Observation of carrier transports at exciton-plasmon coupling in MoS_2 monolayers and 1D plamsmonic nanogrooves

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Abstract

Two-dimensional transition metal dichalcogenides (TMDCs) have studied intensively owing to their unique optical and electronic properties [1]. Among TMDCs, monolayer molybdenum disulfide (MoS_2) is a direct bandgap semiconductor with strong binding energies which make it as a perfect candidate for light-matter coupling system. In the current work, we fabricated hybrid systems of MoS_2 monolayers [2] and 1D plasmonic nanogrooves made of gold (Au) to study exciton-plasmon coupling, particularly the carrier transport at the coupling state (see Fig. 1(a)). The nanogrooves were suited to excite in-plane plasmons, which are different from metallic-nanoparticle-on-mirror configuration.

The exciton-plasmon couplings were confirmed by the reflectance measurements and the dispersion relations were plotted from the reflectance measurements as shown in Fig. 1(b). In Fig. 1(b), the plasmon-exciton coupling of the upper polariton and lower polariton were plotted as a function of detuning. The splitting energy was as large as 65 meV, which is one of the largest among the values reported so far at room temperature. The exciton-plasmon coupling has also been confirmed by the Kelvin probe force microscope (KPFM) which recorded the surface potentials. As shown in Fig. 1(c), while there was no surface potential change for the MoS_2 on planar Au film, a surface potential shift of 13.5 meV was observed for the MoS_2 on nanogroove upon laser irradiation at 532 nm. This is a direct evidence that surface potential shift was induced at the exciton-plasmon coupling. Our results indicated that the 1D plasmonic nanogrooves are appropriate structures to study exciton-plasmon coupling with large splitting energy at room temperature.

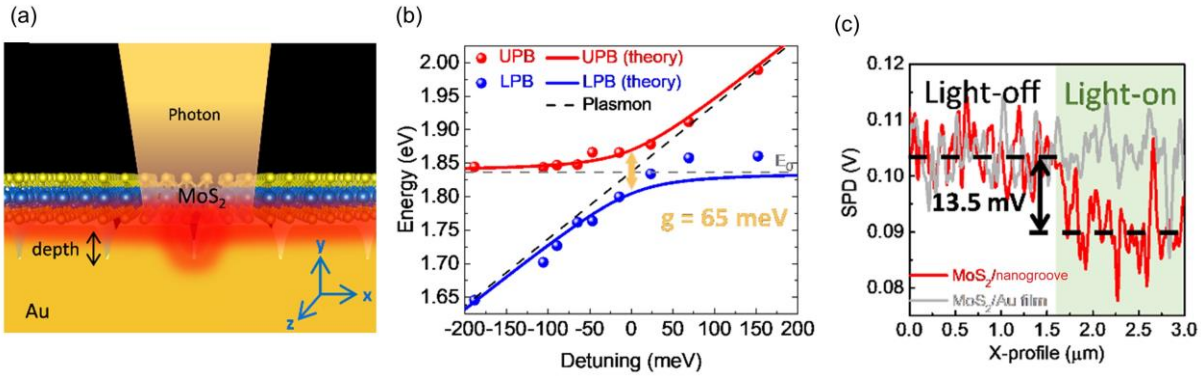

Fig 1. (a) Schematic of exciton-plasmon hybrid system with a monolayer MoS_2 and Au nanogrooves. (b) Dispersion of plasmon-exciton coupling of the upper polariton and lower polariton varied as a function of detuning. The blue and red dots are experimental data extracted from the reflectance spectra. The Rabi-splitting energy was estimated to be 65 meV. (c) Surface potential differences (SPDs) of MoS_2 on nanogrooves and MoS_2 on planar Au film. The 532 nm laser was tuned on after ~1.6 μm in x-axis and the SPDs were measured by the KPFM.

References

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