Optical Properties of Laterally-Confined Monolayer Semiconductors

Nathaniel P. Stern[1], Guohua Wei[1], David A. Czaplewski[2], Erik J. Lenferink[1], Il Woong Jung[2], and Teodor K. Stanev[1]

[1]Department of Physics and Astronomy, Northwestern University,
2145 Sheridan Rd, Evanston, IL, 60201, USA
[2]Center for Nanoscale Materials, Argonne National Laboratory,
9700 S Cass Avenue, Argonne, IL 60439, USA
n-stern@northwestern.edu

Abstract

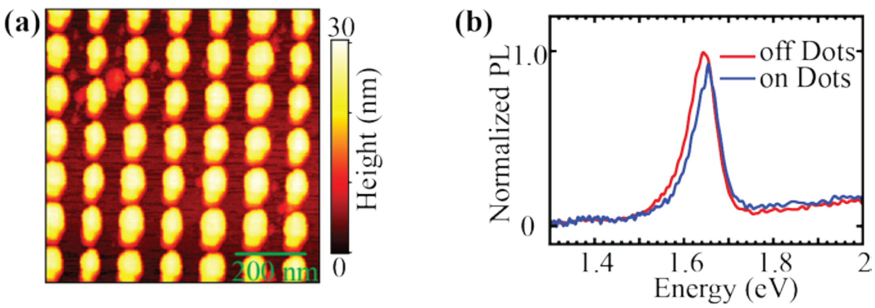
Size-dependent control of material properties in semiconductors is an important feature exploited for numerous fundamental and technological applications. In semiconductor quantum dots (QDs), the full three-dimensional confinement of carrier wavefunctions affords a high degree of optical and electronic tunability. In 2D semiconductors such as transition metal dichalcogenides (TMDs), out-of-plane vertical confinement arises naturally from the layered structure, but because of the small exciton Bohr radius of ~1 nm [1], size-dependent control using *lateral* confinement is challenging. Despite the observation of lateral confinement effects in monolayer nanoflakes [2] and non-classical light emission from localized TMD defects [3], systematic size-dependent control of optical and electronic properties of TMD monolayers is not well established. Here, we present measurements of the optical properties of laterally-confined monolayer semiconductor quantum dots created through controlled nanopatterning of single TMD layers into nearly circular nanoflakes. Size-dependent exciton energies are observed from lateral confinement in monolayers of MoS_2 and WSe_2. Our measurements show that the weak confinement regime of monolayer TMD QDs shares the valley polarization properties familiar from unprocessed monolayer TMDs [4,5].

This work is supported by the Institute for Sustainability and Energy at Northwestern, the U.S. Department of Energy (DE-SC0012130), the National Science Foundation's MRSEC program (DMR-1121262), and Argonne National Laboratory. Use of the Center for Nanoscale Materials was supported by the U. S. Department of Energy under Contract No. DE-AC02-06CH11357. N.P.S. is an Alfred P. Sloan Research Fellow.

References

[1] T. Cheiwchanchamnangij and W. R. Lambrecht, Phys. Rev. B **85** (2012) 205302.
[2] Z. Gan, L. Liu, H. Wu, Y. Hao, Y. Shan, X. Wu, and P. K. Chu, Appl. Phys. Lett. **106**, 233113.
[3] A. Srivastava, M. Sidler, A. V. Allain, D. S. Lembke, A. Kis, and A. Imamoğlu, Nature Nanotech. **10** (2015) 491.
[4] G.-B. Liu, H. Pang, Y. Yao, and W. Yao, New J. Phys. **16** (2014) 105011.
[5] G. Wei, D. A. Czaplewski, E. J. Lenferink, T. K. Stanev, I.-W. Jung, and N. P. Stern, arXiv:1510.09135 (2015), http://arxiv.org/abs/1510.09135.

Figures



(a) AFM scan of a 1 μm x 1 μm region of patterned QDs with dot pitch of 150 nm.
(b) Photoluminescence spectra from a flake of WSe_2 from the QD (on dots) and unpatterned region (off dots). The QD blue shift of energy is evident.