Morphological manipulation of the luminescent response of atomically thin Indium Selenide nanosheets

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Abstract

Many efforts have been devoted to manipulate the morphology of two-dimensional (2D) materials to tune and improve their functionalities. It is usually believed that morphological manipulation strategies, such as nanotexturing, reduce transport abilities of 2D systems whereas introduces or enhances other functionalities. It is the case, for instance, of graphene [1,2]. Single layers (SLs) of transition-metal dichalcogenides [3,4] offer unquestionable technological applications [5-8]. Nevertheless, tuning their properties for optoelectronic applications is challenging due to the intrinsically localized nature and orbital character of the d-states that dominate their valence and conduction bands. 2D forms of other layered semiconductors, as Indium Selenide, are less explored and may exhibit interesting and tunable properties [9-11]. First-principles calculations predicted that 2D InSe should produce a band-gap tuning window as large as 1.1 eV [10] and, experimentally, a blue shift of the optical band gap of 0.2 eV has been already observed in 5 nm thick InSe nanosheets [10,11]. Also, devices based on few-layer InSe have shown promising applications [12-14]. In this communication, we show the ability of nanotexturing strategies to enhance the luminescent response of atomically thin Indium Selenide nanosheets. Besides, quantum-size effects make this two-dimensional semiconductor to exhibit one of the largest band gap tunability ranges observed in a two-dimensional semiconductor: from 1.25 eV, in bulk, to 2.1 eV, in the single layer. These results are relevant for the design of new optoelectronic devices, including heterostructures of two-dimensional materials with optimized band gap functionalities and in-plane heterojunctions with minimal junction defect density.

References

[1] C. H. Lui, L. Liu, K. F. Mak, G. W. Flynn, and T. F. Heinz, Nature, **462** (2009, 339-341.

[2] C. R. Dean, A. F. Young, I. Meric, C. Lee, L. Wang, S. Sorgenfrei, K. Watanabe, T. Taniguchi, P. Kim, K. L. Shepard, and J. Hone, Nature Nanotech. **5** (2010) 722-726.

[3] K. F. Mak, C. Lee, J. Hone, J. Shan, and T. F. Heinz, Phys. Rev. Lett., **105** (2010), 136805.

[4] A. Splendiani, L. Sun, Y. B. Zhang, T. S. Li, J. Kim, C. Y. Chim, G. Galli, and F. Wang, Nano Lett., **10** (2010) 1271-1275.

[5] B. Radisavljevic, A. Radenovic, J. Brivio, A. V. Giacometti, and A. Kis, Nature Nanotech., **6** (2011) 147-150.

[6] F. K. Perkins, A. L. Friedman, E. Cobas, P. M. Campbell, G. G. Jernigan, and B. T. Jonker, Nano Lett., **13** (2013) 668-673.

[7] M. Bernardi, M. Palummo, and J. C. Grossman, Nano Lett., **13** (2013) 3664-3670.

[8] Y. J. Zhang, T. Oka, R. Suzuki, J. T. Ye, and Y. Iwasa, Science, **344** (2014) 725-728.

[9] M. Brotons-Gisbert, J. F. Sánchez-Royo, and J. P. Martínez-Pastor, Appl. Surf. Sci., **354B**, (2014) 453-458.

[10] J. F. Sánchez-Royo, G. Muñoz-Matutano, M. Brotons-Gisbert, J. P. Martínez-Pastor, A. Segura, A. Cantarero, R. Mata, J. Canet-Ferrer, G. Tobias, E. Canadell, J. Marqués-Hueso, and B. D. Gerardot, Nano Res., **7** (2014) 1556-1568.

[11] G. W. Mudd, S. A. Svatek, T. Ren, A. Patanè, O. Makarovsky, L. Eaves, P. H. Beton, Z. D. Kovalyuk, G. V. Lashkarev, Z. R. Kudrynskyi, and A. I. Dmitriev, Adv. Mater., **25**, (2013) 5714-5718.

[12] W. Feng, W. Zheng, W. Cao, and P. Hu, Adv. Mater., **26** (2014) 6587-6593.

[13] W. Luo, Y. Cao, P. Hu, K. Cai, Q. Feng, F. Yan, T. Yan, X. Zhang, and K. Wang, Adv. Opt. Mater., **3** (2015) 1418-1423.

[14] G. W. Mudd, S. A. Svatek, L. Hague, O. Makarovsky, Z. R. Kudrynskyi, C. J. Mellor, P. H. Beton, L. Eaves, K.S. Novoselov, Z. D. Kovalyuk, E. E. Vdovin, A. J. Marsden, N. R. Wilson, and A. Patanè, Adv. Mater., **27** (2015) 3760-3766.