GAP ENGINEERING AND RELIABILITY STUDY FOR 2D ELECTRONICS

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The main issue of downscaling in the Si field-effect transistors (FETs) is the short channel effect in which the gate control is weakened by the drain bias. Based on an analysis of the electrical potential distribution in the channel region, it is well known that the short channel effect can be neglected when the channel length is ~6 times longer than the scaling length $l = \sqrt{(k_{ch}t_{ch}t_{ox}/Nk_{ox})}$, where N is the effective gate number. This perspective attracts great attention to 2D layered channels in the FET application because of their rigidly controllable atomic thickness (t_{ch}< 1 nm), as well as the low dielectric constant (k_{ch} = ~4) for typical 2D layered channels. Although old-but-new 2D channels, such as transition metal dichalcogenides, black phosphorus, and so on, have been intensively investigated recently, bilayer graphene still has an advantage over the high performance device from the viewpoint of the smaller effective mass (m_{BLG}=~0.037, m_{BP}=0.13, and m_{MoS2}=~0.37). In this talk, we focus on two important aspects toward the 2D electronics.

First one is the low I_{on}/I_{off} issue for bilayer graphene (BLG), which is considered due to the variable range hopping in “gap states”. The gap state density (D_{it}) was for the first time extracted by the conductance measurements after the precise E_G determination by the quantum capacitance measurement (Fig. 1). The possible origins for the gap states, border traps at the edge of Y_2O_3, the local breakdown of A-B stacking in BLG, and the spatial fluctuation of band structure of BLG due to charged impurities at oxide interfaces are discussed. [1] Moreover, the drastic improvement of I_{on}/I_{off} for *h*-BN/BLG/*h*-BN heterostructure will be discussed in the conference.

The other is reliability issue on an insulating layered material, *h*-BN. It is widely utilized as the substrate and gate insulator to achieve high carrier mobility in layered channel materials. It has not been determined whether the dielectric breakdowns of 2D layered materials follow the general breakdown phenomena for 3D amorphous oxides. In this study, the anisotropic dielectric breakdown of *h*-BN is studied. The dielectric breakdown field for the out-of-plane direction is 4 times larger than that for the in-plane direction, and interestingly larger than that of diamond. This can be understood when the structure change from cubic-BN to *h*-BN is considered. *h*-BN can possess a relatively high breakdown field concentrated only in the out-of-plane direction by conceding a weak bonding direction in the highly anisotropic crystal structure. [2]
The perspective on the 2D FET application will be discussed in this conference.

References
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[2] ACS nano, 2015, 9, 916.; ACS appl. mater. Interfaces, 2016, 8, 27877.; & APL, 2016, 109, 253111.

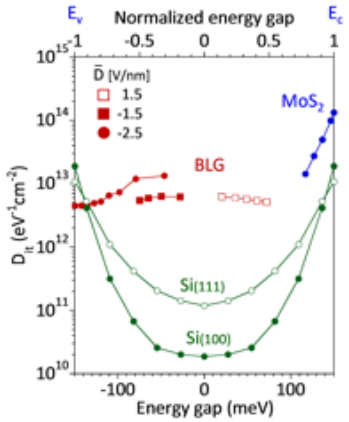

Fig. 1. D_{it} vs E_G for bilayer graphene.

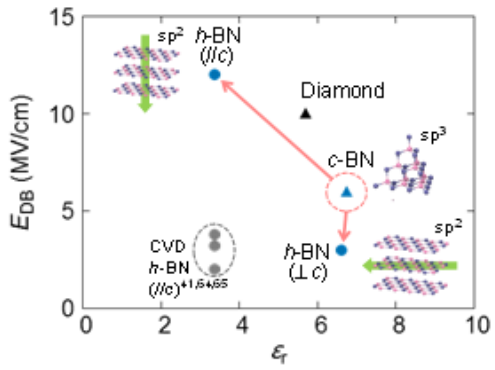

Fig. 2. Dielectric breakdown field vs dielectric constant.