Supporting Information

Adverse Interactions of Luminescent Semiconductor Quantum Dots with Liposomes and *Shewanella oneidensis*

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TEM of ZnSe, and ZnSe/ZnS QD. High Resolution Transmission Electron Microscopy (HR-TEM) images were obtained to determine the size of core and core/shell QD used in the study. The TEM images revealed the luminescent QD were round and highly crystalline with increasing shape irregularities with increasing shell thickness for CdSe/ZnS QD. The TEM measurements were carried out using a Titan 80-300 S/TEM, operating at 300 kV with a Gatan OneView imaging camera. Samples were prepared by drop coating the QD onto mesh copper grids with ultrathin carbon film on holey carbon support film (Ted Pella, Inc.). Grids were then placed in vacuum oven overnight before analysis.

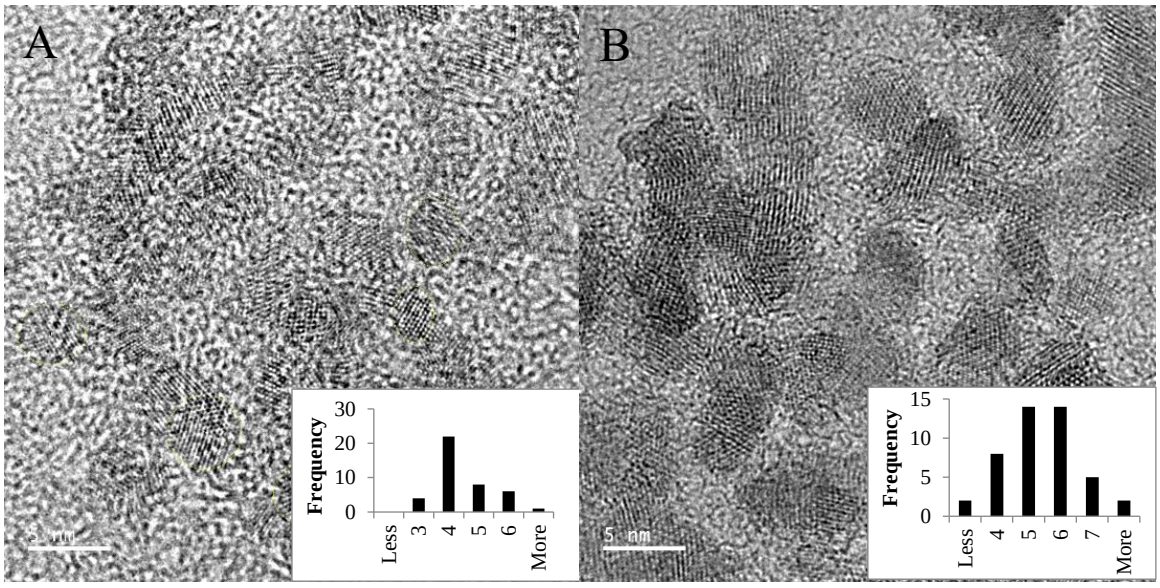

Figure S1 - TEM images of 3.5 ± 0.4 nm ZnSe core QD (A) and 5.0 ± 1.2 nm ZnSe/ZnS QD (B). These and similar images were used to obtain the QD size distribution. The QD size distribution for each image (N > 50) is shown in the insert.

TEM of CdSe, CdSe/ZnS (1ML), CdSe/ZnS (3ML), and CdSe/ZnS (6ML) QD.

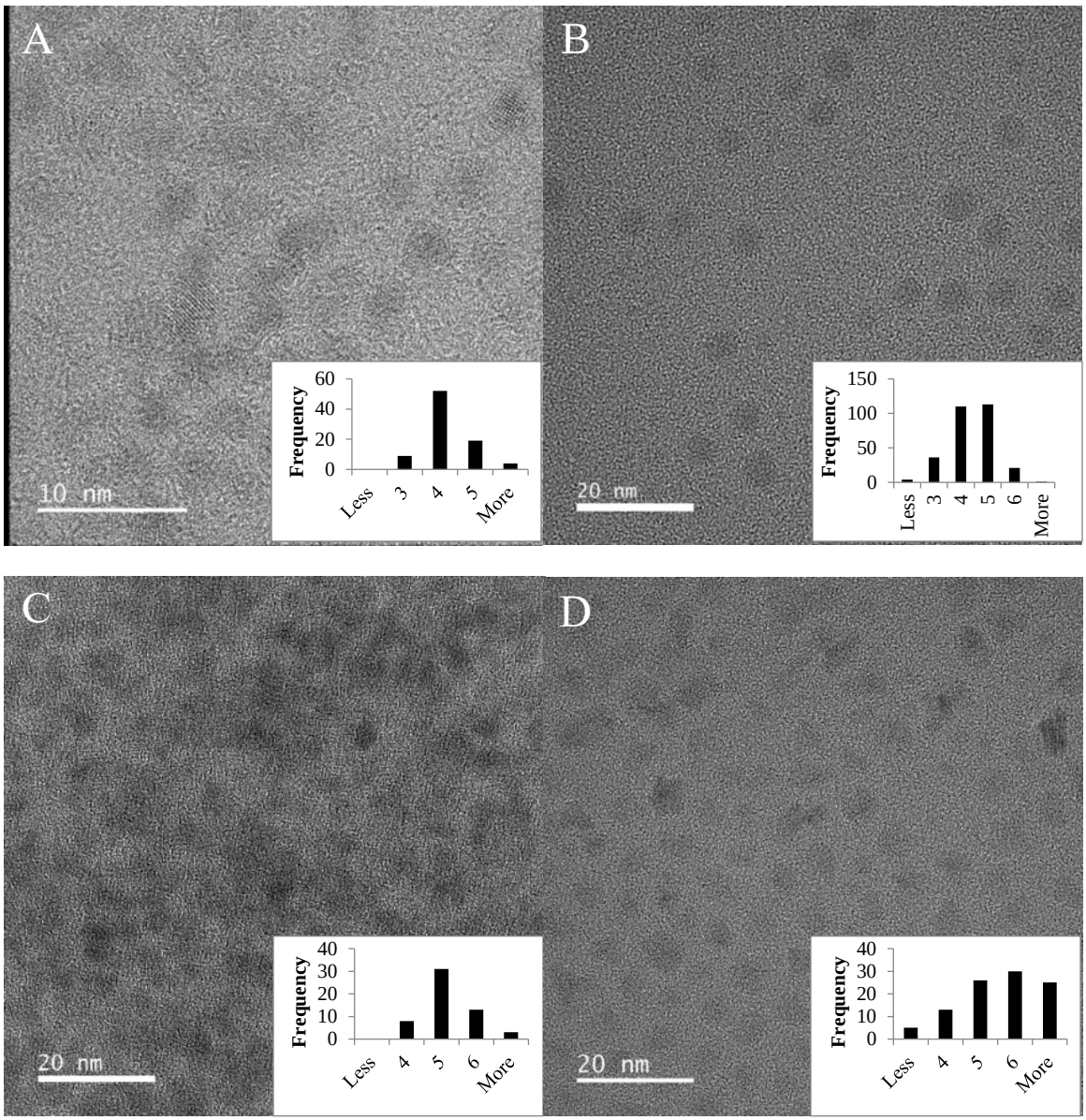

Figure S2. TEM images of 3.9 ± 0.5 nm CdSe core QD (A), 4.2 ± 0.8 nm CdSe/ZnS (1ML) QD (B), 5.0 ± 0.9nm CdSe/ZnS (3ML) QD (C), and 5.9 ± 0.8 nm CdSe/ZnS (6ML) QD (D). These and similar images were used to obtain the QD size distribution. The QD size distribution for each image (N > 50) is shown in the insert.

Time resolved photoluminescence measurements of ZnSe and ZnSe/ZnS QD. Time resolved photoluminescence measurements were carried out to determine the impact of the ZnS shell on the QD optical performance and to assess the quality of the luminescent QD. The LUDOX TMA colloidal silica standard in water, λ_{em} = 372 nm, was used as the standard. The decrease in fluorescence lifetime of core QD when passivated with a higher energy bandgap shell is attributed to increased confinement of the excited electrons in the core QD, and is consistent with previous studies.[1]

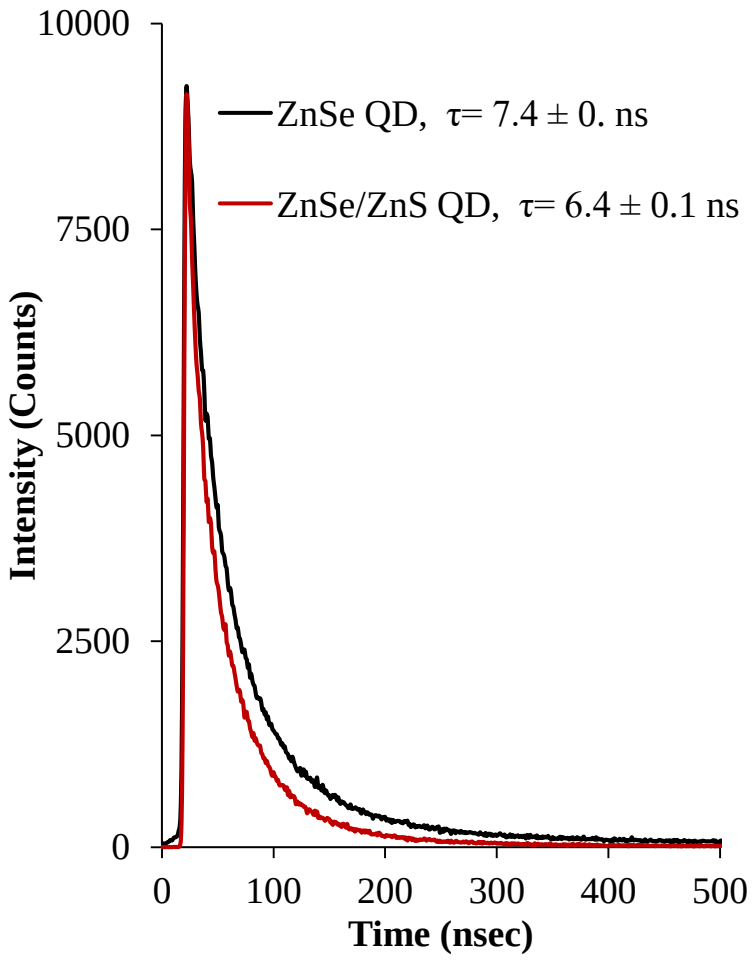

Figure S3. Time resolved photoluminescence decay curves of ZnSe and ZnSe/ZnS QD in chloroform. A decrease in the fluorescence lifetime of the ZnSe QD is observed when they are coated with a higher energy bandgap shell.

Time resolved photoluminescence measurements of CdSe, CdSe/ZnS (1ML), CdSe/ZnS (3ML), and CdSe/ZnS (6ML) QD.

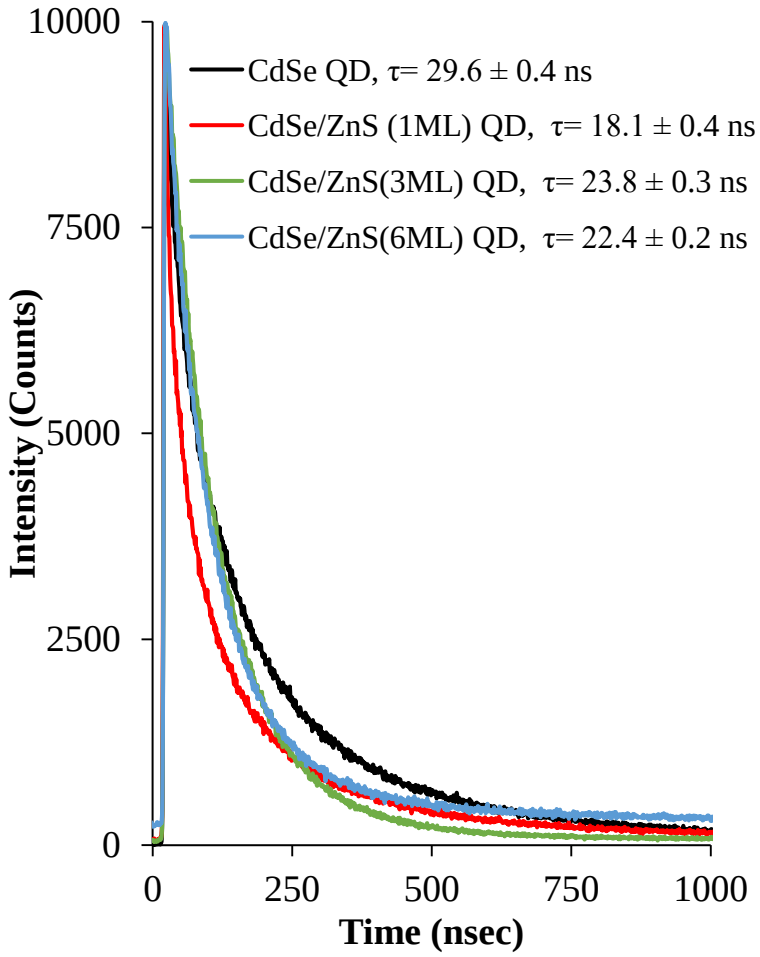

Figure S4. Time resolved photoluminescence decay curves of CdSe, CdSe/ZnS (1ML), CdSe/ZnS (3ML), and CdSe/ZnS (6ML) QD in chloroform. The fluorescence lifetime of the CdSe QD decreases significantly when they are coated with a higher energy bandgap ZnS shell. The majority of the impact is realized when the CdSe QD are coated with one monolayer ZnS shell.

Dynamic Light Scattering (DLS) Measurements of Liposomes when Exposed to Zinc and Cadmium Ions. DLS measurements were used to determine the size distributions of liposomes before and after >15 minute exposures to 1% Triton X solution, 1-20 ppm cadmium ion, and 1-20 ppm zinc ion control solutions. Measurements were carried out in triplicate to determine the mean liposome size and standard deviation. The DLS measurements were carried out on using a Malvern Zetasizer Nano ZS. Figure S5 shows the impact of liposome exposure to 1% Triton X solution (red), 20 ppm zinc ions (green), and 20 ppm cadmium ions (blue) on their structural integrity. The concentration of zinc and cadmium ion was chosen as 20 ppm since this is the upper limit of ion concentration in our QD experiments if they completely dissolve. Significant changes to the liposome size distribution were detected only following the exposure of the liposomes to Triton X, as evident by the disappearance of the ~100 nm liposome peak and the appearance of large peaks at ~10 nm (small phospholipid particles) and at ~300 nm (large phospholipid aggregates). The lack of changes in the liposome size distributions following the addition of ions indicates that the dissolution of free QD that are not associated with the liposome membrane is not a major contributor of QD-induced membrane disruption.

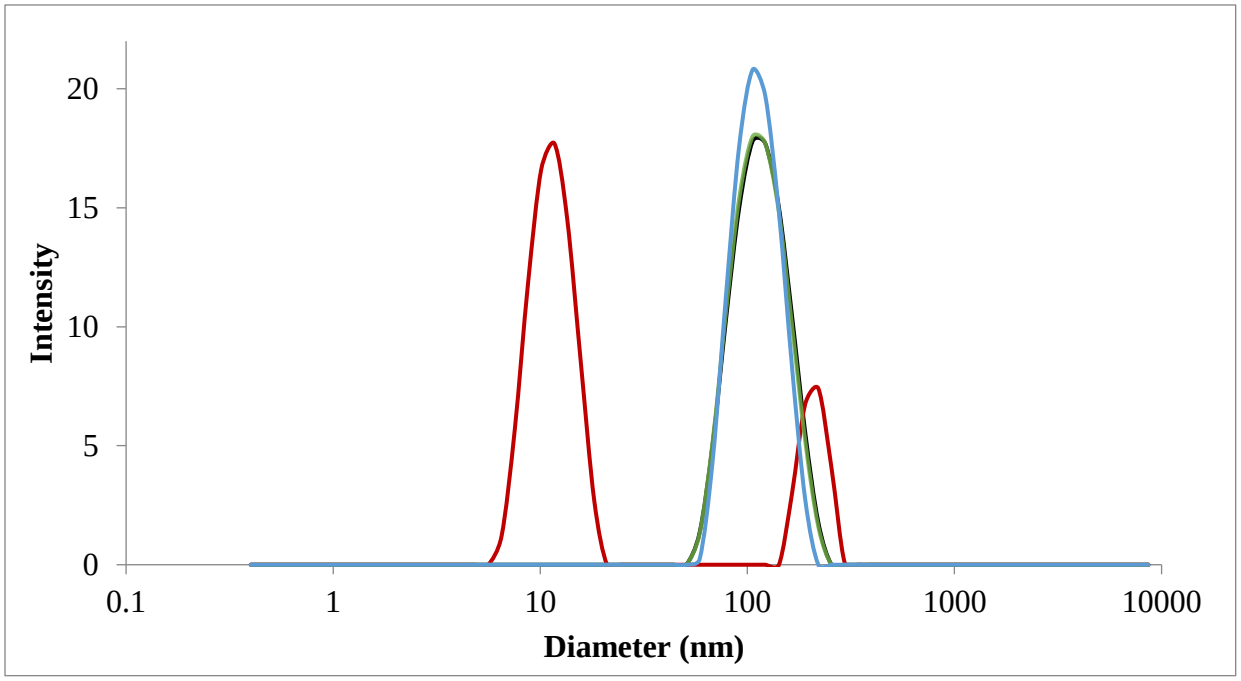

Figure S5. DLS of POPC:POPG liposomes in HEPES solution at pH 7.4 (black), and following 15 minute-long exposure to 1% Triton X solution (red), 20 ppm zinc ions (green), and 20 ppm cadmium ions (blue). The DLS data show that the impact of zinc and cadmium ions under our exposure conditions (20 ppm for 15 minutes) is negligible (the liposomes and liposomes + 20 ppm zinc ions' curves overlay each other).

Bacterial viability studies of *Shewanella oneidensis* MR-1 cells exposed to ZnSe and ZnSe/ZnS QD. *Shewanella oneidensis* MR-1 bacteria were treated with QD for 15 minutes at varying concentrations, and their viability was determined using a drop-plate colony-counting protocol on the next day.[2] Bacterial cell cultures of *Shewanella oneidensis* MR-1 exposed to ZnSe and ZnSe/ZnS QD indicated QD had negligible impact on cell viability even at the highest concentration of 5mg/L zinc ion equivalents in the core (0.5 mg/L selenium equivalents). This is contrary to the results of bacterial exposures to CdSe and CdSe/ZnS QD (Figure 8 in the main paper), which demonstrated that exposing the bacterial cells to cadmium-containing QD induces a concentration-dependent decrease in bacterial cell viability at similar selenium ion concentration equivalents.

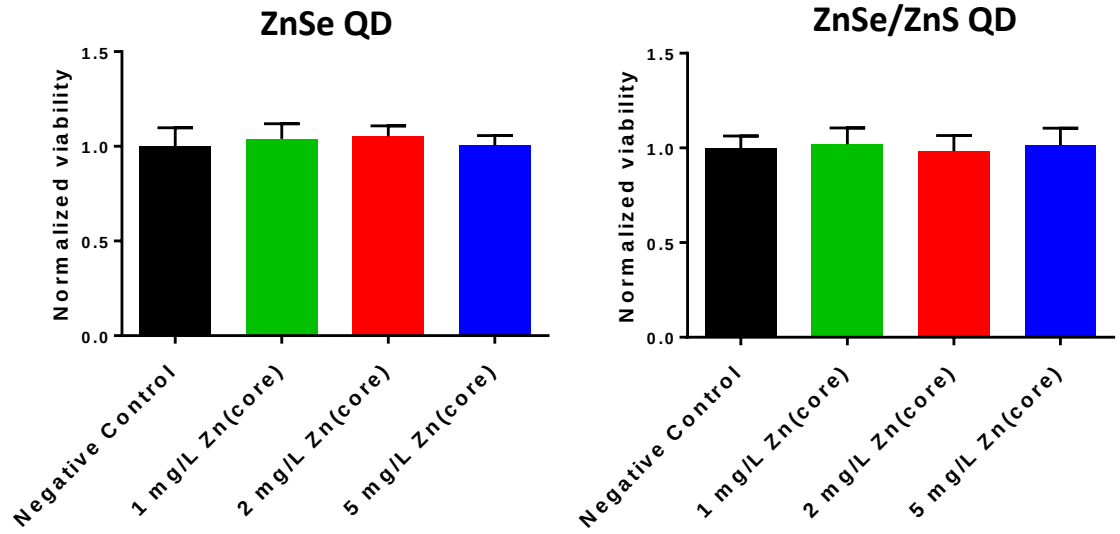

Figure S6. Viability of *Shewanella oneidensis MR-1* following their exposure to increasing concentrations of ZnSe (A) and ZnSe/ZnS (B) QD. The viability values are normalized to negative controls of unexposed bacteria cells. N=4 biological replicates for each condition, and the error bars represent standard deviation among those replicates.

References

1. Lyons, T.; Williams, D.; Rosenzweig, Z., Addition of Fluorescence Lifetime Spectroscopy to the Tool Kit Used to Study the Formation and Degradation of Luminescent Quantum Dots in Solution. Langmuir **2017**, *33*, 3018-3027.
2. Feng, Z.; Gunsolus, I.; Qiu, T.; Hurley, K.; Nyberg, L.; Frew, H.; Johnson, K.; Vartanian, A.; Jacob, L.; Lohse, S.; Torelli, M.; Hamers, R.; Murphy, C.; Haynes, C., Impacts of Gold Nanoparticle Charge and Ligand Type on Surface Binding and Toxicity to Gram-negative and Gram-positive Bacteria. *Chem. Sci.* **2015,** *6*, 5186-5196.