Radiative lifetime of free excitons in hexagonal boron nitride.[1]

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We have developed a new time-resolved cathodoluminescence (TRCL) system dedicated to the UV spectral range. It provides a first estimate of the radiative lifetime (τ_r) of free excitons in hBN, evaluated from a single experiment comparing hBN crystals issued from different synthesis routes. On each sample, the internal quantum yield (η_i) was evaluated from the absolute luminescence intensity under continuous excitation[2], and the exciton lifetime (τ) was deduced from the decay time of free excitons in the time domain.
Since $\eta_i = \tau / \tau_r$,we estimated τ_r at 27ns from the proportionality measured between τ and η_i, as shown in the figure (a). It is much shorter than in other indirect bandgap semiconductors [3,4], which is first explained first by the close proximity of the electron and the hole in the exciton complex, see Figure (b). The unusually high luminescence efficiency of hBN for an indirect bandgap is therefore semi-quantitatively understood.
Beyond that, the demonstration of the intrinsic character of the radiative lifetime of the exciton has a practical application to compare quantitatively hBN samples. The linear relation between the free exciton lifetime and the internal quantum yield indeed provides a scaling of the sample quality, which can be obtained from a single experiment carried out at room temperature. This tool can be capitalized for linking hBN quality to the expected performances of 2D materials in devices using hBN layers.

References

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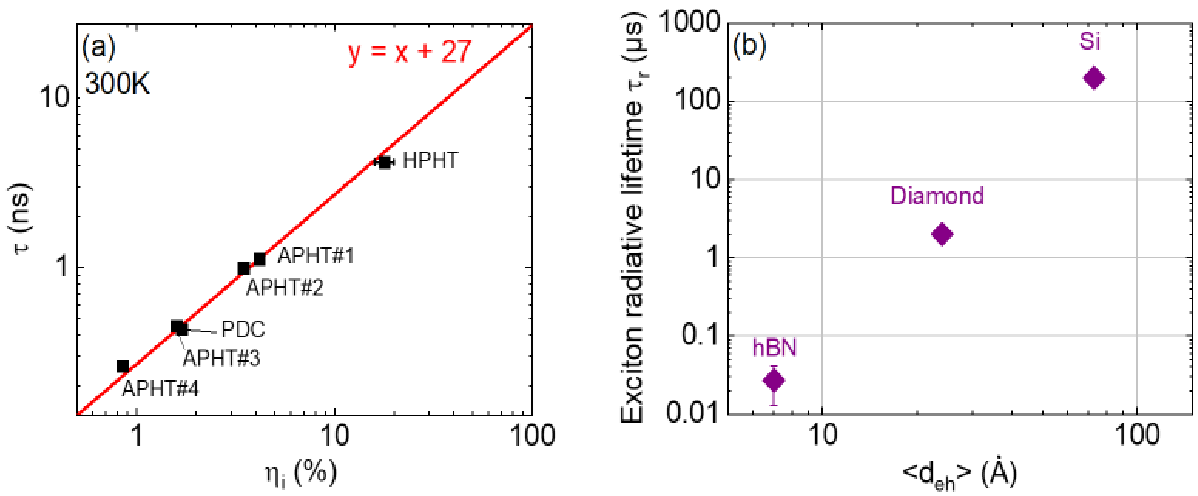
Figures



(a) Free exciton lifetime (τ) as a function of the internal quantum yield (η_i) for the intrinsic luminescence in hBN. The radiative lifetime (τ_r) of hBN indirect excitons is estimated at 27 ns from the linear fit (red curve). **(b)** Radiative lifetimes of free excitons in silicon[2], diamond[3] and of hexagonal boron nitride as a function of the average distance between electron and hole forming the exciton ($\langle d_{eh} \rangle$). We observe an unusual short radiative lifetime of hBN exciton for an indirect exciton, which is explained in a first order by the close proximity between its constitutive electron and hole.