Kinetic Requirements for Spatiotemporal Chemical Imaging with Nanosensors

Daniel Meyer[1,2], Annika Hagemann[1,2], Sebastian Kruss[1,2]*

[1]Institute of Physical Chemistry, Göttingen University, Germany
[2]Center for Nanoscale Microscopy and Molecular Physiology of the Brain (CNMPB), Göttingen, Germany

* Corresponding author: Sebastian Kruss, email: skruss@uni-goettingen.de

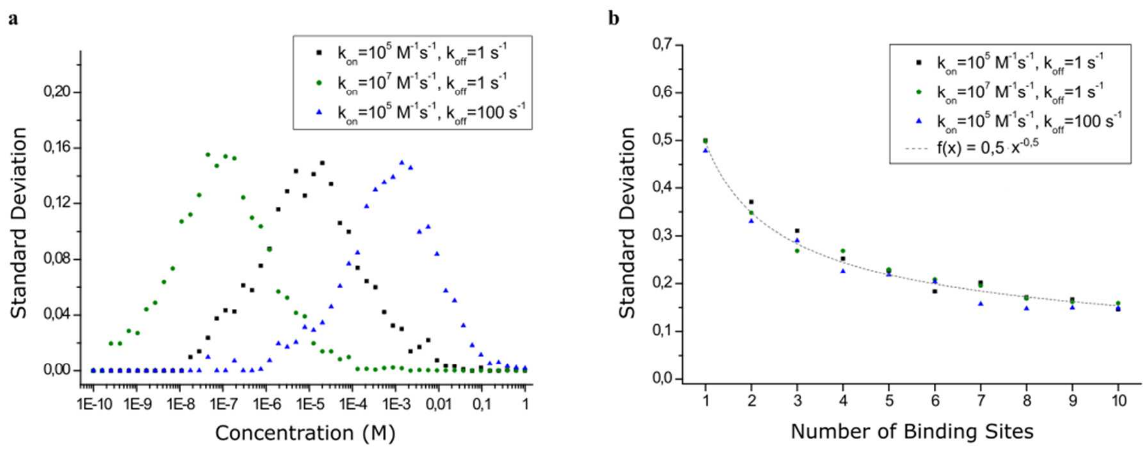

***Figure S1: Stochastic fluctuations in fluorescence response**. **a,** Relative intensity fluctuations (defined as standard deviation for n = 100 simulation runs) as a function of the analyte concentration and the rate constants k_{on} and k_{off}. **b,** Relative fluctuations for different numbers of total binding sites. As the intensity of the sensor is defined by the average number of bound binding sites, the intensity fluctuation decrease by increasing the number of binding sites.*

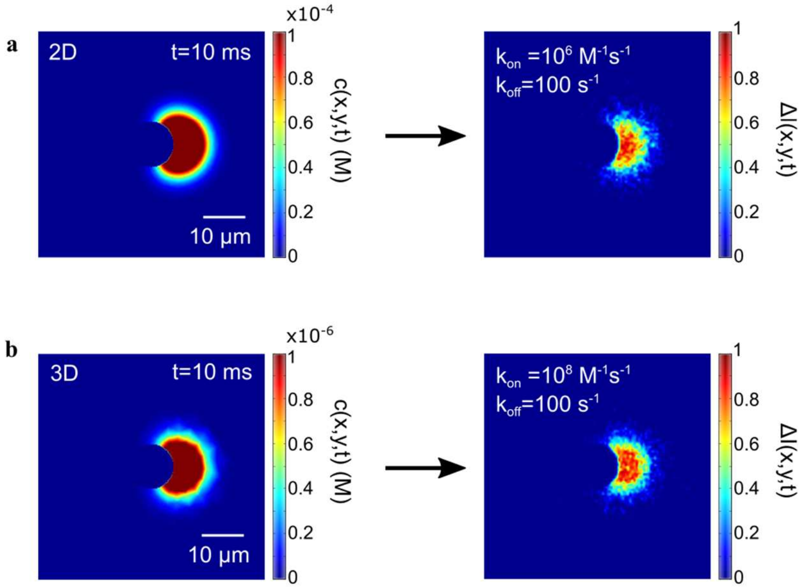

Figure S2: Comparison of 2D versus 3D simulation. a, *Concentration profile of a 2D diffusion simulation and the corresponding intensity profile for given values of* k_{on} *and* k_{off}. ***b****, The concentration profiles in 3D are qualitatively similar although the absolute concentrations are different. The response images are similar if the rate constants are changed accordingly.*

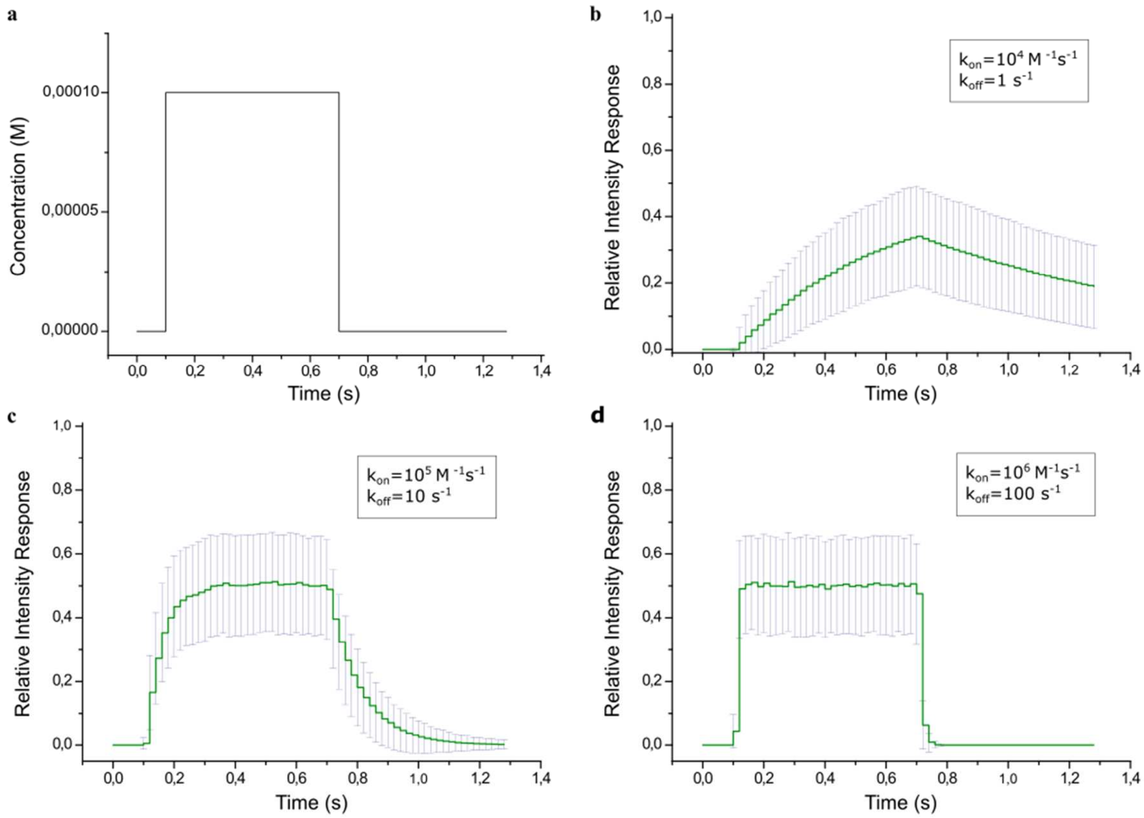

Figure S3: Mean single sensor response to a rectangular concentration profile*. *a, *Concentration profile.* ***b-d,*** *Average response of a single binding site for different values of k_{on} and k_{off} but equivalent $K_D = 10^{-4}$ M. For bigger values of k_{on} and k_{off}, the response time of the sensor becomes smaller. Bigger values of k_{on} lead to a faster binding of an analyte until a maximum probability $p_{on} \approx 1$ is reached. If also k_{off} reaches a significant level the disassociation probability becomes high ($p_{off} \approx 1$) leading to an average intensity response of 0.5 (τ_{on} and τ_{off} have equivalent lengths). Bigger k_{off} values, however, also lead to fast unbinding events. Error bars are standard deviations for n = 100 simulation runs.*

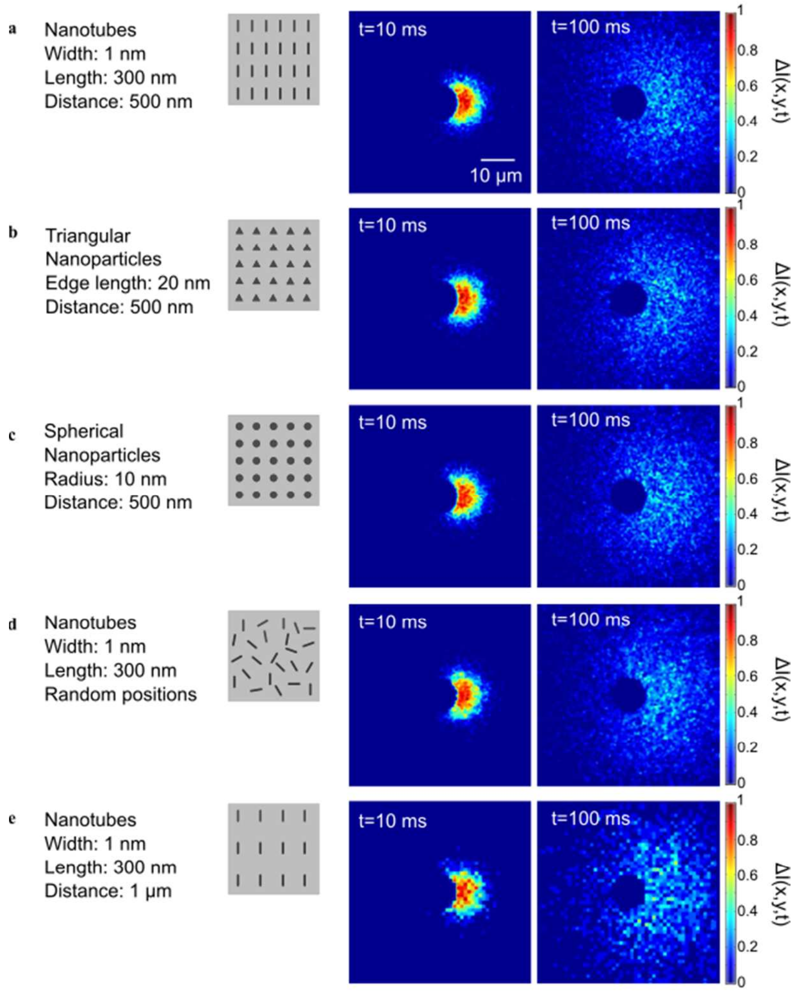

Figure S4: Impact of shape and array geometry on response images. *Different nanoparticle shapes and distances between the nanosensors were used. However, no or only subtle differences could be found in the resulting intensity profiles* $\boldsymbol{\Delta I}(x,y,t)$ *(*$t_{int} = 10$ *ms).* ***a-c,*** *Impact of sensor shape. Due to the resolution limit (airy disk) rod like, triangular and spherical nanoparticles show the same response.* ***d****, The order of the sensors does not have an impact if the density of sensor is high (here n = 9801).* ***e,*** *If distances between sensors get larger the response image becomes more stochastic* ($k_{on} = 10^6\, M^{-1} s^{-1}$, $k_{off} = 10^2 s^{-1}$).

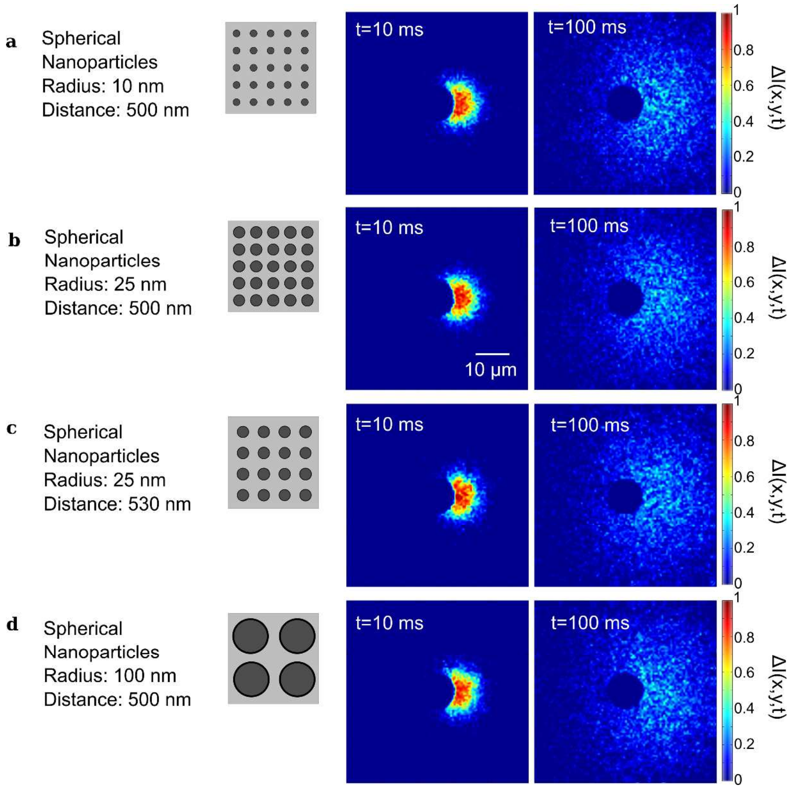

Figure S5: Impact of sensor size on response images. *The size of spherical nanosensors was changed to assess its impact on fluorescence response images at different time points (t = 10 ms, t = 100 ms). Similar to figure S4 no relevant differences were found.* ***a,*** *Radius r = 10 nm and distance d = 500 nm to its next neighbor.* ***b****, r = 25 nm and d = 500 nm* ***c****, r = 25 nm and d = 530 nm to have the same distance between the edge of two sensors.* ***d****, r = 100 nm, d = 500 nm.*

Supplementary movies

Movie M1: *Time-lapse movie of the corresponding concentration profile used in figures 3-6. As described in the materials & methods part, a COMSOL simulation software was used to simulate diffusion. A* $r = 5$ *µm circle was put into the center of a* 50×50 *µm*^{2} *sensor area to mimic a cell body. Analytes (typically* $N = 1.85 \times 10^6$*) were then released from a hypothetical vesicle.*

Movie M2: *Time-lapse movie of the response image of the sensor array (*$k_{on} = 10^3\ M^{-1}s^{-1}$*,* $k_{off} = 1\ s^{-1}$*).*

Movie M3: *Time-lapse movie of the response image of the sensor array (*$k_{on} = 10^5 M^{-1}s^{-1}$*,* $k_{off} = 1\ s^{-1}$*).*

Movie M4: *Time-lapse movie of the response image of the sensor array (*$k_{on} = 10^6\ M^{-1}s^{-1}$ *and* $k_{off} = 10^2\ s^{-1}$*).*

Movie M5: *Time-lapse movie of the response image of the sensor array (*$k_{on} = 10^7\ M^{-1}s^{-1}$*,* $k_{off} = 1\ s^{-1}$*).*