Graphene based flow sensors

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Graphene is chemically and mechanical resistant and can therefore readily be used for applications in harsh environments. This makes graphene, also owing to its excellent electrical properties, a very promising material for use in medicine, chemistry, food industry as well as in electronics, optoelectronics, robotics and nanotechnology. One of the areas of research, which is currently being widely investigated, is the use of graphene as a liquid flow sensor. The reports addressing such sensors, which were published so far, are very contradictory [1) 2)]. This indicates that the underlying physics is still not well understood and that more in-depth studies are needed in order to shed more light on this subject.

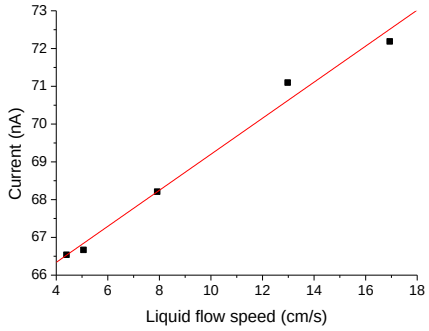

Fig. 1 Relationship between liquid flow speed and generated current signal.

In this communication we present results on our research on graphene flow sensor structures. We were able to obtain sensors, which showed, in certain range, a linear dependence on the liquid flow velocity. We show that this sensors functioned in different liquids like deionized water (DI) or acid solutions.

The main element of the investigated sensors is graphene on different substrates immersed in a flowing liquid. We used epitaxial graphene on SiC with different resistivities and graphene grown on Cu which was then transferred to SiO_2 or PET (polyethylene terephthalate). Different kinds of electric contacts, which were made of Pd/Au, Cr/Au or Ti/Au were fabricated and studied. Furthermore, we investigated samples with Ti/Au metallization and an additional SiO_2 contact passivation. To completely exclude possible effects on the generated signals due to the metallization, we constructed a sample for which the electrical connections were not immersed in the liquid. Various liquids like DI, aqueous solutions of NaCl and HCl and organic liquids (isopropanol and ethanol) were investigated. Two types of configurations, with and without additional gate were used in our experiments. As a gate, we used Pt or Cu wires and in some cases we extended the setup to work with an additional Ag/AgCl electrode. We performed measurements in a passive system, which allowed for the investigation of voltage/current generation caused by the flow of liquids (as reported in ref 1). In order to broaden the picture we also studied configurations with external voltages applied to the gate, as well as a configuration in which current was forced through the graphene sample.

To understand the phenomena we have to take into account the presence of a double layer at the graphene/liquid interface. A double layer is made of two layers of oppositely charged ions forming at the interface inside the liquid. We conclude that the main reason responsible for the observed generated signals could be the perturbation of this double layer. Our studies provide new important information that help to gain a better understanding of the observed phenomena.

[1] P. Dhiman, *Nano Lett*. **11**, 3123–3127 (2011)
[2] J. Yin, *Nano Lett.* **12**, 1736−1741 (2012)