Towards silicon-graphene based heterojunction transistors

C. Strobel[1], C.A. Chavarin[2], J. Kitzmann[2], Ch. Wenger[3], M. Albert[1], J.W. Bartha[1]

1 Technische Universität Dresden, Semiconductor and Microsystems Technology Laboratory, Nöthnitzer Straße 64, 01187 Dresden, Germany
2 IHP, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany
3 Brandenburg Medical School Theodor Fontane, 16816 Neuruppin, Germany

carsten.strobel@tu-dresden.de

Abstract: The graphene-base heterojunction transistor (GBHT [1], see Fig. 1) is an attractive device concept to reach THz operation frequencies. The novel transistor consists of two n-doped silicon layers with a graphene monolayer in between. The structure of the device is similar to an n-p-n bipolar transistor with the base being replaced by graphene. This innovative concept exhibits a vertical arrangement of the emitter (E), base (B) and collector (C), thus potentially allowing for very high cut-off frequencies (f_T) due to the very low base-transit time.
To realize a graphene-base heterojunction transistor it is necessary not only to transfer graphene to a silicon surface, but also to deposit a silicon layer on top of graphene. Up to now, reports about the deposition of silicon on graphene are scarce. Recently, a deposition technology (very high frequency plasma enhanced chemical vapor deposition – VHF PECVD) was successfully introduced for the fabrication of silicon-based thin-film layers on graphene without creating defects in the underlying monolayer [2]. This method is used in the present study to deposit n-doped amorphous silicon (a-Si:H) on graphene.
In this work the current state of GBHT development at TU-Dresden/IHP will be presented. First, the innovative non-destructive deposition technology for n-a-Si:H on graphene will be highlighted. Next, the successful control of the graphene/silicon interfaces is described. Up to now, highly rectifying Schottky diodes (I_{ON}/I_{OFF} 10^4 - 10^5, +/- 1V) have been achieved for both the BE and BC graphene-silicon interface [3]. Finally, first GBHT prototypes were prepared and analyzed. It is verified, that the vertical current between the (n)-a-Si:H layers is successfully controlled by the ultra-thin graphene base voltage [4]. While current saturation is yet to be achieved, a transconductance of ~230 µS was obtained, demonstrating a moderate modulation of the collector-emitter current by the ultra-thin graphene base voltage.

References

[1] V. Di Lecce, R. Grassi, A. Gnudi, E. Gnani, S. Reggiani and G. Baccarani, IEEE transactions on electron devices, Vol. 60, No. 12, (2013) pp. 4263-4268
[2] G. Lupina, C. Strobel, J. Dabrowski, G. Lippert, J. Kitzmann, H. M. Krause, Ch. Wenger, M. Lukosius, A. Wolff, M. Albert, and J. W. Bartha, Appl. Phys. Lett. 108, (2016) 193105
[3] C. Strobel, C. A. Chavarin, J. Kitzmann, G. Lupina, Ch. Wenger, M. Albert, and J. W. Bartha, J. Appl. Phys. 121, 245302 (2017)
[4] C.A. Chavarin, C. Strobel, J. Kitzmann, A. Di Bartolomeo, M. Lukosius, M. Albert, J.W. Bartha and Ch. Wenger, Materials (2018), 11(3), 345

Figures

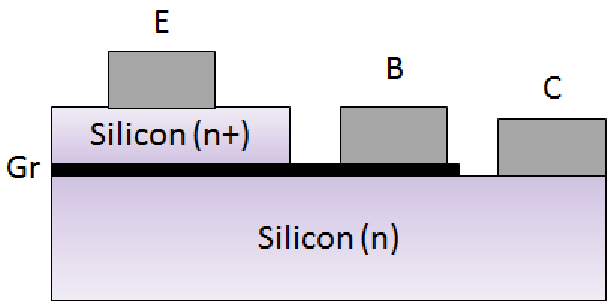

Figure 1: Schematics of the graphene-base heterojunction transistor with emitter(E), base(B) and collector (C) as proposed in [1]