## **Supporting Information**

Aminoalkanoic Acids as Alternatives to Mercaptoalkanoic Acids for the Linker-Assisted Attachment of Quantum Dots to TiO<sub>2</sub>

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- **Figure S3.** Representative plots of  $\ln(1-\theta)/C$  vs. time, where  $\theta$  is fractional surface coverage ( $\Gamma/\Gamma_0$ ) and *C* is concentration, for the attachment of CdSe QDs to TiO<sub>2</sub> films functionalized with ADA and MDA at saturation surface coverages.
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- **Table S3.** Values of  $A_i$  and  $\tau_i$  from fits to representative emission decay traces within the bandedge and surface emission bands for dispersions containing CdSe QDs.

### Appendix S1. Synthesis of CdSe QDs

Nominally tri-*n*-octylphosphine oxide (TOPO)-capped CdSe QDs were synthesized following the method of Peng and co-workers.<sup>1.2</sup> The selenide precursor was a mixture of selenium powder (0.800 g, 10.1 mmol) and tri-*n*-octylphosphine (TOP) (24.1 mL, 54.0 mmol). The cadmium precursor was prepared by adding TOPO (40.0 g, 103 mmol) and cadmium acetate dihydrate (0.500 g, 1.88 mmol) to a three-necked round-bottomed flask, then heating the mixture to 330 °C under Ar flow. The resulting mixture was cooled to 280 °C, and then the selenide precursor was added. The reaction mixture was heated at ~280 °C until the desired absorption spectrum of CdSe QDs was obtained. The reaction mixture was then cooled to 60-80 °C. The resulting dispersions of CdSe QDs were purified using nonsolvent/solvent washing to remove excess TOPO and other capping ligands. For the first purification cycle, methanol (MeOH) (30 mL) was added to the reaction mixture containing as-synthesized CdSe QDs (10 mL). The flocculate was removed by centrifugation and then re-dispersed in tetrahydrofuran (THF) (5 mL). In subsequent purification cycles, MeOH (15 mL) was added to a THF dispersion of CdSe QDs (5 mL). The resulting flocculate was removed using centrifugation and re-dispersed in THF (5 mL). This purification procedure was repeated 2-3 times.

# Appendix S2. Preparation of mixed dispersions for steady-state and time-resolved emission measurements

The concentration of CdSe QDs was equal in all mixed dispersions. For dispersions containing CdSe QDs, ABA, and/or metal oxide NPs, the absorbance of the stock dispersion of CdSe QDs in THF at the first excitonic absorption maximum (490 nm), with path length of 1 cm, was approximately 0.17-0.18. Concentrations of the stock solution of ABA in DMSO and the stock dispersions of metal oxides (in formula units) in ethanol were 2.45 mM and 33 mM, respectively. The mixed dispersions were prepared as follows:

Sample	Volume of stock QDVolume of stock ABAVolume of stock MO2dispersion in THF (mL)solution (mL) in DMSOdispersion (mL) in ethano		Volume of stock MO <sub>2</sub> dispersion (mL) in ethanol	Volume of ethanol (mL)	Total volume (mL)			
QDs alone	5	0	0	5	10			
QD-ABA-ZrO <sub>2</sub>	5	3	2	0	10			
QD-ABA-TiO <sub>2</sub>	5	3	2	0	10			

**Table S1.** Compositions of mixed dispersions containing CdSe QDs and/or ABA, metal oxide NPs for spectroscopic analysis.

For dispersions containing CdSe QDs, MBA, and/or metal oxide NPs, the absorbance of the stock dispersion of CdSe QDs in toluene at the first excitonic absorption maximum (490 nm), with path length of 1 cm, was approximately 0.17-0.18. Concentrations of the stock solution of

MBA and the stock dispersions of metal oxides (in formula units) in ethanol were 2.45 mM and 33 mM, respectively. The mixed dispersions were prepared as follows:

Sample	Volume of stock QD dispersion (mL) in toluene	Volume of stock MBA solution (mL) in ethanol	Volume of stock MO <sub>2</sub> dispersion (mL) in ethanol	Volume of toluene (mL)	Total volume (mL)
QDs alone	5	0	0	5	10
QD-MBA-ZrO <sub>2</sub>	5	3	2	0	10
QD-MBA-TiO <sub>2</sub>	5	3	2	0	10

**Table S2.** Compositions of mixed dispersions containing CdSe QDs and/or MBA, metal oxide NPs for spectroscopic analysis.

### Appendix S3. Time-correlated single photon counting measurements

Time-resolved emission data were acquired with a Becker and Hickl Tau-130 system. A pulsed diode laser (BDL 445 SMC) excited samples at 445 nm. The full width at half maximum (FWHM) of the pulse was 40-90 ps at a power of 1 mW and a repetition rate of 50 MHz. The laser could be operated at repetition rates of 1 MHz, 20 MHz, and 50 MHz. All data were acquired at 1 MHz to avoid re-exciting samples before their emission decayed to baseline. A delay cable equivalent to 50 ns was employed in the sync channel, and the time-to-amplitude converter (TAC) was fixed to 50 ns to acquire decay traces corresponding to the first 50 ns of decay. For acquiring complete decay profiles (1 µs TAC window), decay profiles were acquired without using delay cables. QD-containing dispersions were housed in a four-sided quartz cuvette with a path length of 1 cm. Emission was collected at 90° to the excitation beam and focused into a polychromator coupled to a 16-channel photomultiplier tube (PML 16-C). Each channel corresponded to a 12.5 nm window. Data were acquired at magic angle conditions<sup>3</sup> by placing a polarizer in the emission channel at 54.7° to the polarization of the excitation beam. A 460 nm long-pass filter was placed in the emission channel before the polychromator to minimize scattering of the excitation light from samples. A neutral density filter was used to adjust the intensity of the excitation beam such that the probability of detection of a photon per excitation pulse was less than 0.01. TRPL decay traces were obtained over 1024 time bins with time resolution of 48.8 ps. Decay traces were collected over 600 s for band-edge emission (475-525 nm) and 2000 s for surface emission (622-705 nm). The instrument response function (IRF) was acquired by using a light-scattering suspension of silica LUDOX and measuring a decay trace at the excitation wavelength. At a laser gain of 20% and a detector gain of 90%, FWHM for the IRF was approximately 240 ps. Emission decay traces were fitted using Fluofit software by Picoquant.



**Fig. S1.** Plots to assess whether equilibrium-binding data for the adsorption of ADA and MDA to TiO<sub>2</sub> follow the Langmuir adsorption isotherm. (a) Reciprocal of surface coverage  $(1/\Gamma)$  of ADA and MDA on TiO<sub>2</sub> as a function of the reciprocal of concentration (1/[Linker]) of solutions from which they were adsorbed. (b) [Linker]/ $\Gamma$  as a function of [Linker]. Superimposed on the data are linear fits. Error bars are plus-or-minus one standard deviation relative to the average value for 3-4 films.



**Fig. S2.** EDS spectra of CdSe QD-functionalized TiO<sub>2</sub> films prepared by immersing ADA-functionalized (a) or MDA-functionalized (b) TiO<sub>2</sub> films in a THF dispersion of CdSe QDs (15  $\mu$ M).



**Fig. S3.** Representative plots of  $\ln(1-\theta)/C$  vs. time, where  $\theta$  is fractional surface coverage  $(\Gamma/\Gamma_0)$  and *C* is concentration, for the attachment of CdSe QDs to TiO<sub>2</sub> films functionalized with ADA and MDA at saturation surface coverages. Superimposed on the data are linear fits from which values of  $k_{ad}$  were extracted. Error bars are plus-or-minus one standard deviation relative to the average value for 4 films. CdSe QDs were deposited from THF dispersions with *C* of 1.0  $\mu$ M. Adsorption times that gave rise to  $\theta \le 0.5$  were included in the plots. Values of  $k_{ad}$  reported in the text are the averages from data obtained with *C* of 0.25. 0.50. 0.75. and 1.0  $\mu$ M.



**Fig. S4.** Representative plots of normalized emission intensity as a function of equilibration time for dispersions of CdSe QDs alone, QD-ABA-ZrO<sub>2</sub> dispersions, and QD-ABA-TiO<sub>2</sub> dispersions (a, b) and for QDs alone, QD-MBA-ZrO<sub>2</sub> and QD-MBA-TiO<sub>2</sub> dispersions (c, d), measured at the band-edge maximum (a, c) and the surface maximum (b, d).

**Fig. S5.** Top graphs: Emission decay traces (blue), IRF (red), and multiexponential reconvolution fits from eq. 2 (black) from representative measurements for each type of QD-containing dispersion at various wavelengths. Bottom graphs: corresponding residuals (data minus fit). Each set of graphs shows fits to monoexponential (left), biexponential (middle), and triexponential (right) functions. Corresponding chi-square values are in the insets.





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**Fig. S6.** Emission decay traces and corresponding fits for band-edge emission and surface emission from dispersions of free CdSe QDs, QD-linker-ZrO<sub>2</sub> dispersions, and QD-linker-TiO<sub>2</sub> dispersions with ABA (a, b) and MBA (c, d) as linkers. Solvents were 5:3:2 THF/DMSO/ETOH (a, b) and 1:1 toluene/EtOH (c, d).

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Sample	Emission wavelength $(\lambda_{em})$ (nm)	$A_1$ (norm.)	$\tau_l$ (ns)	$A_2$ (norm.)	$ au_2$ (ns)	$A_3$ (norm.)	$ au_3$ (ns)
CdSe QDs	500 (BE)	$0.16\pm0.01$	25.5±2.6	0.29±0.01	4.3±0.5	0.55±0.01	$0.72 \pm 0.08$
alone <sup>a</sup>	672 (S)	0.21±0.02	42.0±1.5	$0.26\pm0.02$	3.9±0.2	0.54±0.03	$0.28\pm0.04$
QD-ABA-	500 (BE)	0.15±0.01	29.7±1.1	0.33±0.01	4.3±0.1	$0.52 \pm 0.02$	0.75±0.03
$ZrO_2^{a}$	672 (S)	0.23±0.01	42.6±1.2	0.24±0.02	3.8±0.2	0.53±0.03	0.34±0.04
QD-ABA-	500 (BE)	0.08±0.02	16.8±2.7	0.25±0.01	3.7±0.7	$0.67 \pm 0.01$	0.65±0.14
$\operatorname{TiO}_2 a$	672 (S)	0.12±0.01	22.4±0.9	0.28±0.02	2.5±0.2	0.60±0.03	0.24±0.03
CdSe QDs	500 (BE)	0.17±0.02	29.0±3.9	0.28±0.02	4.2±0.7	$0.55 \pm 0.00$	0.59±0.11
alone <sup>b</sup>	672 (S)	0.20±0.02	41.0±0.7	0.26±0.01	3.5±0.1	0.54±0.03	0.32±0.07
QD-MBA-	500 (BE)	0.10±0.02	22.7±2.6	0.39±0.01	4.1±0.3	$0.50\pm0.02$	$0.84\pm0.02$
$\operatorname{ZrO}_2{}^b$	672 (S)	0.22±0.01	34.2±0.3	0.28±0.01	3.5±0.1	$0.50\pm0.01$	$0.36 \pm 0.02$
QD-MBA-	500 (BE)	0.23±0.02	6.4±0.8	0.77±0.02	$0.92\pm0.09$	_	_
TiO <sub>2</sub> <sup>b</sup>	672 (S)	$0.04\pm0.02$	15.6±0.8	$0.12 \pm 0.05$	2.1±0.1	$0.84 \pm 0.07$	0.11±0.03

**Table S3.** Values of  $A_i$  and  $\tau_i$  from fits to representative emission decay traces within the bandedge (BE) and surface (S) emission bands for dispersions containing CdSe QDs.

<sup>*a*</sup> Solvent was 5:3:2 THF/DMSO/ETOH by volume; <sup>*b*</sup> solvent was 1:1 toluene/ETOH by volume.

#### References

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