The excitons (electron-hole pairs) generated by semiconductor materials excited by light could recombine through: direct recombination of electrons and holes, indirect recombination luminescence through surface defect states, and recombination luminescence through impurity levels. These luminescence modes compete with each other, and proportion of luminescence modes will depend on specific structures of the quantum dots. Fewer surface defects of quantum dots will induce fewer trapped electrons and holes, increasing the probability of exciton state luminescence wand yielding strong illuminance intensity of the exciton state. Otherwise, the corresponding exciton state luminescence intensity will be weak. Therefore, exciton luminescence could be improved through fabrication of quantum dots with intact surfaces or by modification of quantum dots surfaces by ligands or their encapsulation in matrices.

The effect of temperature on bandgap width of bulk material primarily depends on thermal expansion and electroacoustic interaction of the crystal lattice. The relationship between bandgap width and energy band of bulk semiconductor materials can be described by the well-known Varshni empirical formula (Equation 1), which could also be used for quantum dots.

$$E_g(T) = E_g(0) - \frac{\alpha T^2}{\beta + T} \tag{1}$$

where: $E_g(0)$ represents gap width of the material at 0 K in eV, α is the thermal expansion system of the material in eV·K^{-1}, T is temperature in K, β is approximate Debye temperature of material in K. [43, 44]

As can be seen from the Varshni empirical formula, increase in temperature should raise the value of $\frac{\alpha T^2}{\beta + T}$ factor but gap width of the material will decrease. This would reduce optical band gaps of quantum dots.

The relationship between photon energy and optical bandgap E_g^{QD} could be expressed by (Equation 2):

$$\frac{hc}{\lambda} = E_g^{QD} \tag{2}$$

where h presents the Planck constant in J·s, c is speed of light in m·s^{-1}, λ is wavelength of emitting photon in m, and E_g^{QD} is the optical band gap of quantum dots in J.

By differentiating (Equation 2) with respect to temperature T, energy will be converted into electron volts to obtain the relation between wavelength of emitted photons and both bandgap and temperature (Equation 3).

$$\frac{d\lambda}{dT} = -\frac{\lambda^2}{1239.84}\frac{dE_g^{QD}}{dT} \qquad (3)$$

(Equation 3) shows the relationship between the photoluminescence wavelength of quantum dots and temperature. Also, the optical band gap of quantum dots illustrating the effect of temperature on optical band gap of quantum dots is reflected by changes in fluorescence peak wavelength of quantum dots. The increase in temperature of quantum dots should raise the fluorescence peak wavelength. Thanks to this characteristic, quantum dots can be employed as temperature measurement probes.