Joint PhD Project Description

The description for the Joint PhD program will be posted online as a sub-page to

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Home University	Nanyang Technological University	
Partner University	Sungkyunkwan University	
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Project Title	**Development of 2D/3D heterointerface on nanostructured Si to exceed quantum efficiency beyond limits**	
Project Description (200-300 words)	Our project represents a pioneering study on completely new hybrid-type optoelectronic devices that combine two different materials: two-dimensional (2D) thin films coated on three-dimensional (3D) nanostructured black silicon (b-Si). Further advancement in the device performance will be achieved through the investigations on the conformal coating of 2D materials onto 3D nanostructures, 2D/b-Si heterointerface, and interface passivation via plasma treatment. Unlike traditional 3D devices, the combination of 2D and 3D materials creates a unique junction with exceptional thermal and electrical conductivity and remarkable responsivity. However, 2D/3D heterostructures face challenges such as limited light absorption and high interface defect density, which affect device performance. Our project aims to overcome these hurdles by combining 2D/3D heterojunction technology, nanostructured b-Si, and novel plasma-based interface passivation into a single device. Our approach involves conformally coating a 2D monolayer onto nanostructured b-Si via direct growth method, creating nanotextured b-Si, and passivating the surface using plasma treatment. The success of our project will lay the foundation for future technologies, including biosensors and optical communication systems. Importantly, our device is compatible with current complementary metal-oxide-semiconductor (CMOS) technology, enabling integration with advanced CMOS devices and circuits like CMOS image sensors. This extends the impact of our innovation beyond Singapore to the global stage. Additionally, our research has the potential to generate new knowledge on carrier transport mechanisms, heterointerface, and photomultiplication across 2D/3D interfaces, contributing to a deeper understanding of these phenomena.	

Program/Center Website(s)	https://www.ntu.edu.sg/coeb
Additional Information (e.g., files with project details)	The project can be summarized into four self-contained yet interconnected work packages (WPs). WP1 is the fundamental study of the coating process for large size defect-less graphene (Gr) and hexagonal boron nitride (hBN), and the nanotexturing process of b-Si, involving plasma treatment passivation. WP2 will focus on the formation of passivated 2D/3D heterointerface on a nanostructured b-Si. This will be achieved through two key methodologies: the direct growth of 2D layers and Cl-based plasma passivation. Based on the successful implementation of WP1 and WP2, WP3 will perform theoretical and experimental study of the heterointerface. Particular attention will be paid to understanding carrier recombination dynamics within our 2D/3D heterojunction nanostructures. Building on the theoretical and practical insights gained in the preceding WPs, WP4 focuses on the development of high-performance self-powered devices with superior quantum efficiency. The aim is to implement the knowledge to further enhance device performance through refinement and innovative strategies. Following figure provides a visual representation of the implementation plan across the four WPs.