Electrical control of optical properties of MBE $MoSe_2$/MOVPE hBN structures

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Recent developments in the field of 2D materials have identified them as ideal candidates for numerous future applications in electronics, sensing, and quantum computing. However, small, few-microns size and unrepeatable fabrication of van der Waals crystals flakes remain the bottleneck in the development of real-life devices based on such ultrathin layers.

In this study, we present a combined, heteroepitaxial technique that effectively addresses the challenge of upscaling monolayers of different materials. We use metalorganic vapour phase epitaxy (MOVPE) to grow high-quality, few-nanometres thick hexagonal boron nitride (hBN) on 2-inch sapphire wafers [1]. Then, we introduce an additional wet-delamination step to straighten out the hBN layer. Subsequently, we use molecular beam epitaxy (MBE) to deposit a single atomic layer of molybdenum diselenide ($MoSe_2$), a representative of transition metal dichalcogenides, on top of the structure [2,3].

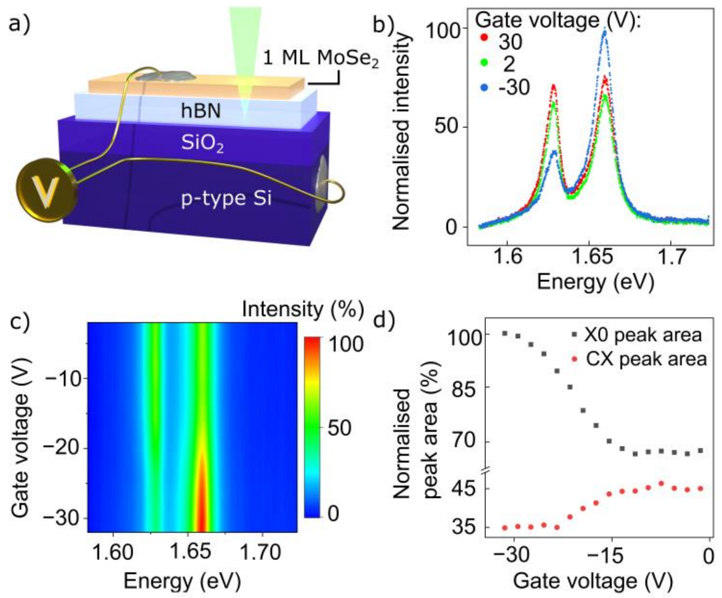

Fig. 1: a) An illustration of the ~cm^2 sized fabricated device, b) low-temperature photoluminescence spectra showing that the charged to neutral exciton intensity ratio can be electrically tuned. c) photoluminescence intensity map as a function of gate voltage, d) charged and neutral exciton peak area as a function of gate voltage.

Our optical studies reveal a high uniformity of the grown material on the macroscale (~cm2). The low-temperature photoluminescence spectra provide convincing evidence of the material's high optical quality, demonstrated by narrow, well-resolved excitonic lines (Fig. 1b). As compared to our previous results, excitonic linewidths are 2 times smaller (~13 meV), similar to linewidths measured for the material grown on flat, exfoliated hBN flakes. Moreover, we show that the whole heterostructure can be gated, allowing electrical control of the $MoSe_2$ charged exciton intensity (Fig 1).

Our method provides a reliable solution for scaling up various ultrathin crystals. Electrical control of fabricated structures makes them promising for applications in novel optoelectronic devices.

[1] A.K. Dabrowska et al. 2D Mater., **8**, 015017 (2021)

[2] W. Pacuski et al. Nano Lett. 2020, **20, 5,** 3058-3066

[3] K. Ludwiczak et al., ACS Appl. Mater. Interfaces (2021), **13, 40**, 47904–47911

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