Electronic Supplementary Material (ESI) for RSC Advances.

Supplementary Information

Microstructure-driven Electrical Conductivity Optimization in Additively Manufactured Microscale Copper Interconnects

Maxence Menétrey,[a‡] Cathelijn van Nisselroy,[b‡] Mengjia Xu,[b] Julian Hengsteler,[b] Ralph Spolenak,[*a] Tomaso Zambelli[*b]

[a] Laboratory for Nanometallurgy, Department of Materials, ETH Zürich, Vladimir-Prelog-Weg 1-5/10, 8093 Zürich, Switzerland, ralph.spolenak@mat.ethz.ch
[b] Laboratory of Biosensors and Bioelectronics, Department of Information Technology and Electrical Engineering, ETH Zürich, Gloriastrasse 35, 8092 Zürich, Switzerland, ztomaso@ethz.ch
‡ These authors contributed equally to this work
* Corresponding authors

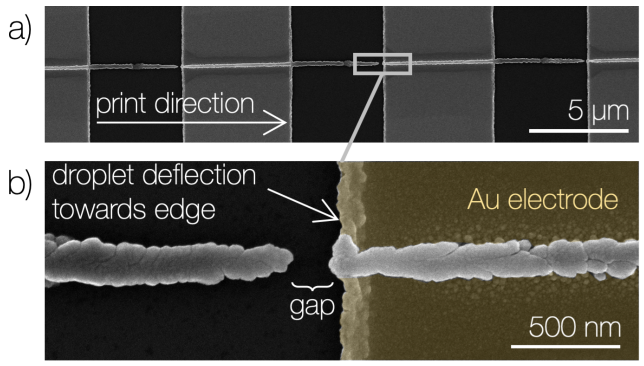

Figure 1: (a) SEM micrograph of a line printed by EHD-RP and displaying a clear disconnection at the transition from the non-conductive Si_3N_4 wafer and the gold electrode. (b) Enlarged view showing the 200 nm gap. The distance between the nozzle and the substrate was ≈7.5 µm.

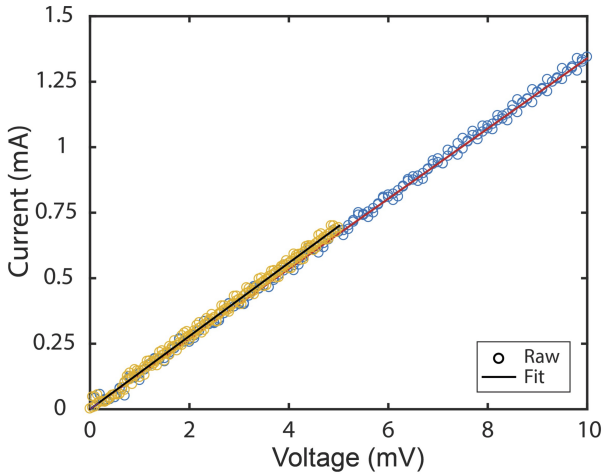

Figure 2: IV curve obtained for the electrical characterization of a Λ-bridge deposited by FluidFM. The measurement is performed in 4-point configuration with 5 and 10 mV sweep.

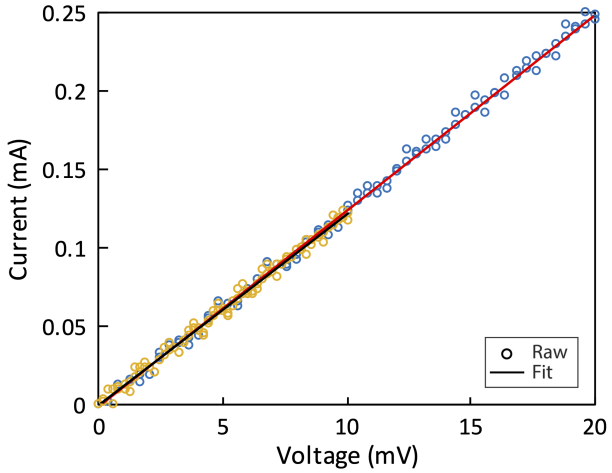

Figure 3: IV curve obtained for the electrical characterization of copper line deposited by EHD-RP. The measurement is performed in 4-point configuration with 10 and 20 mV sweep.

Process Step	*Parameters*
Mask Design & Fabrication	Mask design in KLayout Mask writing using the DWL 2000 GS (Heidelberg Instruments) on a 5-inch soda lime glass with a 30 nm chromium layer and 500 nm of photoresist (AZ 1505) on top. Development of the photolithography mask in AZ 400K diluted 1:4 in DI water. Washing of the mask in DI water, followed by a chromium wet etch, after which another washing step in DI water is performed. Stripping of the photoresist with acetone, followed by an IPA rinse and blow dry with the nitrogen gun. Ready for use.
Wet chemical cleaning of wafer	10 s acetone flush 5 min in Acetone (ultrasonic bath) 10s IPA flush 5 min IPA (ultrasonic bath) Blow dry wafer with nitrogen gun
Dehydration Bake	Hot plate HT-302 D, Torrey Pines Scientific 10 min at 200 °C
Plasma clean	Plasma cleaner 100-E Plasma Systems Technics Plasma GmbH 2 min at 100 W
Spincoat photoresist S1805	Spincoater Suess Microtec Ramp (200 rpm/sec) to 500 rpm for 5 s Ramp (1500 rpm/sec) to 3000 rpm for 30 Expected thickness = 0.5 µm
Softbake	Hot plate HT-302 D, Torrey Pines Scientific RT ramp up to 115 °C (240 °C/hr) 1 min at 115 °C Cool down to RT
Exposure	Mask aligner: Karl Suss MA-5, Suss MicroTec Hard contact, 20 um alignment gap 1 cycle of 11.54 sec (power = 13mW/cm^2 @broadband (CP)) Total dose: W = 150 mJ/cm^2 For **glass** wafers: put black foil underneath wafer to absorb UV scattering
Development	For **Si_3N_4** wafers: 10s in a (fresh) bath of MF-319 For **glass** wafers: 5 s in (fresh) bath of MF-319 Dip the wafer in DI water (gently) Blow dry N2 (gently)
Optical Inspection	Check features under optical light microscope
Evaporation of gold film	3 nm Ti, followed by 25 nm Au
Photoresist Removal (Lift Off)	10 s acetone flush 5 min in Acetone (ultrasonic bath) 10s IPA flush 5 min IPA (ultrasonic bath) Blow dry wafer with nitrogen gun
Spincoat photoresist MaN 1420	Spincoater Suess Microtec Ramp (100 rpm/s) to 500 rpm for 5 s Ramp (1000 rpm/s) to 3000 rpm for 30 s Expected thickness = 2 µm
Softbake	Hot plate HT-302 D, Torrey Pines Scientific 2 min at 100 °C
Wafer Dicing	20 x 20 mm
Photoresist Removal	10 s acetone flush 5 min in Acetone (ultrasonic bath) 10s IPA flush 5 min IPA (ultrasonic bath) Blow dry wafer with nitrogen gun
Optical Inspection	Check final electrode structures under optical light microscope

Figure 4: Detailed overview of the lithography process steps for the fabrication of the electrode substrates.