Electronic Supplementary Information

Hybrid nanomaterials of WS_2 or MoS_2 nanosheets with liposomes: biointerfaces and multiplexed drug delivery

Yibo Liu and Juewen Liu*

Department of Chemistry, Waterloo Institute for Nanotechnology, University of Waterloo, Waterloo, Ontario, N2L 3G1, Canada

Email: liujw@uwaterloo.ca

Additional experimental methods

Atomic force microscopy (AFM) and Raman spectroscopy. For AFM analysis, a WS_2 suspension (200 μg/mL) was spun coated onto a freshly cleaved mica substrate. AFM measurements were performed with a Nanoscope MultiMode™ AFM instrument (Veeco) in the tapping mode. The height profile was obtained using Gwyddion software. Raman spectra were collected using a Horiba HR800 spectrometer operating at $\lambda = 532$ nm.

Flow cytometry. HeLa cells were seeded in 24-well plates at around 100 000 cells per well in 500 μL of DMEM/F12 cell culture medium and incubated at 37 °C in 5% CO_2 humidified atmosphere for 24 h. The medium was then replaced with fresh medium, and WS_2/CF-DOPC or WS_2DOX/CF-DOPC was added with a final WS_2 concentration of 20 μg mL^{-1} and DOPC concentration of 20 μg mL^{-1}. For the control sample, the cells were incubated with the cell culture medium only. After 1 h incubation, the cells were washed with PBS buffer 3 times, harvested, and suspended in 250 μL of 0.5 % formaldehyde for analyses using a FACSAria Fusion flow cytometer. The data were analyzed using BD Facsdiva software.

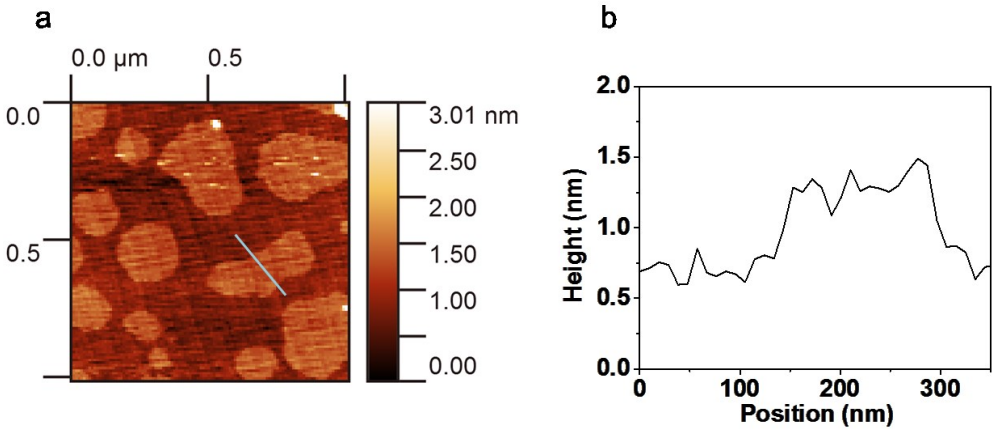

Figure S1. (a) An AFM micrograph and (b) its height profile our WS_2 nanosheets.

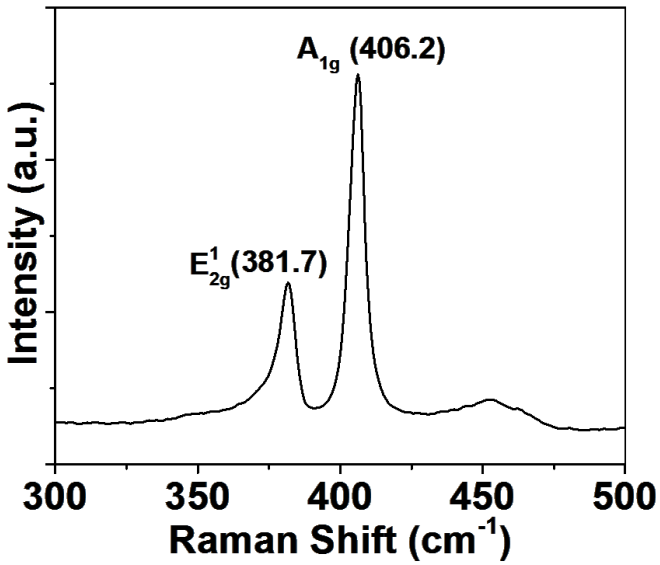

Figure S2. A Raman spectrum of MoS_2. The strong Raman peaks at 381.7 cm^{-1} and 406.2 cm^{-1} are corresponding to the in-plane E^1_{2g} and out-of-plane A_{1g} of lithium borohydride ($LiBH_4$) exfoliated MoS_2.[S1]

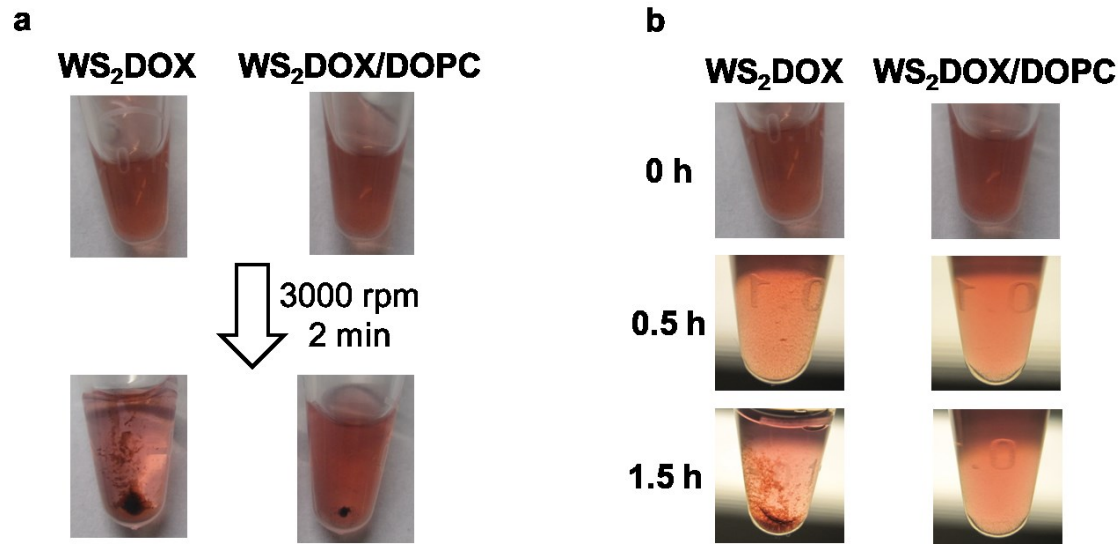

Figure S3. Colloidal stability test of WS_2DOX and WS_2DOX/DOPC in the cell culture medium by (a) centrifugation and (b) without centrifugation. The observed red color was due to the cell culture medium and DOX. Both WS_2DOX and WS_2DOX/DOPC in the cell culture medium were transparent after a gentle bath sonication. However, after centrifugation at 3000 rpm for 2 min, a large amount of precipitant was observed for WS_2DOX while WS_2DOX/DOPC remained stable. This indicated that the colloidal stability of WS_2DOX increased with adsorption of DOPC liposomes. The increased stability was also illustrated when WS_2DOX and WS_2DOX/DOPC were left at room temperature without centrifugation. After sitting for 30 min, small aggregates were observed for WS_2DOX. After 2 h, large aggregates formed. While the WS_2DOX/DOPC sample remained transparent up to 2 h.

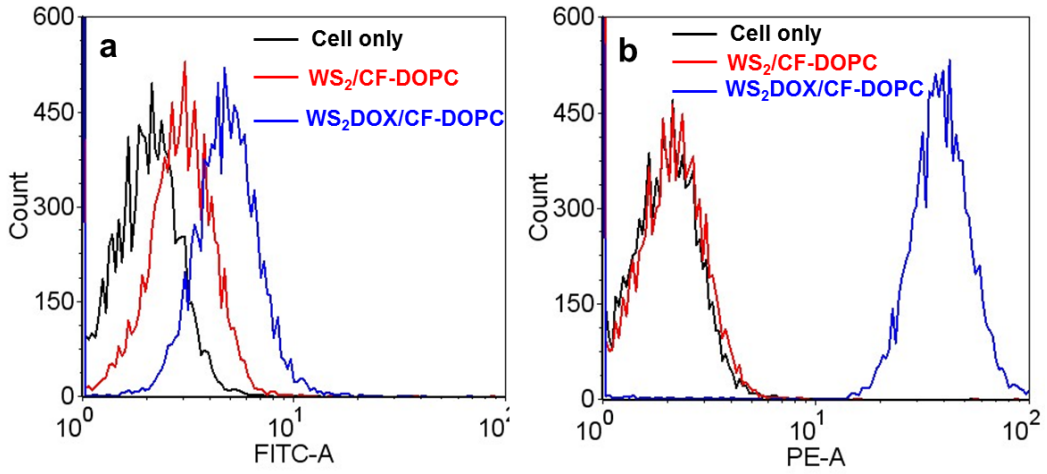

Figure S4. Flow cytometry histograms of the control (untreated HeLa cells), and WS_2/CF-DOPC and WS_2DOX/CF-DOPC treated HeLa cells. (a) The green CF channel and (b) the red DOX channel. The increased green fluorescence in (a) has indicated the uptake of the hybrid material, consistent with the confocal fluorescence microscopy results. In (b), the WS_2/CF-DOPC sample did not have any red dye and thus it showed no shift in the red channel, while the DOX containing sample was strongly fluorescent due to uptake of DOX.

Additional references

S1. D. Voiry, M. Salehi, R. Silva, T. Fujita, M. Chen, T. Asefa, V. B. Shenoy, G. Eda and M. Chhowalla, *Nano Lett.*, 2013, **13**, 6222-6227.