Fabrication of triple-gate fin-type hydrogenated diamond MOSFETs

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Recently, fabrication processes for H-diamond metal-oxide-semiconductor field-effect transistors (MOSFETs) have been developed. The maximum drain-source current of a MOSFET fabricated on NO_2-treated H-diamond was as much as −1.35 A mm^{-1} [1]. The cut-off frequency of the device was more than 10 GHz over a wide gate-source voltage (V_{GS}) range of approximately 10.0 V. In addition, the operational performance of H-diamond-based MOSFETs was comparable to that of SiC- or GaN-based MOSFETs in high temperature and high voltage operation [2].

While these H-diamond-based MOSFETs showed excellent electrical properties, the absence of large-area single-crystal diamond wafers has hindered their development for widespread practical applications. This issue has led us to downscale diamond electronic devices. In our previous study [3], downscaled H-diamond MOSFETs were fabricated by eliminating the interspacing between the source/drain and gate contacts ($IS_{S/D\text{-}G}$). The on-resistance of the H-diamond MOSFET without $IS_{S/D\text{-}G}$ was considerably lower than the corresponding device with $IS_{S/D\text{-}G}$. The device's current output and extrinsic transconductance (g_m) were also greatly improved. Recently, triple-gate MOSFET architecture has been developed in the Si-, InGaAs-, and GaN-based MOSFETs to extend device downscaling, reduce leakage current, and control device short channel effects [4]. Also, because the triple-gate MOSFET can allow carriers to travel in both its planar and lateral sides, the device current output is much higher than that of a planar-type device with the same area.

Here, we design and fabricate a H-diamond triple-gate MOSFET. The schematic structure of it is shown in Fig. 1 (a). The device's electrical properties are compared with those of planar-type MOSFETs [Fig. 1 (b)], which are fabricated simultaneously on the same substrate. Fig. 1 (c) shows a top view of the entire surface of the sample. The total number of designed MOSFETs was 128. However, three ohmic contacts fell off during the fabrication process. The triple-gate MOSFET's output current is more than five times higher than that of the planar-type device, and the on/off ratio and subthreshold swing are more than 10^8 and as low as 110 mV dec^{-1}, respectively. The fabrication of these H-diamond triple-gate MOSFETs will drive diamond electronic device development forward towards practical applications [5].

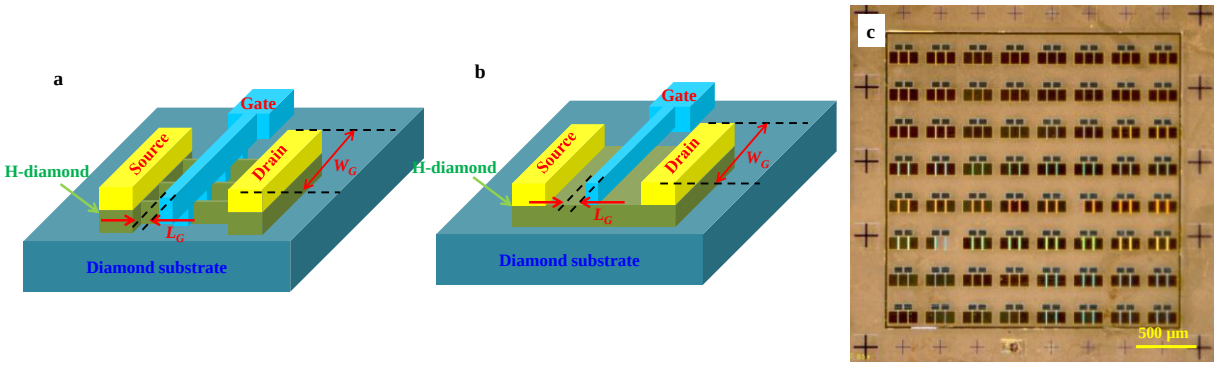

Fig.1 Schematic structures of the H-diamond-based (a) triple-gate fin-type and (b) planar-type MOSFETs, respectively, and (c) top view of the entire sample

Reference

[1] K. Hirama, H. Sato, Y. Harada, H. Yamamoto, and M. Kasu, Jpn. J. Appl. Phys. **51**, 090112 (2012).
[2] H. Kawarada, H. Tsuboi, T. Naruo, T. Yamada, D. Xu, A. Daicho, T. Saito, and A. Hiraiwa, Appl. Phys. Lett. **105**, 013510 (2014).
[3] J. W. Liu, M. Y. Liao, M. Imura, A. Tanaka, H. Iwai, and Y. Koide, Sci. Rep. **4**, 6395 (2014).
[4] E. J. Nowak, IBM J. RES. & Dev. **46**, 169 (2002).
[5] J. W. Liu, H. Ohsato, X. Wang, M. Y. Liao, and Y. Koide, submitted.