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Article

Engineering Multicolor Radiative Centers in hBN Flakes by Varying the Electron Beam Irradiation Parameters

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Abstract: Recently, hBN has become an interesting platform for quantum optics due to the peculiar defect-related luminescence properties. In this work, multicolor radiative emissions are engineered and tailored by position-controlled low-energy electron irradiation. Varying the irradiation parameters, such as the electron beam energy and/or area dose, we are able to induce light emissions at different wavelengths in the green–red range. In particular, the 10 keV and 20 keV irradiation levels induce the appearance of broad emission in the orange–red range (600–660 nm), while 15 keV gives rise to a sharp emission in the green range (535 nm). The cumulative dose density increase demonstrates the presence of a threshold value. The overcoming of the threshold, which is different for each electron beam energy level, causes the generation of non-radiative recombination pathways.

Keywords: hexagonal boron nitride; electron irradiation; photoluminescence; defect-related light emission

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1. Introduction

Electron irradiation has been an interesting tool for engineering layered materials and tailoring their properties [1–3]. It is possible to consider two main classes of electron irradiation process: low-energy irradiation, where the electron beam energy is compatible with a scanning electron microscope (SEM) or a transmission electron microscope (TEM), i.e., 5–300 keV, and high-energy bombardment that is a process involving electrons with energy beyond 1 MeV.

Among two-dimensional (2D) materials, graphene was the first one in which electron-irradiation-induced defects were studied both experimentally and theoretically [4–9]. The interaction of the electrons with the graphene lattice can induce profound structural modifications. The graphene can suffer a decrease of its crystallinity in favor of a nanocrystalline or amorphous nature, depending on the irradiation doses. This can be obtained even at beam energy in the low-energy range [6,7,10–13]. Importantly, electron-induced defects in graphene have already demonstrated an enhancing of its chemical reactivity, leading to graphene chemical functionalization [14–16]. In addition, electron-irradiation-induced defects have been employed in the engineering of graphene electronic properties [17–21] and, more generally, in sensing applications [22–29]. In the case of high-energy electron irradiation, graphene has been mainly employed in composites for radiation shielding applications [30], therefore structural defects induced by MeV electrons in graphene sheets have been very poorly studied [31,32].

Transition metal dichalcogenides (TMDs) are another class of layered materials, where the effect of the interaction with electron beams has been widely explored for tuning their structural and optical properties [2]. In terms of structural properties, molybdenum-based TMDs, namely MoS_2 and $MoTe_2$, undergo a transition from the semiconducting phase (2H for MoS_2 and 1H for $MoTe_2$) to the metallic phase (1T for MoS_2 and 1T′ for $MoTe_2$), under