Observation of Exciton Polariton Band Structure

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Principal Investigator(s): Bo Zhen
User(s): Zhi Wang

Affiliation(s): Department of Physics and Astronomy, University of Pennsylvania

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Contact: bozhen@sas.upenn.edu, zhiw@sas.upenn.edu

Research Group Website: https://web.sas.upenn.edu/bozhen/

Primary CNF Tools Used: Plasma Enhanced Chemical Vapor Deposition (PECVD), Chemical Mechanical Polishing

Abstract:

Exciton polaritons are hybrid light-matter quasi-particles formed by the strong coupling between excitons (electron-hole pairs) in semiconductor materials and photons in photonic structures, such as cavity or photonic crystal (PhC) slabs. In our project, we want to observe polaritonic bands using molybdenum diselenide ($MoSe_2$) monolayer and PhC slab.

Summary of Research:

To realize strong coupling, the coupling strength should be far greater than the linewidth of excitonic resonance and the linewidth of photonic resonance. Narrow linewidth of photonic resonance is easier to achieve compared to excitonic resonance. Therefore, a narrower linewidth of excitonic resonance is preferred in our experiment. The linewidth of excitons in $MoSe_2$ monolayer is easily affected by surrounding dielectric environment. People usually encapsulate the monolayer with hBN flakes, which have atomically flat surface to reduce the inhomogeneous broadening [1.] However, it's not doable for us now because the lateral size of PhC slabs is at least larger than 100 μm for observing a good band in experiment, and it is difficult to get very large and high quality hBN thin flakes by mechanical exfoliation. Also, large size $MoSe_2$ monolayers cannot be obtained by mechanical exfoliation. Good thing is that recently people can use gold exfoliation to get millimeter scale monolayers [2]. And dodecanal encapsulation method is used to make the gold exfoliated monolayer more intrinsic [3]. We are using these dodecanal encapsulated and gold exfoliated $MoSe_2$ monolayers in our devices.

The PhC slabs we used are square lattices in silicon nitride layer. The square lattice consisted of air cylinder holes that were fabricated by etching the silicon nitride layer and later filled by plasma enhanced chemical vapor deposition (PECVD) TEOS oxide left a unflatten surface. To avoid the influence to monolayer caused by unflatten surface of PhC slab, chemical mechanical polishing (CMP) is needed.

Conclusions and Future Steps:

We already used PECVD TEOS to fill the air cylinder holes very well without voids. However, CMP process needs some improvements to get flat surface. And we already made some devices (Figure 1) but haven't observe polaritonic bands due to the unsuccessful CMP process which left unflatten surface and influenced the linewidth of excitonic resonance.

We will continue to improve CMP process and hopefully we will get some good data soon.

References:

[1] F. Cadiz, et al., Excitonic Linewidth Approaching the Homogeneous Limit in MoS2-Based van der Waals Heterostructures. Phys. Rev. X 7, 021026 (2017).

[2] Li, Q., et al. Macroscopic transition metal dichalcogenides monolayers with uniformly high optical quality. Nat Commun 14, 1837 (2023).

[3] Liu, F., et al. Disassembling 2D van der Waals crystals into macroscopic monolayers and reassembling into artificial lattices. Science 367, 903-906 (2020).

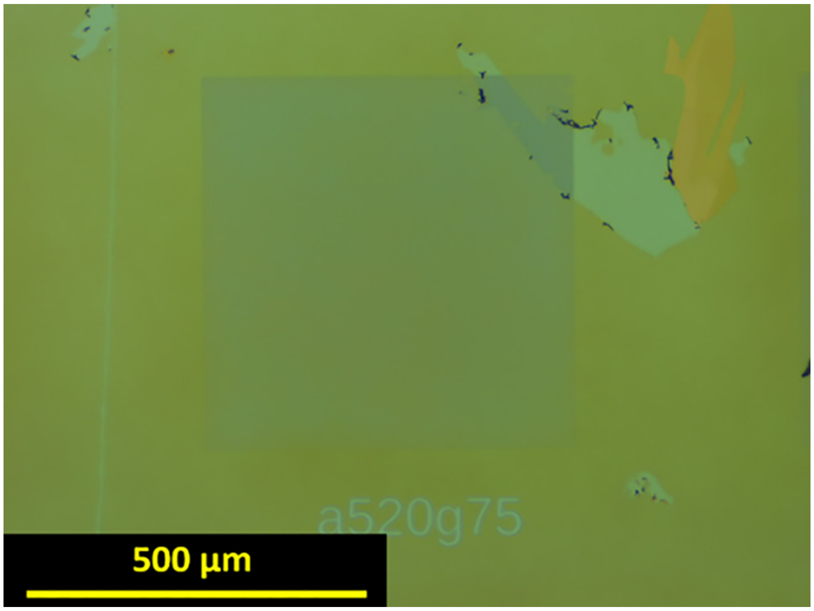

Figure 1: Dodecanal encapsulated $MoSe_2$ monolayer on a square lattice PhC slab.