Bi-intercalated WS_2 on Ag(111): a nearly free standing semiconducting single-layer of WS_2

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An epitaxial approach can be used to realize large-area, high quality layers of two-dimensional materials such as graphene and single layer transition metal dichalcogenides on single crystal substrates; and the interaction with the substrate can be used to control the crystalline orientation of the two-dimensional material [1-3]. However, a strong interaction with the substrate can also lead to hybridization effects and to the deterioration of the two-dimensional materials' properties. For example, a semiconducting single-layer WS_2 was found to be metallic when grown on Ag (111) [4]. In the case of graphene, this dilemma can be solved by decoupling the graphene from the surface it is grown on via the intercalation of atoms or molecules. Here we show that this is also possible for a single-layer of WS_2 grown on Ag(111). For this system, the intercalation of Bi atoms is followed by angle-resolved photoemission spectroscopy, scanning tunnelling microscopy and low energy electron diffraction. The most significant effect of the intercalation is a reduction of WS_2-substrate interaction, leading to a valence band structure that closely resembles that of the free-standing layer.

References:
[1] J. A. Miwa, S. Ulstrup, S. G. Sørensen, M. Dendzik, A. G. Cabo, M. Bianchi, J. V. Lauritsen, and P. Hofmann, Phys. Rev. Lett. **114**, 046802, (2015).
[2] M. Dendzik, M. Michiardi, C. Sanders, M. Bianchi, J. A. Miwa, S. S. Grønborg, J. V. Lauritsen, A. Bruix, B. Hammer, and P. Hofmann, Phys. Rev. B **92**, 245442, (2015).
[3] C. E. Sanders, M. Dendzik, A. S. Ngankeu, A. Eich, A. Bruix, M. Bianchi, J. A. Miwa, B. Hammer, A. A. Khajetoorians, and P. Hofmann, Phys. Rev. B **94**, 081404, (2016).
[4] M. Dendzik, A. Bruix, M. Michiardi, A. S. Ngankeu, M. Bianchi, J. A. Miwa, B. Hammer, P. Hofmann, and C. E. Sanders, Phys. Rev. B **96**, 235440 (2017).