Dark exciton-based molecules sensors

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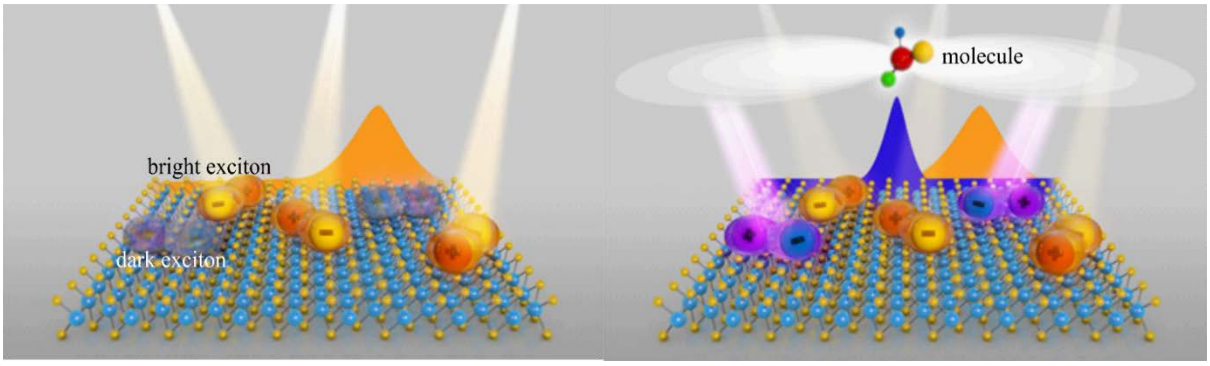

Fig. 1: Dark excitons make molecules visible. (a) An optical pulse can only excite bright excitons resulting in a pronounced resonance in optical spectra (orange peak). (b) In presence of molecules, dark excitons can be activated via efficient exciton-molecule coupling. The resulting additional resonance (blue peak) can be exploited for sensing of molecules.

What is it? Exploiting dark exciton states in atomically thin materials, scientists at Chalmers University of Technology have suggested a novel method to unambiguously detect molecules.

Why does it matter? Common optical sensing schemes rely on small changes in optical spectra of materials including tiny changes of optical resonances and intensities. The proposed sensing mechanism is based on pronounced features that are entirely induced by the presence of molecules and that are hence more easily accessible.

How does it work? Due to the two-dimensional confinement of carriers and a weak dielectric screening, the Coulomb interaction is very strong in atomically thin 2D materials. This leads to the formation of excitons (Coulomb-bound electron-hole pairs) with binding energies in the range of hundreds of meV. As a result, excitons are stable even at room temperature and dominate the optical response and the ultrafast dynamics in these materials. Besides regular bright excitons that can be directly accessed by light, there are also spin- and momentum-dark excitonic states that cannot be observed in optical spectra of these materials. This is due to the required spin-flip or momentum-transfer that cannot be provided by light. However, we have revealed that momentum-dark excitons can be activated in presence of molecules resulting in an additional pronounced resonance in optical spectra (cf. Fig. 1). This presents an unambiguous signature of the attached molecules and can thus be used for their detection. In summary, activation of dark excitons in atomically thin TMD materials has the potential as a novel optical sensor mechanism for molecules.

Publication Maja Feierabend, Gunnar Berghäuser, Andreas Knorr, and Ermin Malic, *Proposal for dark exciton-based chemical sensors*, **Nature Communication** 8, 14776 (2017)

Patent Maja Feierabend, Gunnar Berghäuser, Andreas Knorr, and Ermin Malic, *A method and a sensor for detecting the presence of molecules with a dipole moment*. No 16194861.7 - 1554 (2017)

Media coverage
Dark-state gas sensors https://graphene-flagship.eu/dark-state-gas-sensors

Optical fingerprints can reveal environmental gases
https://www.chalmers.se/en/departments/physics/news/Pages/Optical-fingerprint-can-reveal-environmental-gases.aspx