Supplementary Information

Luminescence and Thermal Behaviors of Free and Trapped Excitons in Cesium Lead Halide Perovskite Nanosheets

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The temperature-dependent linewidth broadening (solid squares) of the two peaks is plotted in Figure S1 and fitted using the equation[S1,2]

$$\Gamma(T) = \Gamma_0 + \Gamma_{ac}T + \frac{\Gamma_{op}}{e^{\hbar w_{op}/k_B T} - 1} \qquad (1)$$

in which the first term Γ_0 is the inhomogeneous broadening, while Γ_{ac} and Γ_{op} account for the contributions of exciton-acoustic phonon interaction and exciton-optical phonon, respectively, to the linewidth broadening. It should be noted that Eq. (1) is derived for the temperature-dependent linewidth broadening of luminescence of free excitons.[S1] As expected, the temperature dependence of luminescence linewidth of free excitons (e.g., Peak 2) can be represented with Eq. (1). The solid line in Figure S1(b) is a fitting curve with Eq. (1) for $\hbar w_{op}$ = 34.4±0.8 meV. This effective optical phonon energy is comparable to that (e.g., 29±3 meV) of $CsPbBr_3$ obtained by Cho *et al*.[S2] For the temperature dependence of luminescence linewidth of trapped excitons in low temperature range of 10-60 K, acoustic phonon scattering may be dominant. We thus use the two former terms on the right hand side of Eq. (1) to make a fit. A fitting curve is depicted in solid linear line in Figure S1(a) for Γ_0=67.2±4.1 meV and

Γ_{ac}=0.8±0.1 meV K^{-1}. Clearly, inhomogeneous broadening due to broad defect state distribution makes a major contribution. These data tend to be consistent with the assignment of Peak 2 to free excitonic luminescence and Peak 1 to trapped excitonic one.

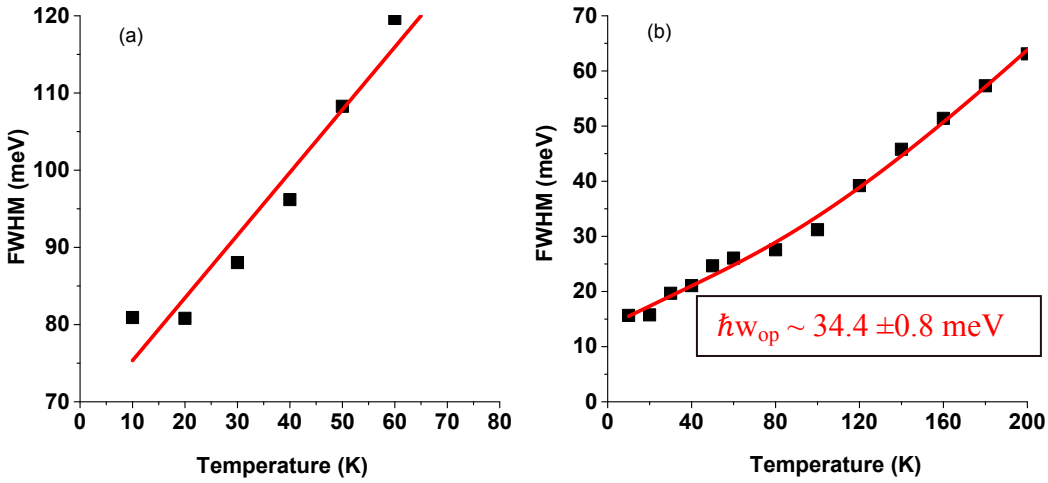

Figure S1 Linewidths vs. temperature for Peak 1 (a) and Peak 2 (b).

References

S1 S. Rudin, T. L. Reinecke, B. Segall, *Phys. Rev. B* 1990, **42**, 11218-11231

S2 H. Cho, C. Wolf, J. S. Kim, H. J. Yun, J. S. Bae, H. Kim, J.-M. Heo, S. Ahn, T.-W. Lee, *Adv. Mater.* 2017, **29**, 1-8.