Reduced dielectric screening and enhanced energy transfer in single and few-layer MoS_2

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Abstract

The excitonic nature of optical excitations in monolayer transition metal dichalcogenides (TMDCs) opens up possibilities to construct hybrid architectures in which different nanomaterials are coupled through efficient nonradiative energy transfer. Energy transfer between donor and acceptor materials can be used to enhance optoelectronic device performance, enabling broadband optical down-conversion and color shifting in light-emitting devices as well as energy transfer sensitized photovoltaics. One possible approach is to interface two-dimensional TMDCs with zero-dimensional semiconductor nanocrystals, also known as quantum dots (QDs).

We report highly efficient nonradiative energy transfer from cadmium selenide (CdSe) quantum dots to monolayer and few-layer molybdenum disulfide (MoS_2).[1] Interestingly, we observe an increasing energy transfer rate (and efficiency) as the number of MoS_2 layers decreases. This result is counterintuitive, as additional MoS_2 layers should offer additional pathways for energy transfer. We can, however, explain these observations in the context of recent theoretical predictions[2,3] of anomalous dielectric screening effects that can present themselves in thin semiconductor structures with highly anisotropic permittivity. Thin MoS_2 flakes turn out to be characteristic examples of materials that exhibit this effect. MoS_2 has a large permittivity,[4,5] and its dielectric function is reported to be highly anisotropic with the resonant transitions polarized completely in the plane of the material.[6] As a result, the energy transfer efficiency reaches as high as 95% for monolayer MoS_2. These results demonstrate the advantages that 0D-2D hybrid architectures can offer for enhanced optoelectronic device performance.

References

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