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Sheet Resistance Measurement of Thin Metal Films Using Reflection-Mode THz-TDS

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Abstract—Micro four-point probe technology can reliably be used to measure the sheet resistance of thin metal films, with great accuracy and repeatability. In this work, we investigate the suitability of using reflection-mode terahertz time-domain spectroscopy for the same task. The agreement between the two methods places reflection-mode terahertz time-domain spectroscopy as a viable tool for thin metal film analysis.

I. INTRODUCTION

TERAHERTZ time-domain spectroscopy (THz-TDS) [1] is a proven method for the characterization of thin metal films in a non-destructive, contactless fashion [2,3]. Commonly, THz-TDS measurements are done in transmission (e.g., [2,3]). Reflection-mode THz-TDS has its merits, but is challenging, as demonstrated in [4] for graphene measurements. Here, we demonstrate accurate measurement of the dc sheet resistance, $R_{s,dc}$, of titanium (Ti) thin metal films on a silicon (Si) substrate, using reflection-mode THz-TDS. The results are benchmarked against values obtained using Capres A/S state-of-the-art micro four-point probe (M4PP) technology.

II. RESULTS

A THz-TDS system (Toptica TeraFlash Pro) was used to acquire time traces reflected from Ti thin metal films (5 to 15 nm in thickness) on an Si substrate, as schematically shown in Fig. 1(a) and (b). Time traces, for various Ti film thicknesses and Si substrate only, are shown in Fig. 1(c).

The complex, frequency dependent sheet conductance, $\sigma_s(\omega)$, can be calculated using the formula

$$(1) \sigma_s(\omega) = \frac{(1 + n_{sub})[1 - \tilde{R}(\omega)]}{Z_0[\tilde{R}(\omega) + (1 + n_{sub})/(1 - n_{sub})]}$$

where $\tilde{R}(\omega)$ is the ratio of the Fourier transforms of the thin film trace and the substrate reference trace, n_{sub} is the refractive index of the substrate and Z_0 is the free space impedance. To reliably extract the dc sheet resistance value, $R_{s,dc} = 1/\sigma_{s,dc}$, from the THz-TDS data, our algorithm relies on Eq. (1) and additional concepts that result from a Drude model-based reasoning (note that $\sigma_s(\omega) \approx \sigma_{s,dc}/(1 - i\omega\tau)$, according to the Drude model). These concepts help mitigate the possibly strong influence of minute misalignments between the thin film and substrate-only reference measurements. Each thin metal film was measured at up to 25 different points using both M4PP and THz-TDS. Results are summarized in Table 1, showing mean values obtained by M4PP and THz-TDS in good agreement and with comparable standard deviations (SDs). We believe that these results demonstrate that reflection-mode THz-TDS can serve as a viable tool for thin metal film analysis.

Fig. 1. (a), (b) Simplified schematic of the THz-TDS experimental setup and (c) thin film THz-TDS traces.

Thickness	5 nm		7 nm		10 nm		15 nm	
	mean	SD	mean	SD	mean	SD	mean	SD
M4PP	1522.4	50.62	516.45	6.26	272.64	2.51	166.24	1.91
THz-TDS	1481.5	69.59	513.02	11.17	268.42	3.41	164.13	2.69

Table 1. Sheet resistance mean and standard deviation (SD) values [Ω] measured using M4PP and THz-TDS.

REFERENCES

- [1] P. U. Jepsen, D. G. Cooke, and M. Koch, "Terahertz spectroscopy and imaging – Modern techniques and application," *Laser Photonics Rev.* 5(1), 124–166, 2011.
- [2] N. Laman and D. Grischkowsky, "Terahertz conductivity of thin metal films," *Appl. Phys. Lett.* 93, 051105, 2008.
- [3] Z. Wang, Y. Han, N. Xu, L. Chen, C. Li, L. Wu, and W. Zhang, "Characterization of thin metal films using Terahertz spectroscopy," *IEEE Trans. Terahertz Sci. and Tech.* 8(2), 161–164, 2018.
- [4] H. Lin, P. Braeuninger-Weimer, V. S. Kamboj, D. S. Jessop, R. Degl'Innocenti, H. E. Beere, D. A. Ritchie, J. A. Zeitler, and S. Hofmann, "Contactless graphene conductivity mapping on a wide range of substrates with terahertz time-domain reflection spectroscopy," *Sci. Rep.* 7, 10625, 2017.