Kwansei Gakuin University
Report of Research Outcome

2021/10/27

To President

Department : Science and Technology
Position : Postdoctoral fellow
Name : Li Wang

I report the outcome of the research as follows.

Name of the Fund/Program	□Sabbatical leave with grant □Sabbatical leave with no grant □KGU Joint Research □Individual Special Research ☒Postdoctoral fellow ※Please report by designated form as for "International Research Collaboration".
Research Theme	界面エンジニアリングによる高効率青色発光半導体量子ドットの合成とキャリア素過程
Research Site/Venue	Tamai Group
Research period	2021/04/01 ～ 2021/09/30 （ 6 month）

◆ **Summary of the research outcome** （approx. 2,500 words）

Please write down the outcomes in detail regarding the research theme above.

Colloidal quantum dots (QDs) exhibit unique size-tunable optoelectronic properties by strong quantum confinement effects, making them as potential candidates for optoelectronic devices. Recently, heavy metal-free QDs become interesting to reduce environmental impact. ZnSe with 2.7 eV bulk bandgap is a suitable choice for violet-blue nano-emitters. All the applications are based on exciton dynamics in colloidal QDs. Nonradiative Auger recombination in semiconductor QDs becomes much efficient owing to relaxation of momentum conservation and increasing Coulomb coupling in strong spatial confinement. However, carrier dynamics, especially Auger recombination, in ZnSe QDs has been seldom reported. In my research, ZnSe QDs with various sizes were synthesized, and their carrier dynamics were monitored by transient absorption (TA) spectroscopy with 266, 330, and 400 nm excitation.

Six ZnSe nanocrystals were prepared by a hot injection method with slight modifications and characterized by steady-state and transient absorption spectroscopies. As shown in Figure 1a, 1S peak wavelengths of steady-state absorption spectra shift to the red with increasing their sizes. Bleach signal in TA spectra of semiconductor QDs is induced by

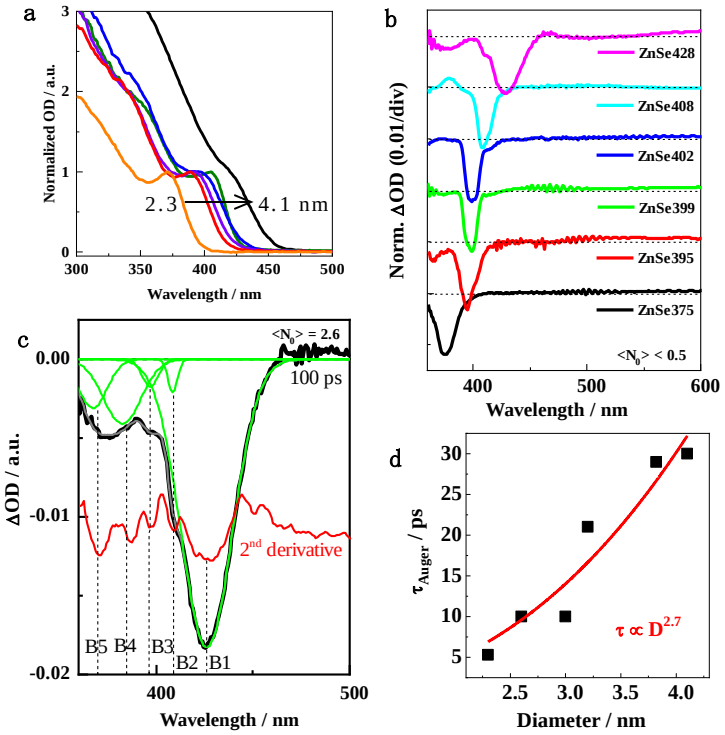

Figure 1. Steady-state absorption spectra (a), TA spectra at 10 ps delay time after 330 nm excitation (b), and Auger recombination lifetime obtained by the difference of decay profiles at 1S peak wavelength with two different excitation intensities (d) of ZnSe QDs with six different sizes. TA spectrum (black) at 100 ps time delay under high excitation fluence with Gaussian fitting curves (green and gray) and 2nd derivative of steady-state absorption spectrum (red) of ZnSe426 QDs (c)

state filling of excited electron in conduction band. In Figure 1b, bleach peak wavelengths of TA spectra also shift to the red correspondingly. In Figure 1c, TA spectra of ZnSe426 at 100 ps time delay with high excitation fluence of 330 nm were illustrated. The transitions are characterized by Gaussian fitting of TA spectrum and the second derivative of steady-state absorption spectrum. Bleach at 426 nm with a shoulder on 410 nm in TA spectra of ZnSe426 are corresponding to the transitions of $1S(e)-1S_{3/2}(h)$ and $1S(e)-2S_{3/2}(h)$, respectively. The transition of $1S(e)-1S_{1/2}(h)$ at 396 nm becomes distinguishable. Another broad bleaching signal from 390 to 360 nm was usually assigned to transitions of $1P(e)-1P_{3/2}(h)$ and $1S(e)-2S_{1/2}(h)$. TA signal around 380 nm represents an additional fast decay for high excitation fluences. With higher excitation influence, the lowest excited state 1S is much more populated and multiexciton exists. Then the exciton populated at 1P state participates in multiexciton Auger recombination with a faster decay component. Therefore, the broad band from 390 to 360 nm is assigned to overlap of $1P(e)-1P_{3/2}(h)$ at 380 nm and $1S(e)-2S_{1/2}(h)$ at 370 nm. TA spectroscopy with different excitation fluences was conducted to determine Auger recombination lifetime in ZnSe QDs. As shown in Figure 1d, Auger lifetime of ZnSe QDs is roughly proportional to D^3, which is in good agreement with reported semiconductor QDs.

In summary, ZnSe with 2.7 eV bulk bandgap is a suitable choice for violet-blue nano-emitters. Six sizes of ZnSe QDs were prepared. Spectral species and their carrier dynamics were characterized by steady-state absorption and TA spectroscopies. Size-dependent Auger recombination in ZnSe QDs follows volume scale and multi-exciton recombination represent to be a free carrier model.

The above research is summarized and will be submitted to The Journal of Physical Chemistry C.

Deadline : Within two months after finishing the research period.

Sabbatical leave with grant: Submit this report to President with confirmation by the dean of school you belong to.

※ Postdoctoral fellow is required to submit this report with confirmation by the dean of graduate school before the end of employment period.

Where to submit : Organization for Research and Development and Outreach (NUC)

◆ We put this report on the web of KGU. If there is any problem about it because of difficulties on your research, please let us know.