Probing exciton-exciton annihilation in hBN with cathodoluminescence experiments

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Hexagonal boron nitride (hBN) is a wide bandgap semiconductor of about 6.4 eV. It is considered as a promising insulating substrate for 2D crystals: preserving the high carrier mobility of graphene [1], enhancing the luminescence properties of transition metal dichalcogenides [2], or decreasing exciton-exciton annihilations in WS_2 [3]. As a key material for prospective devices based on 2D heterostructures, it is crucial to better understand hBN intrinsic properties, in particular luminescence ones that exhibit deep UV emissions governed by tightly-bound excitons.

In this work, we present exciton-exciton annihilation (EEA) experiments in hBN by using cathodoluminescence (CL), following our previous studies on the impact of defects [4,5] and on the thermal stability of excitons [6]. A control of the exciton density in continuous CL is achieved by tuning the focus and the current of the electron beam. Fig. 1 evidences a strong quenching of the luminescence at high exciton densities. In focused conditions, the quenching follows a square root dependence as a function of the beam current, evidencing a bimolecular and non-radiative process attributed to the EEA phenomena. Besides, a significant EEA rate of about 1.7×10^{-6} cm^3/s is estimated thanks to CL experiments as a function of the defocusing. The impact of these results for atomic layers is discussed.

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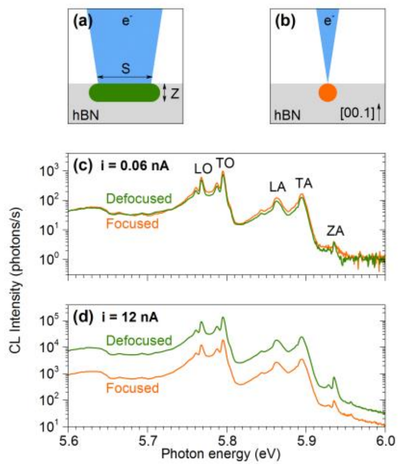

Fig.1 Schematic diagram of defocused (a) and focused (b) electron beams. CL spectra obtained at 10 K, 5 keV and a beam current equal to (c) 0.06 nA or (d) 12 nA. For each current, focused or defocused conditions are compared.