Controlling dark intervalley excitons for strain sensing in WS_2

Gabriele Grosso
Saroj B. Chand, John M. Woods, Enrique Mejia
Photonics Initiative, Advanced Science Research Center, City University of New York, New York, NY 10031, USA
Physics Program, Graduate Center, City University of New York, New York, NY 10016, USA
ggrosso@gc.cuny.edu

Dark excitonic states in transition metal dichalcogenides (TMDs) are attracting growing interest because they represent the lowest excitonic states of the system [1] and can deeply affect transport, dynamics and coherence of bright excitons, hampering optoelectronic properties and device performance [2]. Therefore, it is crucial to create conditions in which these excitonic states can be visualized and controlled. Here, we show that compressive strain in WS_2 change the band alignment and enables phonon scattering of photoexcited electrons between momentum valleys [3], enhancing the formation of dark intervalley ($K\Lambda$) excitons. This mechanism is illustrated in Fig.1a. Our photoluminescence (PL) and hyperspectral experiments indicate that dark excitons appear around compressive strain pockets that are created in the monolayer during the transfer process onto a hexagonal boron nitride (hBN) substrate (Fig.1c) [4]. Moreover, the emission and spectral properties of intervalley excitons are accessible and strongly depend on the local strain environment. Fig. 1b shows how the intensity and energy of $K\Lambda$ excitons change as a function of compressive strain that is characterized by a blueshift of the bright intravalley *KK* excitons. This mechanism is further exploited for strain sensing in two-dimensional semiconductors revealing an optical gauge factor exceeding 10^4, as shown in Fig. 1d.

References

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Figures

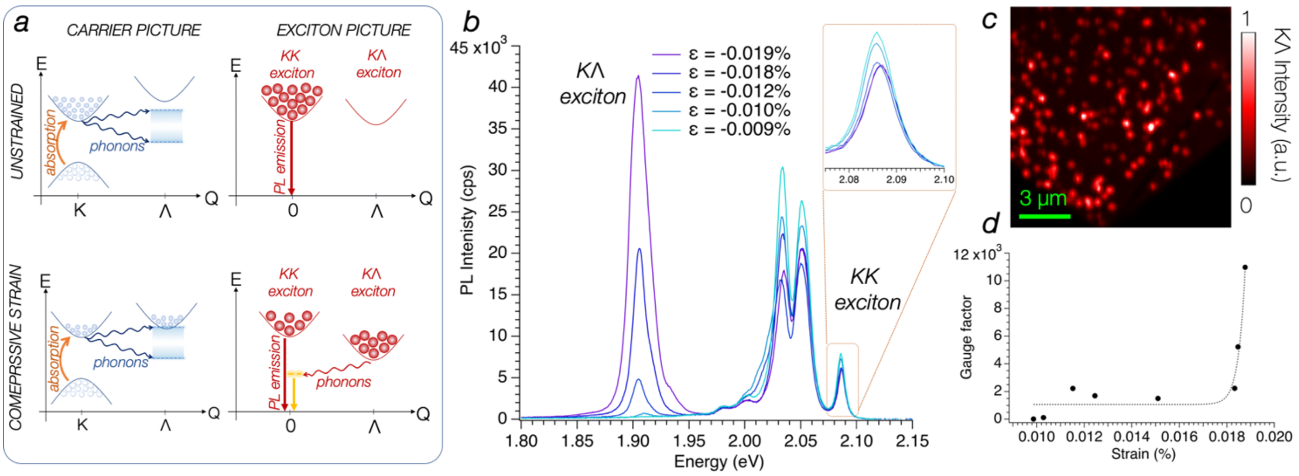

Figure 1: a - Top (bottom) panel shows a cartoon of the band diagram in the carrier and exciton picture for the unstrained (compressive strain) case. With compressive strain the band alignment allows intervalley phonon-assisted scattering and the formation of *KΛ* excitons. b - Emission spectra at different compressive strain levels at T=60 K. The increase of compression in the WS_2 monolayer is characterized by a rise of the *KΛ* exciton peak as well as a blueshift of the *KK* excitons. c - PL map of a WS_2 monolayer with the signal filtered to collect only photons with E<1.94 eV to include only *KΛ* excitons. d - Optical gauge factor shows a nonlinear dependency on the strain with a maximum approaching 12000.