Exploration of polarization properties and Stark effect of blue quantum emitters in hexagonal boron nitride

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Abstract

This study explores the polarization properties and Stark effect of blue quantum emitters within hexagonal boron nitride (hBN), highlighting their potential as future tunable quantum light sources. The emitters are created by lattice defects in hBN using focused electron beam irradiation. Photoluminescence (PL) spectroscopy reveals unique polarization properties in both absorption and emission spectra. Furthermore, the application of a vertical electric field allows a detailed analysis of the Stark effect, revealing distinct polarizability and electric dipole moments. These findings make a significant contribution to the development of tunable quantum light sources.

Introduction

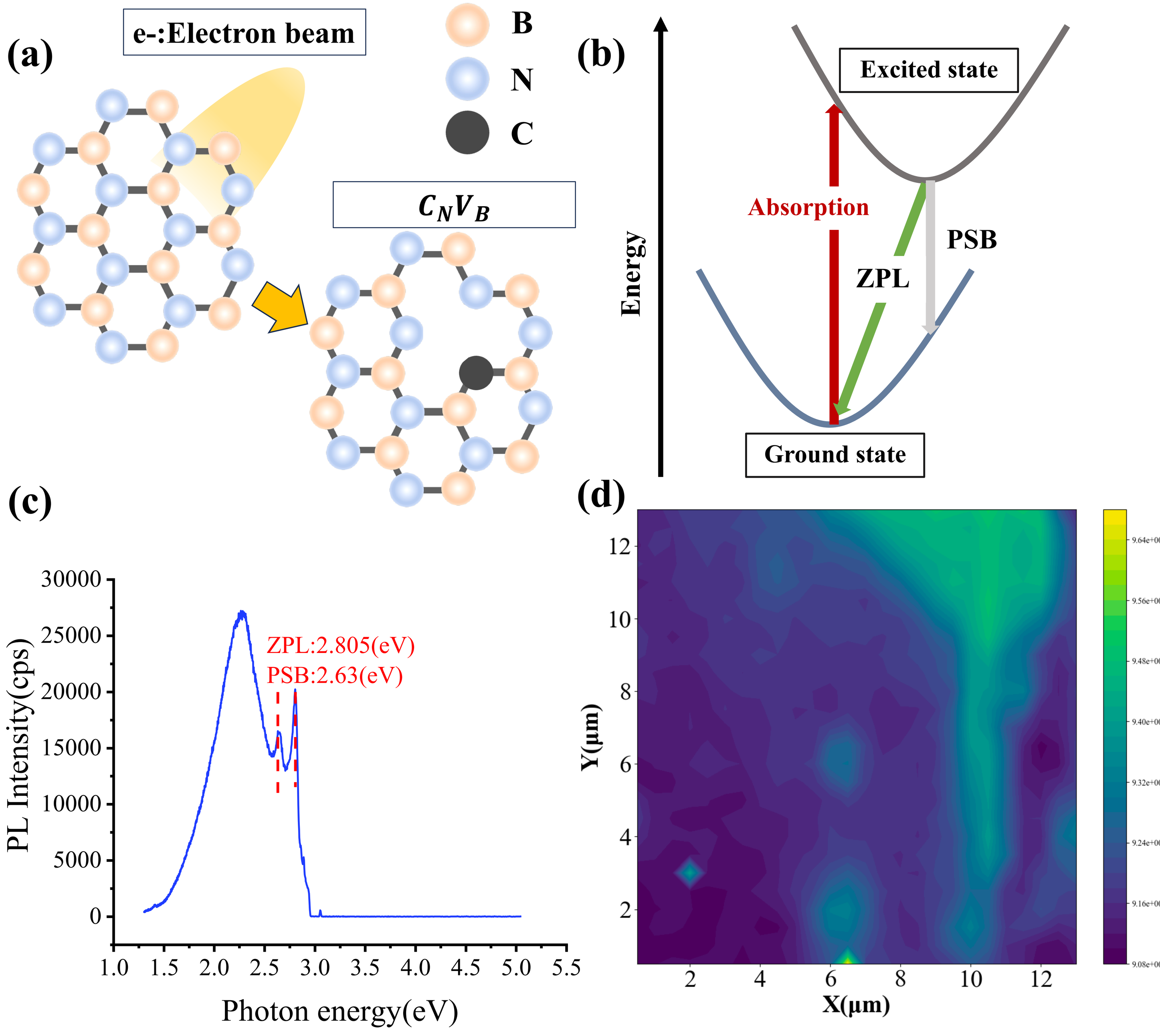

Figure. 1 (a) Lattice defect in hBN produced by electron beam irradiation. (b) Potential energy surface of defect representing the complete excitation and emission process.(c) PL spectrum has a ZPL emission at 2.805 eV and PSB (phonon sideband) at 2.63 eV.(d) the PL mapping of the sample.

Experimental Method

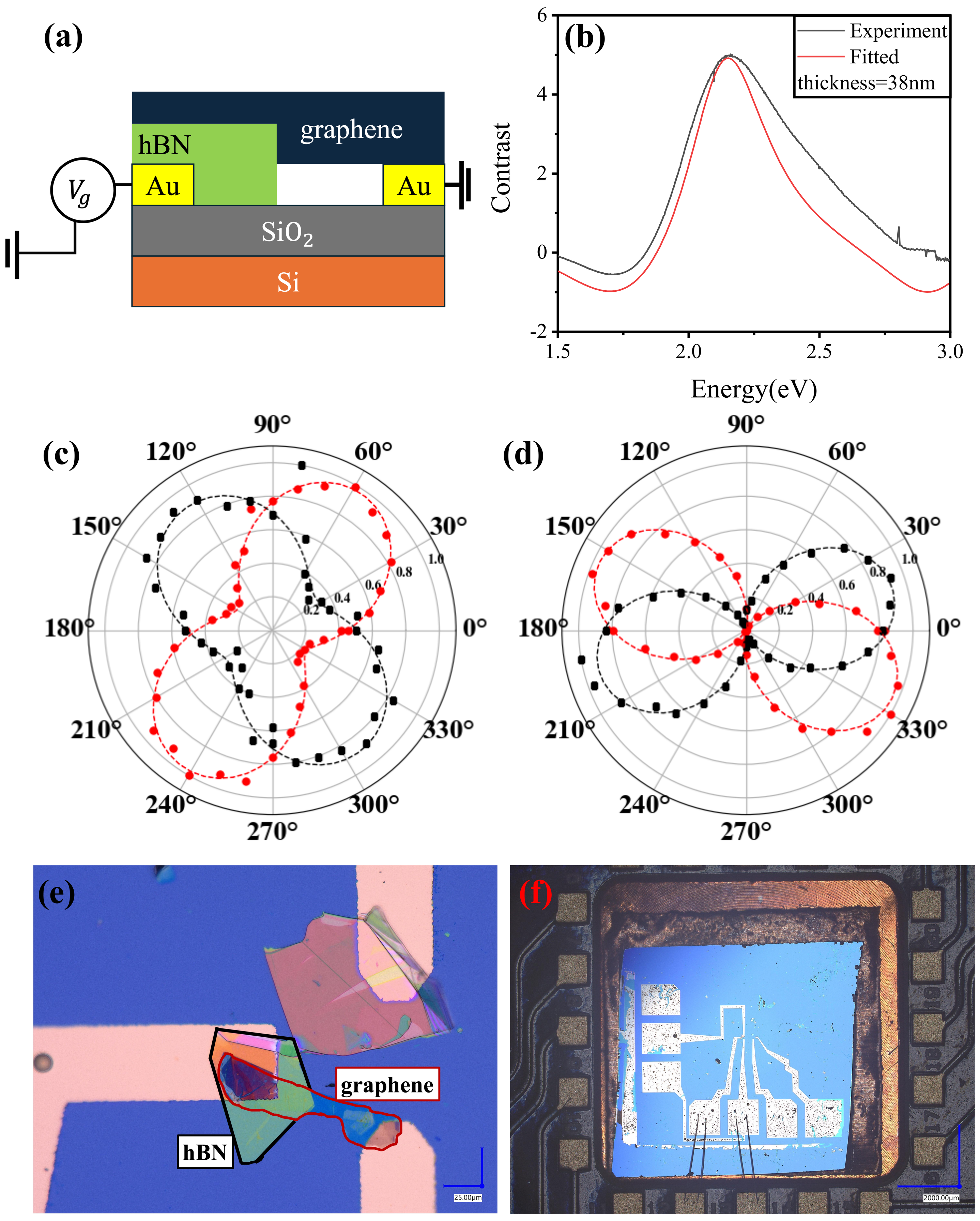

Figure. 2 (a) hBN gate diagram. (b) By differential reflection measurement to obtain the thickness of the hBN flakes. (c)(d) The different QDs' Polarization properties in absorption and emission spectra. (e) The SiO_2/Si substrate is coated with titanium (Ti) and Gold (Au) electrode.

Results

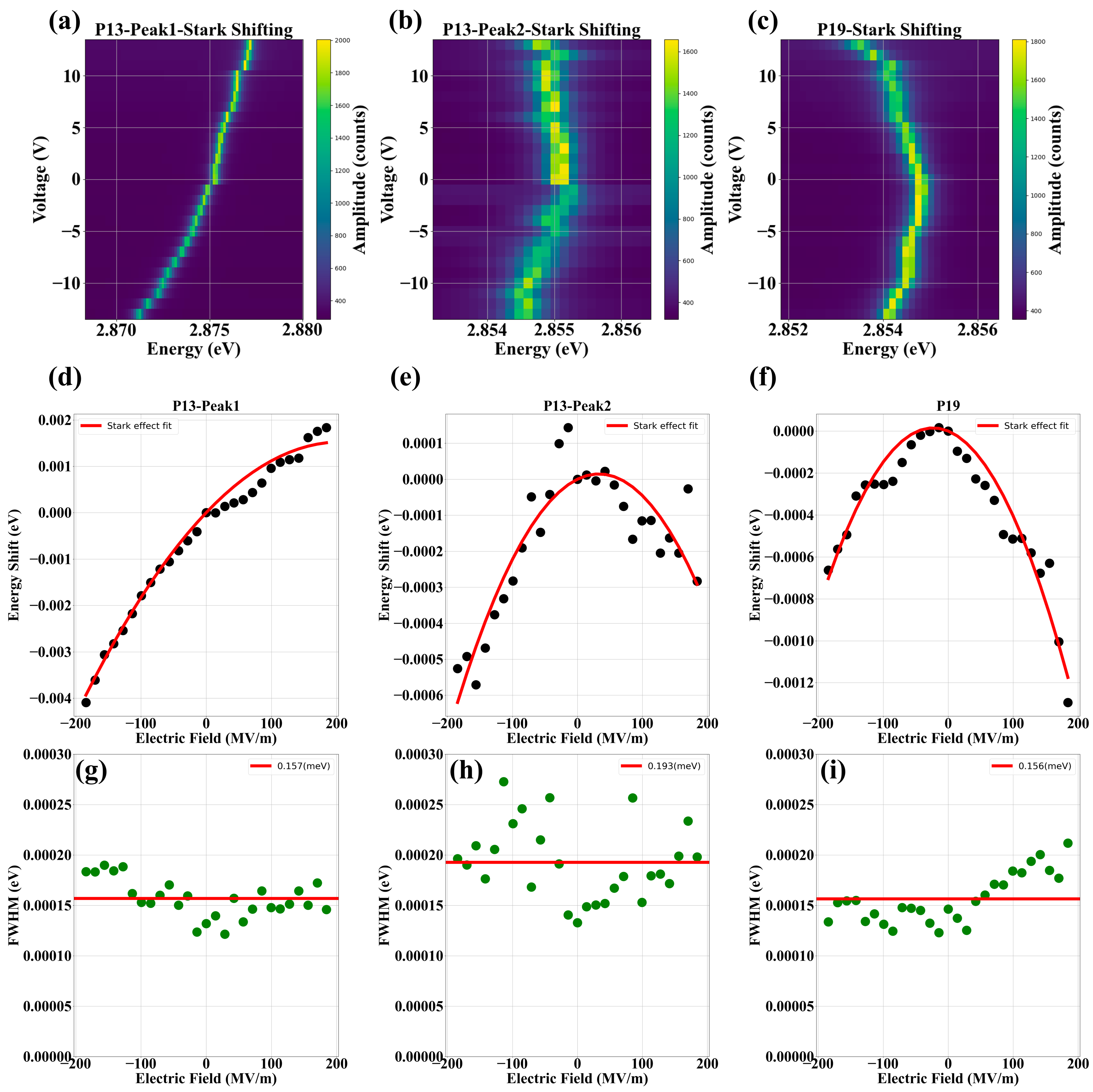

Figure. 3 (a)(b)(c) The change of the quantum dot's ZPL under the external electric field. (d)(e)(f) Second-order Stark effect fitting (Eq.1) . (g)(h)(i) Average FWHM.

Stark effect shifting:

$$\hat{H}_{stark} = qFZ = -\mu F \quad \text{(F : external electric field)}$$

First-order perturbation: $\Delta E^{(1)} = \langle n|\hat{H}_{stark}|0\rangle = -\mu F$

Second-order perturbation: $\Delta E^{(2)} = \sum_{n\neq0}\frac{|\langle n|\hat{H}_{stark}|0\rangle|^2}{E_0-E_n} = \sum_{n\neq0} F^2\frac{|\langle n|\mu|0\rangle|^2}{E_0-E_n} = -\frac{1}{2}\alpha F^2$

$$\alpha = \sum_{n\neq0} -2\frac{|\langle n|\mu|0\rangle|^2}{E_0-E_n}$$

$$\Delta E \cong \Delta E^{(1)} + \Delta E^{(2)} = -\mu F - \frac{1}{2}\alpha F^2 - (1)$$

Table 1: Dipole moment and polarizability for P13-Peak1, P13-Peak2 and P19.

	P13-Peak1	P13-Peak2	P19
Dipole moment μ (Debye)	-0.71	-0.04	0.06
Polarizability α (Å^3)	102.68	38.62	79.54

Conclusion

Using the electron beam, we successfully generated blue-light quantum dots on hBN and observed the shifting of the ZPL under applied voltage. The energy shift was well-fitted to the Stark effect, allowing us to extract the dipole moment and polarizability of SPE. These findings highlight the controllability and potential applications of hBN quantum dots.

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