Wafer-scale fabrication of graphene-based field effect transistor arrays for extracellular measurements

D. Kireev, S. Seyock, J. Schnitker, V. Maybeck, B. Wolfrum, and A. Offenhäusser

d.kireev@fz-juelich.de

Institute of Bioelectronics (PGI-8/ICS-8), Forschungszentrum Jülich, 52425 Jülich, Germany

Abstract: The work is focused on the fabrication and analysis of graphene-based, solution-gated field effect transistor arrays (GFET arrays) in a large scale. The GFETs show extremely high electrolyte-gated transconductance promising exceptional biosensing capability. Signal-to-noise ratio (SNR) of the GFETs is analysed for different graphene areas. In the future we will apply these GFETs for extracellular recordings from neuronal and cardiac cells.

Keywords: graphene, GFET, cell-based biosensors, extracellular measurements.

Introduction

In the field of bioelectronics, graphene is a promising candidate for very efficient [1], flexible, biocompatible and implantable sensors [2].

In this work we aim to establish a large-scale fabrication process in order to use graphene as a transducer of biological information into electrical signals, to be recorded by a computer. When a biological signal changes the state of a cell, “sitting” on the graphene transistor, this can result in a sudden depolarization of the membrane potential – the action potential. This action potential will, in turn, change the gate potential of the GFET and consequently its drain-source current, which is further amplified and recorded.

High-throughput biological measurements require a large number of samples, which are difficult to achieve using exfoliated graphene. To circumvent this problem, we base our fabrication approach on chemical vapor deposited (CVD) graphene despite its inferior electronic properties.

Results and Discussion

We have addressed several issues concerning the efficient fabrication of GFET arrays for bioelectronics applications:

a) *Large-scale fabrication*. We have developed a 4-inch wafer fabrication process, based on CVD-grown graphene. The fabrication results in 52 11*11mm-sized chips, each of which comprises 32 individual GFETs. The design of the wafer is schematically illustrated in Figure 1.

b) *Signal-to-Noise Ratio*. Altering the graphene active area’s shape and size is the key to optimize the SNR. Our parallel fabrication approach allows us to optimize the SNR by producing multiple samples with different widths (2, 5, 10 and 20 µm) and lengths (5, 10 and 20 µm) of the graphene areas on a single wafer.

c) *Interfaces*. In order to improve sensitivity and stability of the devices, it is important to modify the graphene-substrate interface. This is done by tailoring the SiO_2/Si surface with self-assembled monolayers, or by using other substrates like sapphire or polyimide.

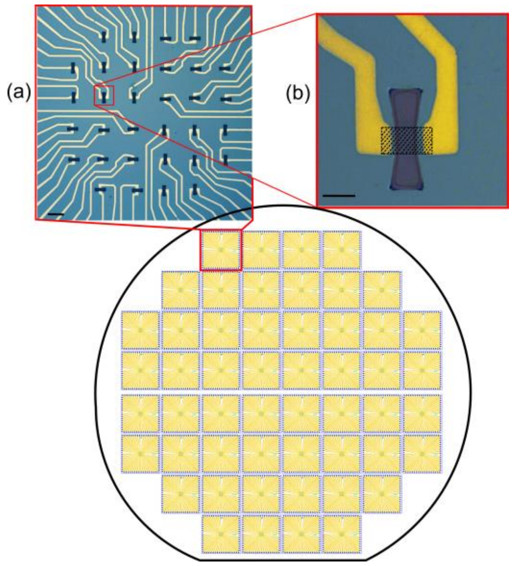

Figure 1: The distribution of the 52 chips at the 4 inches wafer. Insert (a) – the central area of a chip with 32 individual transistors; (b) – a single FET with graphene as the dashed area; Scale bars are 100 µm in (a) and 20 µm in (b).

The measured transconductances of our GFETs are in the range of 20 to 25 µS, which is larger than of Si analogues, but still below the high-performance GFETs produced in a single-device approach using exfoliated graphene [3].

Conclusions

A wafer-scale fabrication of graphene FET arrays has been introduced. The GFETs have been applied for extracellular measurements.

References

[1] Z. Cheng et al., *Nano letters*, **13** (6), 2902–2907 (2013)

[2] L.H. Hess, M. Seifert, J.A. Garrido, *Proceedings of the IEEE*, **101** (7), 1780-1792 (2013)

[3] D. Khodagholy et al., *Nature communications* **4** (2133), 1-6 (2013)

Acknowledgements

The work is performed within the scope of the Helmholtz-CAS joint research group in collaboration with J.A. Garrido (TUM, Germany) and X. Xie (SIMIT, China).