Science of 2.5 Dimensional Materials: Integration of High-Quality 2D Materials for Electronic Devices and Catalysis

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Two-dimensional (2D) materials have intriguing properties and many potential applications due to their unique 2D structures with atom-level thicknesses. The control of van der Waals (vdW) interaction and utilization of vdW nanospace are expected to extend the field of materials science, and such research direction can be expressed with a new concept of "Science of 2.5D materials" [1].

In this presentation, our recent research is introduced based on this 2.5D concept, first showing the controlled CVD growth of bilayer graphene (BLG) and the intercalation of metal chloride molecules and alkaline metal ions, revealing new unique 2D structures with increased electrical conductivity [2,3]. We have also developed the CVD growth of high-quality and large-area multilayer hBN to be used as a building block of various 2.5D materials, such as graphene field-effect transistors (FETs) [4] and magnetic tunnel junction (MTJ) devices [5].

In addition, our recent development on the synthesis of high density, self-aligned MoS_2 nanoribbons is also presented [6]. Different from previous research, we do not need to make atomic steps on substrate surface to align MoS_2 nanoribbons. A high catalytic activity of the edges of the nanoribbon are visualized, signifying the potential application of MoS_2 nanoribbons in the hydrogen evolution reaction (HER), due to their high edge-to-surface ratios. Such high density MoS_2 array is also promising for channels of high-performance semiconductor devices.

I will also introduce our new result of the tape transfer of 2D materials, which is expected to accelerate the 2D/2.5D materials research and applications [7]. We achieved clean and user-friendly transfer of graphene, MoS_2, WS_2, and hBN using the UV tapes whose adhesive force can be decreased about 1/10 by UV light illumination. We do not need to use organic solvent so that we can transfer them onto plastics, and the robust tape allows "cut-and-transfer" for site-selective transfer, which saves 2D materials and production cost.

Finally, Our national project named, "Science of 2.5 Dimensional Materials: Paradigm Shift of Materials Science Toward Future Social Innovation (2021-2026)", supported by MEXT, Japan is briefly introduced [8,9].

References

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