glass slide ε is typically 15%, but increases to 20 - 23% in the flat films and is between 39 – 42% in the wrinkled films, a factor of about 2.5 more than on glass. A consequence of this higher energy transfer efficiency is shown in Fig. 5(a) (inset). As the QD PL moves to longer wavelengths, the spectral overlap between the emission and absorption bands decreases. By comparing the normalized absorption and emission spectra, we calculate that for the wrinkled film the overlap is almost 30% less than in the case of the glass substrate.

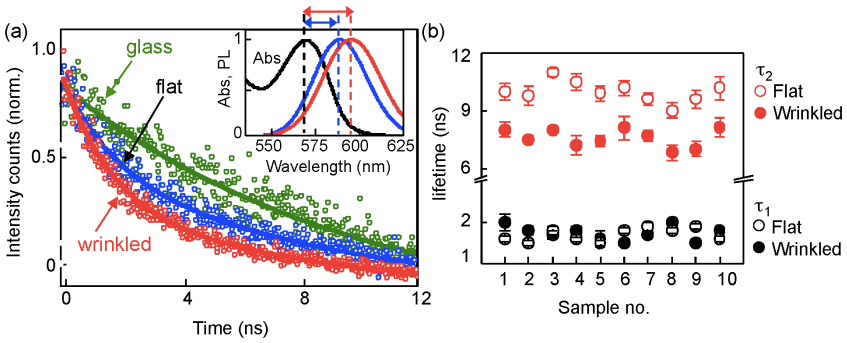

Fig. 5. (a) Time-resolved PL comparing the QD recombination on glass, flat metal and wrinkled metal surfaces. Lines are exponential fits. (inset) Normalized PL spectra of QDs deposited on glass (blue) and wrinkled (red) surfaces alongside the QD absorption (black) curve. The dashed lines indicate the spectral positions of the peaks, and the double headed arrows show the effective Stoke's shifts for QDs on glass (blue) and wrinkled metal (red) surfaces. (b) The short (τ_1) and long (τ_2) QD recombination times for ten different flat (open circles) and wrinkled (filled circles) samples.

4. Conclusions

The spectral red-shift that results as a consequence of intra-ensemble FRET, in turn decreasing the overlap between emission and absorption bands, reducing the occurrence of 'self-absorption'. Self-absorption is a phenomenon where a QD sample re-absorbs its emitted photons and is a critical limiting factor in QD-based luminescent energy harvesting devices [19,20]. The plasmon-mediated effects observed here include a 30% reduction of spectral overlap between absorption and emission bands of the QD spectra, accompanied by three-fold higher emission intensities, both highly desirable properties for application in photovoltaic devices, which will lower self-absorption and increase device efficiency. More importantly, our use of easily fabricated, inexpensive and eminently scalable nano-wrinkled metal films as the plasmonic substrates makes our findings particularly attractive.

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