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Supporting online information for "Suppression of Blinking and Enhanced Exciton Emission from Individual Carbon Nanotubes"

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Dependence of on/off ratio on binning time. We recorded TCPC traces at 1 ms resolution and from this data we obtained count values for larger bin sizes using a summation program created with Matlab. To show how the size of binning time effects the value of the on/off ratio, we plot in Fig. 1 the occurrence of an intensity value within 1, 3, 5, and 10 ms time bins for an entire TCPC trace for samples with (a) and without (b) PMMA. The results show that binning size has a minor influence on the extracted on/off ratio, with on/off values ranging from 107 to 92 for the PMMA sample, and values ranging from 0.07 to 0.04 for the non-PMMA sample.

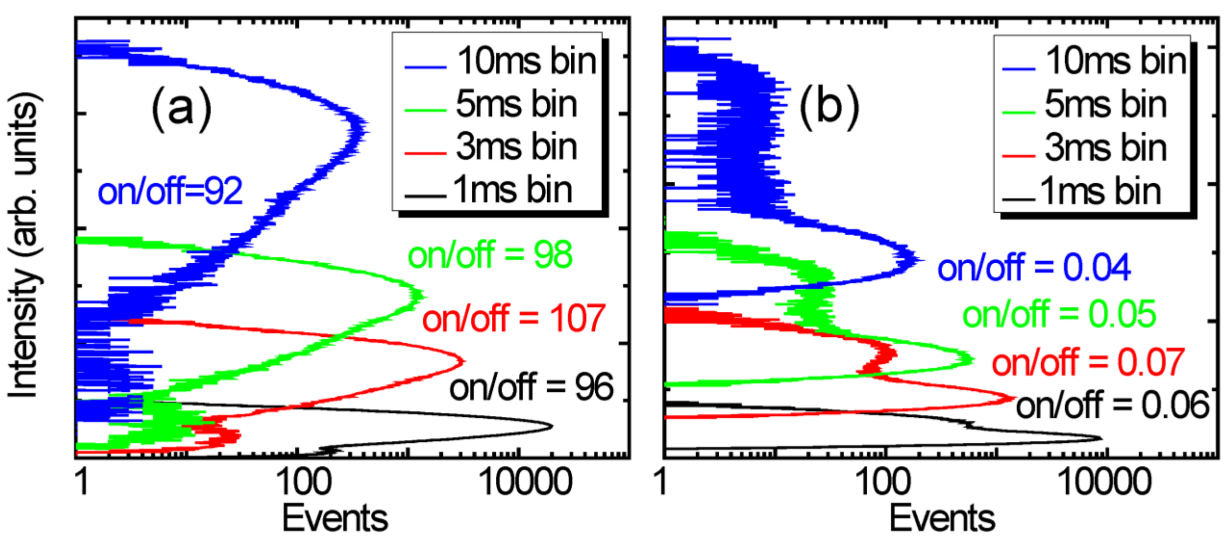

Figure 1. (a,b) Plots of occurrence of a count value within 1,3,5, and 10 ms time bins for an entire TCPC trace with (a) and without (b) PMMA. Data are recorded at 7 K.

Influence of excitation power and capping material on blinking behavior. Plots of occurrence of a count value within 1 ms time bins of an entire TCPC trace were analyzed for samples without PMMA. To show how excitation power affects the type of distribution in the blinking data, we plot occurrence in Fig. 2 for 4 different samples showing tri-modal distributions at either low (a) or high (c) excitation power, as well as bimodal distributions at low (b) or high (d) excitation power. The results show that the type of distribution (bimodal or tri-modal) is not influenced by the laser excitation power, and instead depends on the specific SWCNT chosen, *i.e.* the local dielectric environment of each sample.

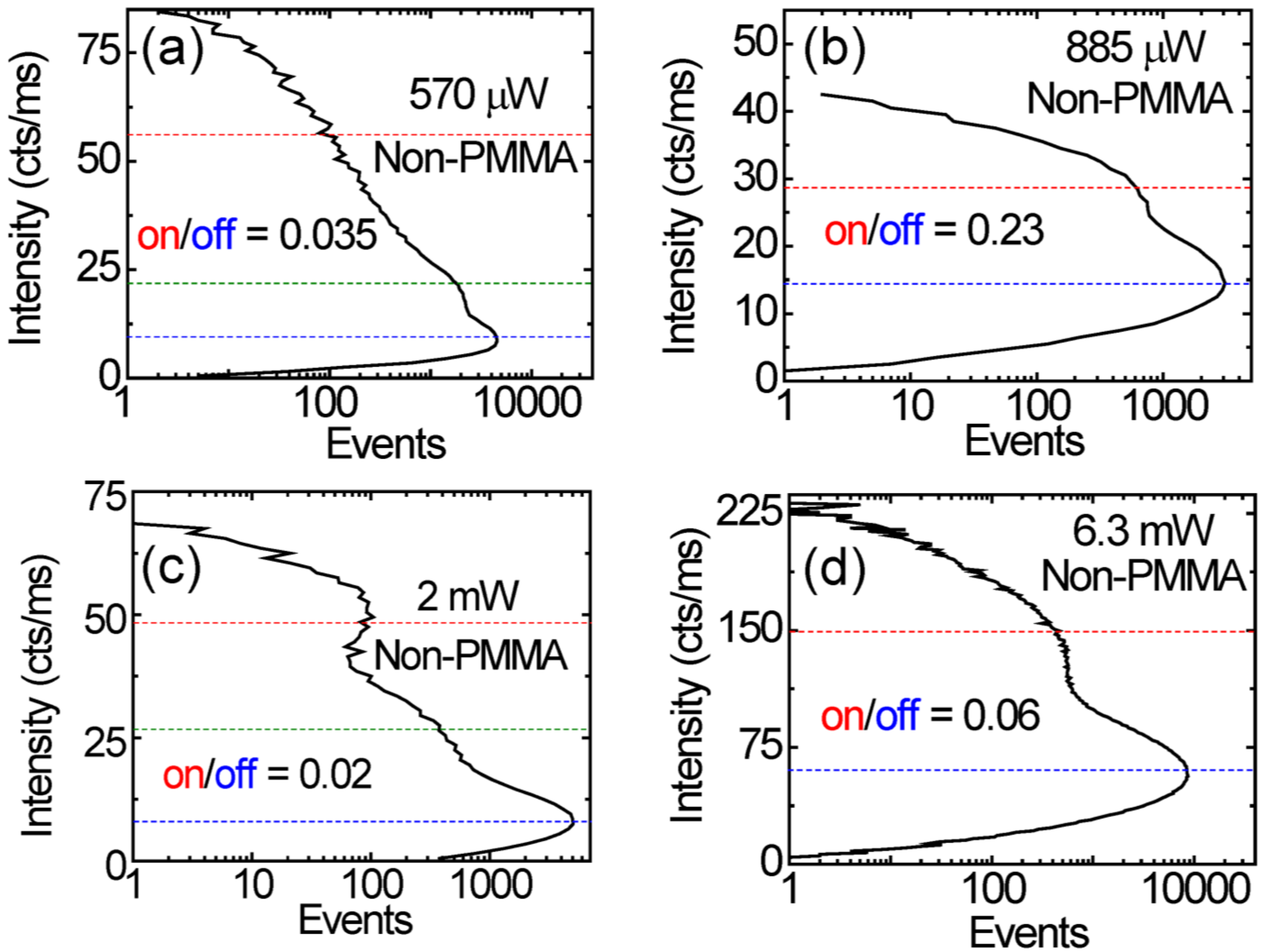

Figure 2. (a,b,c,d) Plots of occurrence of a count value within 1 ms time bins for an entire TCPC trace of 4 different samples without PMMA, showing either tri-modal (a,c) or bimodal (b,d) distributions at various excitation powers. Data are recorded at 7 K.

To show how the type of capping material affects the sample behavior, we compare occurrence plots in Fig. 3 for non-coated, PMMA coated, and PVA coated samples. The PVA sample shows similar behavior as the PMMA sample, with a broad on state and higher count rates than the non-coated sample. However, PVA shows slightly lower count rates than PMMA, and has no visible off state. If we assume the off state has a similar intensity level as the PMMA sample (blue dotted line), then the PVA coated sample has an on/off ratio of 10. Figure 4 shows that spectral diffusion is strongly suppressed, similar to the behavior of PMMA capped samples. These data indicate that the achieved suppression of blinking and enhanced light emission does not depend on the specific chemistry of the chosen polymer.

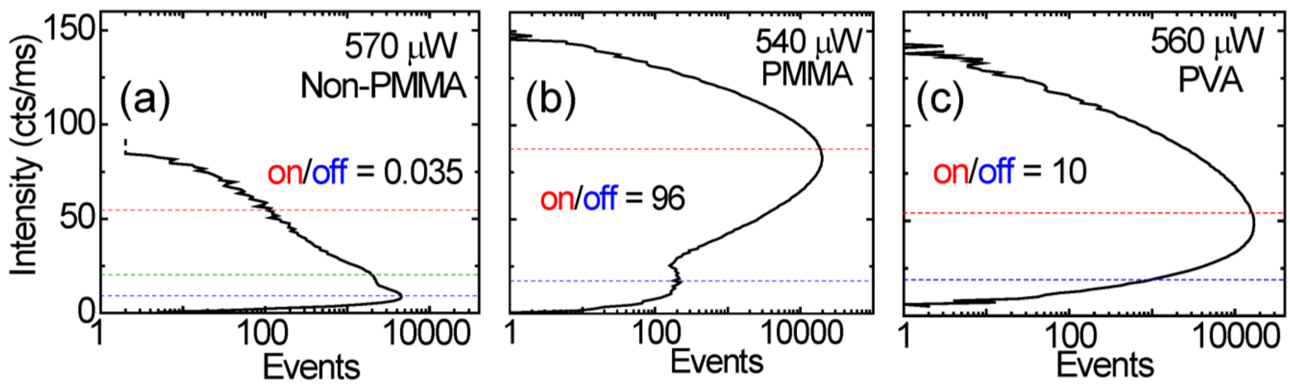

Figure 3. (a,b,c) Plots of occurrence of a count value within 1 ms time bins for an entire TCPC trace of 3 different samples either non-coated (a), PMMA (b), or PVA (c). Data are recorded at 7 K.

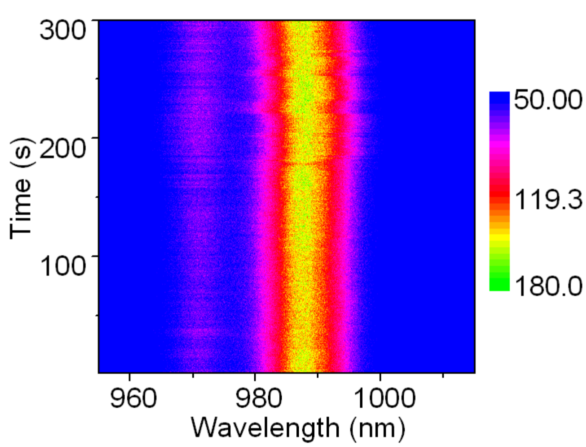

Figure 4. Spectral trajectory of the PL emission shown for SWCNTs capped with PVA and subjected to the same baking procedure. Data are recorded at 7K.

On-time power laws showing no truncation. TCPC traces were analyzed by plotting the on-time probability distribution $P(t_{on})$ in Fig. 5 for 5 samples with (a) and 5 without (b) PMMA. In contrast to most studies on quantum dots, the $P(t_{on})$ dependence for PMMA and non-PMMA devices shows no truncation and follows the simple power law $P(t_{on}) = At_{on}^{-m}$ where A is a constant and m is the on-time slope. For each result we show a solid line fit to the data with the slope labeled at the top of the plot.

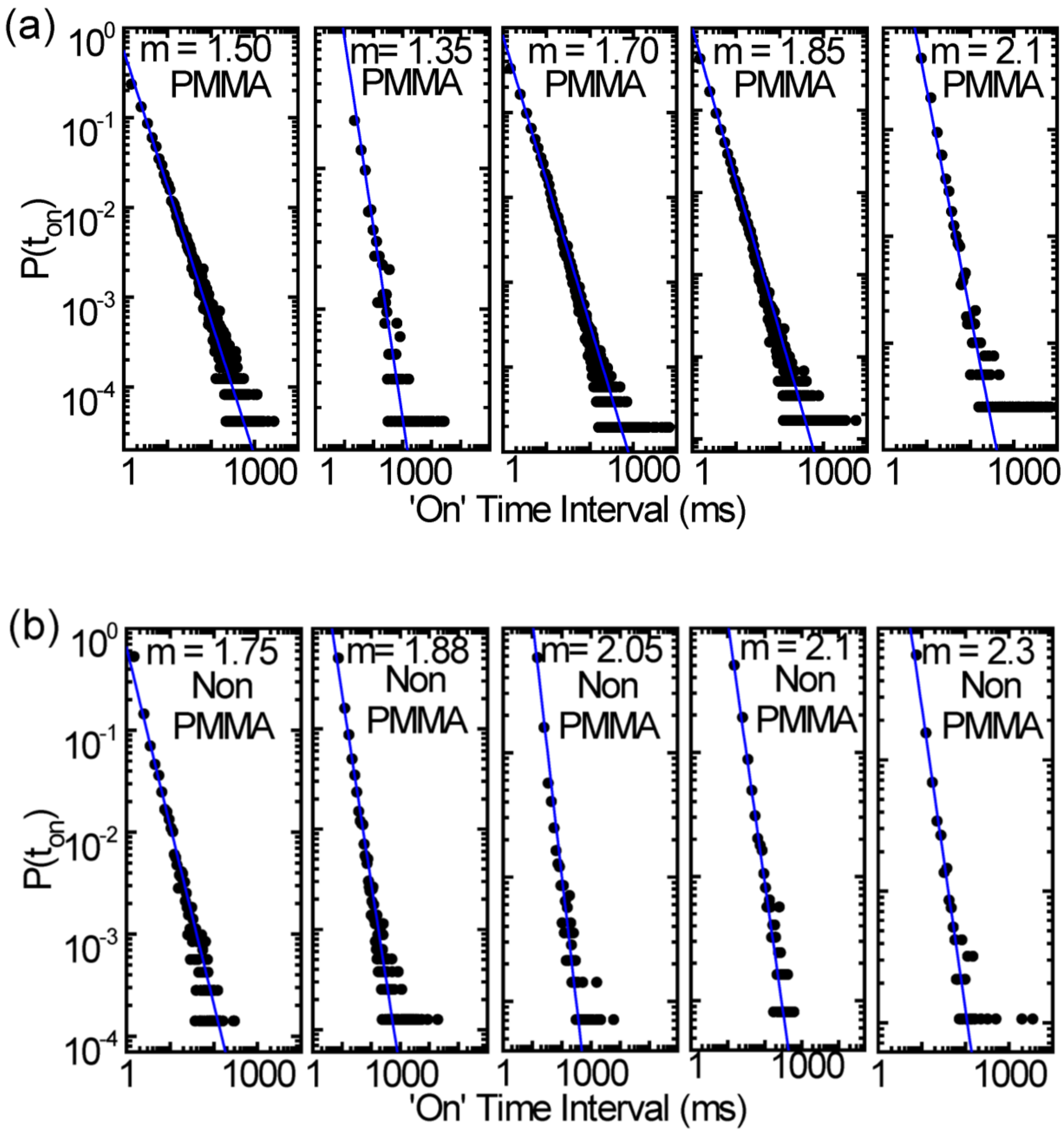

Figure 5. (a,b) Plots of on-time blinking statistics for samples with (a) and without (b) PMMA. The solid lines are fits to a power law with labels for the on-state slope m. Data are recorded at 7 K.

Influence of number of events, threshold, and binning time on extracted slopes from the power laws. A dependence of on-time power law slope on the number of blinking events was analyzed in Fig. 6 for PMMA (dots) and non-PMMA (squares) samples. The slope values for both sample type fall within the range 1.5 to 1.88 when the number of blinking events is greater than 5000. This is within the range $1.5 \leq m \leq 2$ (vertical dashed lines) expected for a Cole-Davidson dielectric medium. Note that the on-state sample size is about an order of magnitude lower for the non-PMMA samples as compared to the PMMA samples, although it was recorded for the same total time of 30 min, which is caused by the fact that the quantum emitter resides mostly in the off-state, creating less frequent on-state events. When the number of blinking events was low (100-5000) the values for m scatter in a larger range between 1.35 and 2.3. One can see the effect of threshold level (T) and binning time (B) by taking 2 PMMA and 2 non-PMMA samples with greater than 5000 events and adjusting T or B in such a way as to reduce the event number below 5000. This causes the slope values for each sample to drift to a larger range between 1.15 and 2.5 indicated by the triangles. Hence, realistic slope values can only be found with T and B that result in more than 5000 blinking events. For samples with slopes satisfying this condition, no clear trend is found between PMMA and non-PMMA, indicating that the on-time slope is not very sensitive to the dielectric environment.

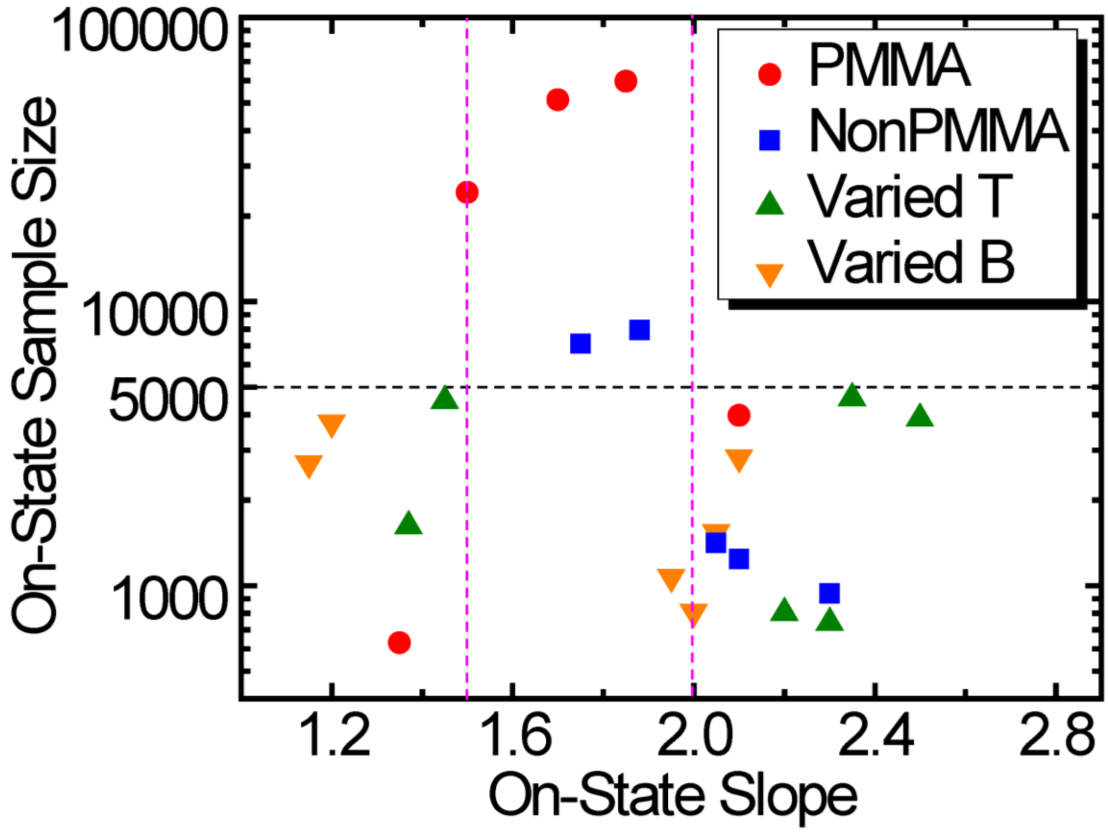

Figure 6. Statistical plot of the dependence of the number of blinking events on the on-time power law slope for samples with (dots) and without (squares) PMMA. Triangles represent slopes found by adjusting the threshold level (T) or binning size (B) for 2 PMMA and 2 non-PMMA samples with more than 5000 events. All data recorded at 7 K.

Numerical simulation of the expected on/off ratio in the power law model. To compare theory with experiment, we calculate the expected on/off ratio using the power law slopes *m* and *n*, as well as the number of on and off blinking events *j* and *k*, from data corresponding to each sample. For long measurement time intervals, and assuming our sampling rate of 1 ms is fast enough, we let on/off = $\sum_i^j t_{on,i} \Big/ \sum_i^k t_{off,i}$ where $t_{on(off),i}$ is the ith time interval of the on (off) state. By setting each simple power law distribution equal to randomly generated blinking time variables $u_i = P(t_{on}), v_i = P(t_{off})$, and taking the inverse in terms of $t_{on(off)}$, we have: on/off = $\sum_i^j (1/u_i)^{1/m} \Big/ \sum_i^k (1/v_i)^{1/n}$. Hence, we show in Table 1 the mean on/off ratio +/- the standard deviation resulting from 100,000 simulated experiments for each sample. In all cases, the theory data follow the trend that on/off ratios in non-PMMA samples are below one and in PMMA coated samples are above one, however, the magnitude is much smaller as compared to the experimental data. This deviation and the observed rather broad on-state distribution indicates that SWCNTs with their inherent one-dimensional density of states do not obey a simple blinking model, in contrast to zero-dimensional quantum dot structures which are well explained by this blinking model.

Table 1. On/off Ratios Found by Measurements or by Theory Using on/off Power Law Slopes, Number of Blinking Events, and Randomly Generated on/off Blinking Times

Sample Type	on-slope (m)	off-slope (n)	# on events (j)	# off events (k)	Measured on/off	Theory on/off
Non PMMA	2.05	1.8	1410	1431	0.23	0.87 +/- 0.07
Non PMMA	2.1	1.45	1238	1235	0.1	0.61 +/- 0.08
Non PMMA	1.75	1.7	7110	7265	0.06	0.94 +/- 0.06
Non PMMA	1.88	1.825	7935	8023	0.035	0.96 +/- 0.05
Non PMMA	2.3	1.325	937	951	0.02	0.47 +/- 0.08
PMMA	1.5	2.8	24248	21742	96	2.15 +/- 0.44
PMMA	2.1	2.4	3976	3969	7.0	1.12 +/- 0.03
PMMA	1.35	2.5	630	612	6.74	2.34 +/- 1.45
PMMA	1.7	2.25	51356	48919	3.40	1.42 +/- 0.04
PMMA	1.85	1.95	59560	58976	1.41	1.07 +/- 0.02