Novel Excitons in $MoSe_2$ from Proximitized Charge Density Waves

Patrick Vora[1,2]
Jaydeep Joshi[1,2], Benedikt Scharf[3], Igor Mazin[1,2], Sergiy Krylyuk[4], Daniel J. Campbell[5], Johnpierre Paglione[5,6], Albert Davydov[2,4,5], Igor Žutić[7]

[1]*Department of Physics and Astronomy, George Mason University, Fairfax, VA 22030, USA*
[2]*Quantum Science and Engineering Center, George Mason University, Fairfax, VA 22030, USA*
[3]*Institute for Theoretical Physics and Astrophysics and Würzburg-Dresden Cluster of Excellence ct.qmats, University of Würzburg, Am Hubland, 97074 Würzburg, Germany*
[4]*Materials Science and Engineering Division, National Institute of Standards and Technology, Gaithersburg, MD 20899, USA*
[5]*Maryland Quantum Materials Center, Department of Physics, University of Maryland, College Park, MD 20742, USA*
[6]*Canadian Institute for Advanced Research, Toronto, Ontario M5G 1Z8, Canada*
[7]*Department of Physics, University at Buffalo, Buffalo, NY 14260, USA*

pvora@gmu.edu

Two-dimensional (2D) materials allow for the construction of heterostructures without the constraint of lattice matching. This increased flexibility enables novel proximity effects through the stacking of strongly correlated 2D materials on 2D semiconductors. A general strategy for engineering quantum matter therefore becomes apparent through the creation of emergent states at the interface of different layered materials. Here we use temperature-dependent photoluminescence (PL) microscopy to reveal a new proximity effect where excitons in monolayer $MoSe_2$ interact with the commensurate charge density wave (CDW) in bulk $TiSe_2$ [1]. Below the CDW ordering temperature we observe a new PL emission line (H1) on the $TiSe_2$-$MoSe_2$ interface that is 30 meV higher in energy than the neutral exciton. This observation is unique compared to other examinations of 2D heterostructures where additional spectral features appear at lower energies compared to the neutral exciton. Power and temperature-dependent measurements show that H1 behaves as a free exciton, therefore excluding interface trapping or localization as an explanation. Most interestingly, we find that H1 disappears above the $TiSe_2$ CDW ordering temperature, which suggests that the CDW plays a vital role in activating this previously unobserved exciton. We discuss possible CDW-based origins of H1 and outline future opportunities for using proximity effects in 2D heterostructures to engineer and achieve ultrafast control over novel excitonic states.

References

[1] Jaydeep Joshi, Benedikt Scharf, Igor Mazin, Sergiy Krylyuk, Daniel J. Campbell, Johnpierre Paglione, Albert Davydov, Igor Žutić, and Patrick M. Vora, APL Materials, 10 (2022) 011103.

Figures

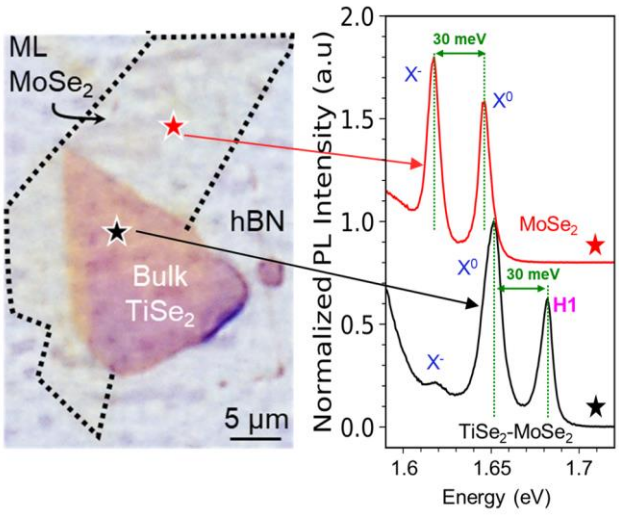

Figure 1: (left) Image of $TiSe_2$-$MoSe_2$ heterostructure. (right) 5 K PL spectra on (black) and off (red) the interface. The negatively charged trion (X^-) and neutral exciton (X^0) are visible in both spectra, however a new emission feature H1 appears 30 meV above the neutral exciton on the $TiSe_2$-$MoSe_2$ interface.