski[1], Martin Otto[3], Zhenxing Wang[3], Daniel Neumaier[3], Michael Nagel[1], Max C. Lemme[2,3]
1) Protemics GmbH, Aachen, Germany – 2) RWTH Aachen University, Aachen Germany
3) AMO GmbH, Aachen, Germany – 4) Sixonia Tech GmbH, Dresden, Germany
sawallich@protemics.com

Large area graphene production tools are available today and new methods to synthesize graphene and graphene-based materials have been developed together with improved ways to transfer these layers from growth to target substrates. Here we present measurement results for graphene and other graphene-based conductive thin-films on flexible substrate materials obtained by high-resolution Terahertz (THz) near-field transmission microscopy.

The key enabling technology for the high-resolution conductivity measurements are photo-conductive THz near-field detectors, as shown in Fig.1a). A spatially resolved THz near-field transmission map with a resolution of a few µm can be achieved by scanning the detector across the sample in close distance [1]. THz data is recorded in transmission mode and allows us to obtain the spatially resolved sheet conductivity of a thin-film such as graphene, which is calculated from the measured THz amplitude reduction.

The result of such a measurement is shown in Fig.1d) for a 6” CVD-graphene sheet on a polyimide (PI) layer supported by a silicon SiO2/Si carrier wafer. The active part of this particular material stack, i.e. the graphene-on-PI is designed for use in flexible electronics applications [2]. While for this measurement the graphene on PI has been fully supported by a rigid carrier wafer, further experiments demonstrate the technique on fully flexible substrates. Such samples include conductive thin-films of deposited exfoliated graphene (EG) flakes obtained via spray-coating or filtration from graphene-flake dispersions (E-ink) produced by electrochemical exfoliation of graphene [3]. The overall nature of these E-graphene based thin-films is intrinsically distinct from mono-layer graphene. And so are the types of defects or sheet resistance variations that are observed on the various samples. Most of the inspected EG-films have sheet resistance values in the range of a few Ω/□, as seen exemplarily from the THz results in Fig. 1e) for sample S4.

Spatially resolved THz near-field inspection provides quantitative results for large-scale conductivity variations, as well as the possibility to identify local defects in the conductive thin-film, also on flexible substrate materials.

We gratefully acknowledge funding by the German BMBF (project GIMMIK, 03XP0210).

References

[1] M. Wächter et. al., Applied Physics Letters 2009, vol. 95, no. 4, 041112
[2] B. Uzlu et.al., Scientific Reports 2019, vol. 9, no. 1, 18059
[3] H. Li et.al., Advanced Energy Materials 2017, vol. 7, no. 4, 1601847

Figures

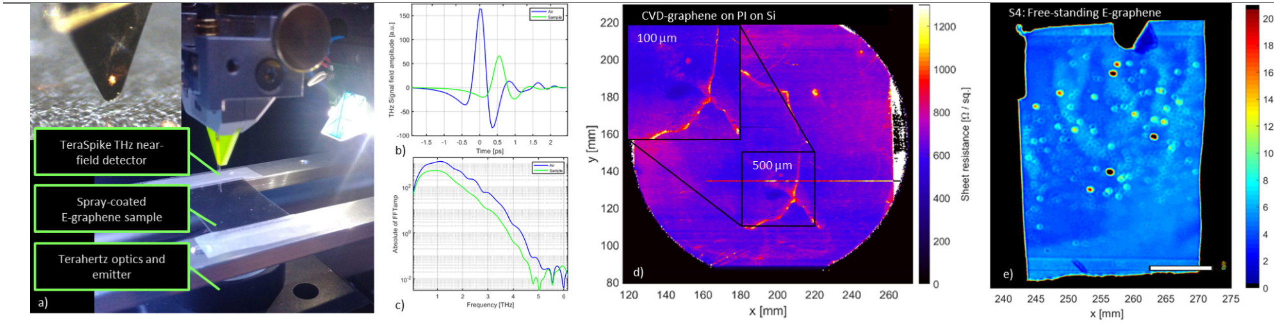

Fig.1: Terahertz near-field inspection setup and results for different samples: a) Photograph of the THz near-field setup. b) & c) Plots of recorded THz transients through air and sample material and corresponding THz spectra. d) THz mapping results for 6” graphene on PI supported by a silicon wafer, and c) for a free-standing layer of E-graphene, produced by filtration from E-ink dispersion.