Fabrication and integration of graphene interdigitated resistors on printed circuit boards for RF interrogation of biological sensors.

Madhav Kumar[1,2], Adrien Hugo[1,2] , Riad Othmen[3], Zheng Han[1,2], Victor Engelhardt[1,2], Christophe Delaveaud[1,2], Camille Jouvaud[1,2] , Julien Renard[3], Vincent Bouchiat[3], Pascal Mailley[1,2], Thomas Alava[1,2]

1 Univ. Grenoble Alpes, F-38000 Grenoble, France
2 CEA, LETI, Minatec Campus, F-38054 Grenoble, France
3 Institut Néel, Université Grenoble Alpes – CNRS:UPR 2940, F-38042 Grenoble, France. C.A de Coulomb

The growing need for adaptable, robust on field sensors is pushing the sensors system developers to always provide sensors with smaller cost smaller size and better performances. Particularly, wireless sensors for the internet of things sums up the more ambitious requirement (cost, size, autonomy, energy consumption, sensitivity, response time). In this study we present first the fabrication of a passive graphene resistive sensor onto a printed circuit board surface, hosting a RF radar type copper communication antenna. We present then the electrical characterization of the device through classic instrumentation and then with RF interrogation inside an anechoic chamber.

The printed circuit boards were purchased with a pre-made RF antenna. We initially perform deposition of an electrically insulating epoxy material locally were the graphene sensor is to be fabricated. This step was completed with gentle grinding of the layer for adjusting the surface roughness of the epoxy patch. Then, gold electrodes were deposited through electron beam sputtering through solid stencil. The stencil were defined by xerography of a mylar layer[1]. Once defined the electrodes, we performed spin coating and patterning of a photoresist layer through photolithography. The pattern was defining the area for the graphene to be transferred onto the electrodes. The graphene layer was transferred through wet transfer onto the gold electrodes. Similarly to Trung *et al.* [2], we successfully performed patterning of the graphene with ultrasonic treatment to prevent short circuit from the copper antenna to the deposited gold electrodes. Finally, we connected the gold electrodes to the RF antenna through ball wire bonding. Electrical characteristic of the graphene resistor was obtained with a probe station before connection to the antenna to assess the overall quality of the fabrication process in term of residual doping of the graphene layer. Raman analysis were consistent with electrical characterization to indicate the presence of defects in the graphene layer due to the unusual roughness of the substrate. We validated RF communication with the antenna connected to a similar device built on a silicon substrate by standard microfabrication. Work is ongoing to validate RF communication to both sensors (built on silicon chip, built on printed circuit board) while the graphene sensors is embedded in a liquid media.

References : [1] Darrieutort, B., Pellet, C., Pibre, G. & Ayela, C. Elaboration of soft and flexible silicone stencils for the wafer-level micropatterning of polymers. in The 15th International Meeting on Chemical Sensors, IMCS 2014 2 pages (2014).
[2] Trung, T. N. et al. Simple and Reliable Lift-Off Patterning Approach for Graphene and Graphene–Ag Nanowire Hybrid Films. ACS Applied Materials & Interfaces 9, 21406–21412 (2017).

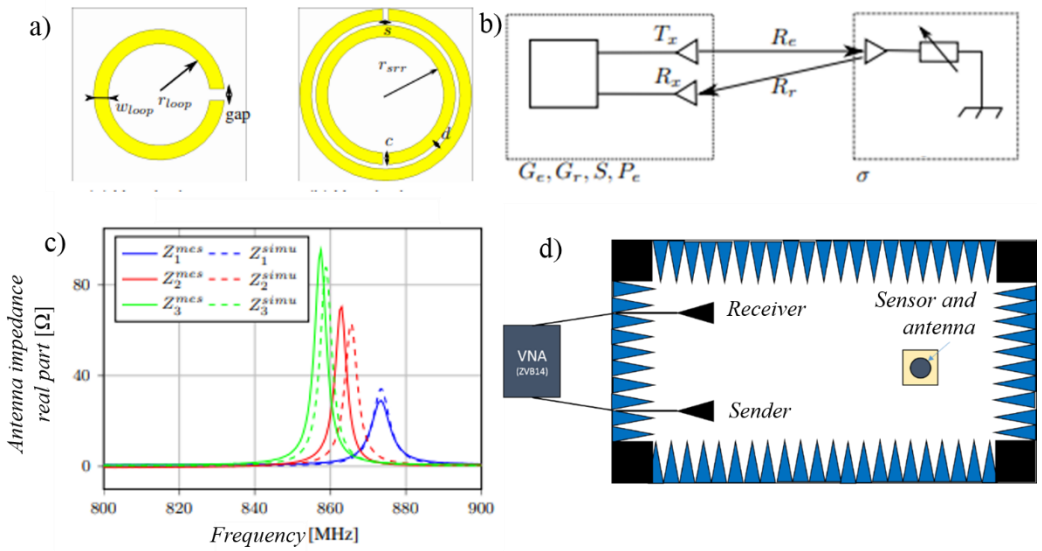

Figure 1: a) Top and back face of the copper layout of the initial printed circuit board bearing the antenna in our case w_{loop}=2 mm r_{loop}=3,5 mm r_{srr}=10,4 mm (gap= 1 mm). b) and d) electrical scheme of the antenna connected to the graphene resistor and interrogated through a sending and a receiving antenna connected by a virtual network analyzer. c) Electrical response of the antenna built on the printed circuit board (courtesy of Darrieutort[1])

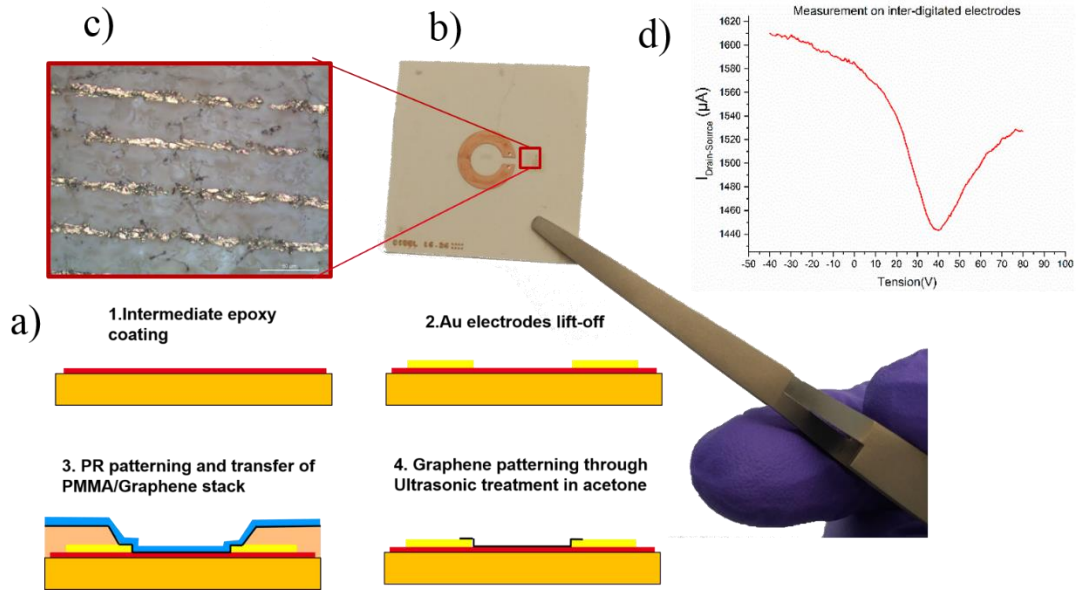

Figure 1: a) Fabrication process used to fabricate the graphene passive resistor onto the printed circuit board bearing the antenna. b) Photograph of the PCB bearing the Graphene sensor and the copper radar antenna. c) Close-up optical micrograph on the interdigitated electrodes of gold on the printed circuit board. d) Electrical characterization of graphene interdigitated electrodes resistor, measured through a probe station in this case.