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Electronic and magnetic behaviors of 2D atom-thin layers: Graphene, black phosphorus, hexagonal boron-nitride and MoS_2

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Two-dimensional (2D) atom-thin layers have attracted significant attention after the discovery of primitive fabrication method of graphene, mechanical exfoliation of graphite using scotch tapes. As a van-der Waals engineering, various atom-thin layers and those hybridization have been recently realized. In the talk, first, I will present magnetism and spintronics arising from edges of 2D atom-thin layers, graphene, few-layer black phosphorus (BP) and hexagonal boron-nitride (hBN). I created nanomesh (NM) structures, consisting of honeycomb like array of hexagonal pores, with specified pore-edge atomic structure (i.e., zigzag type) on individual layers. Interestingly, hydrogen-terminated graphene NM (H-GNM) shows flat-band ferromagnetism, while it disappears in oxygen-terminated GNM. On the other hand, O-BPNM exhibits large ferromagnetism due to ferromagnetic spin coupling of edge O-P bonds, whereas it is eliminated in H-BPNM. O-hBNNM also shows large ferromagnetism due to edge O-B and O-N bonds, while it disappears in H-hBNNM. These are also highly sensitive to annealing temperatures to form zigzag pore edge. These open a considerable avenue for realizing 2D atom-thin flexible magnetic and spintronic devices, fabricated without using rare-earth magnetic atoms. Second, I will show creation of the world-thinnest Schottky junction on few-layer molybdenum disulfide (MoS_2), one of the transition metal dichalcogenides. The 2H-phase of MoS_2 has direct band gaps of 1.5−1.8 eV. It is demonstrated that electron-beam (EB) irradiation to the 2H-phase causes semiconductor-metal transition to 1T-phase and atomically-thin Schottky junction with barrier height of 0.13−0.18 eV is created at the interface of 2H/1T regions. These findings also indicate a possibility that the effective barrier height is highly sensitive to electrostatic charge doping and almost free from Fermi-level pinning when assuming predominance of the thermionic current contribution. This EB top-down patterning opens the possibility to fabricate in-plane lateral heterostructure FETs, which have shown promising scaling prospects in the nanometer range, and/or local interconnects directly with metallic phase (1T) between (2H)MoS2 transistors, resulting in ultimate flexible and wearable in-plane integration circuits without using 3D metal wirings. Finally, I will also briefly talk about introduction of spin-orbit interaction into graphene by light hydrogenation (<0.1%).

Biography

Junji Haruyama graduated from Waseda University, Tokyo, Japan in 1985. Right after that, he joined Quantum device laboratory, NEC Corporation, Japan and worked until 1994. He received PhD in Physics from Waseda University in 1996. During 1995–1997, he worked with the University of Toronto, Canada (Prof. J Xu Lab), and also Ontario Laser and Lightwave Research Center, Canada as a Visiting Scientist. Since 1997, he has worked at the present Aoyama Gakuin University as a Professor until now. He was also a Visiting Professor at NTT Basic Research Laboratories (Dr. Takayanagi's Nano-science Lab), Institute for Solid State Physics (Prof. Iye's Nano-science Lab), The University of Tokyo, and Zero-emission Energy Center, Kyoto University, Japan. He has been a Principal Researcher at Air-Force Office of Scientific Research, USA since 2010. He has peer review publications of over 100 and 4 patents, and has also done more than 150 invited talks. He has been Co-author of over 30 books, a Referee of over 50 journals and a Member of international committees (organizer, adviser and chairman) of over 30 conferences.

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