# Resistive Switching of sub-10 nm $TiO_2$ Nanoparticle Self-Assembled Monolayers

**Dirk Oliver Schmidt [1,2], Nicolas Raab [3,4], Michael Noyong [1,2], Venugopal Santhanam [5], Regina Dittmann [3,4] and Ulrich Simon [1,2,*]**

## Supporting Information

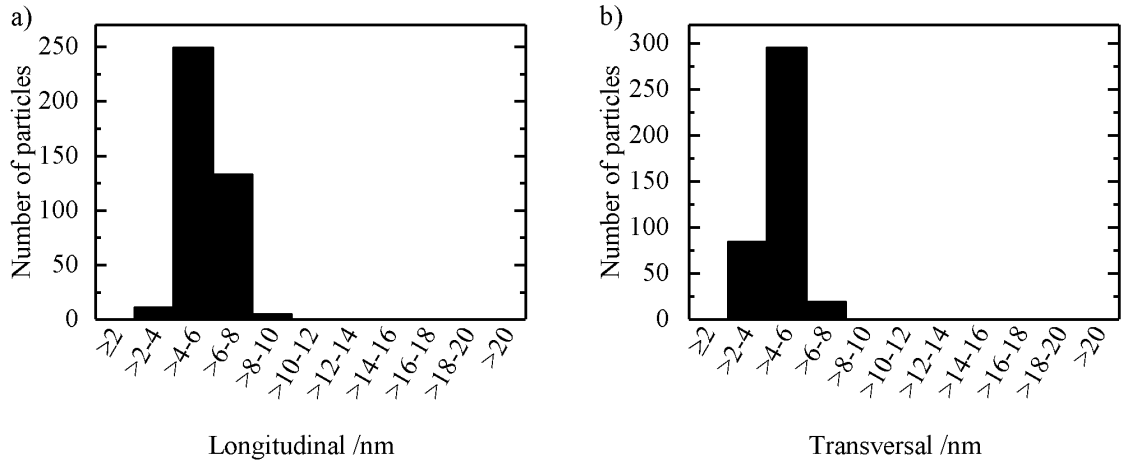
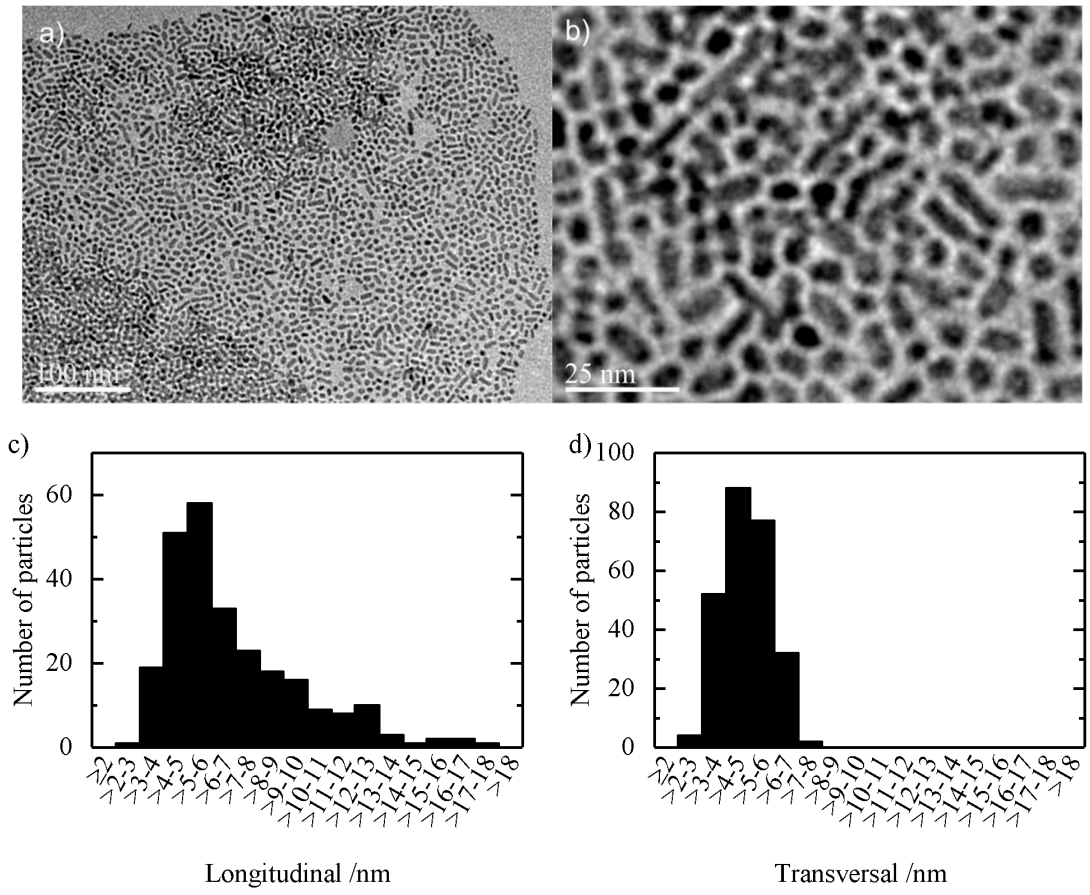



**Figure S1.** Histograms of the synthesized $TiO_2$ NPs' longitudinal and transversal (a, b).



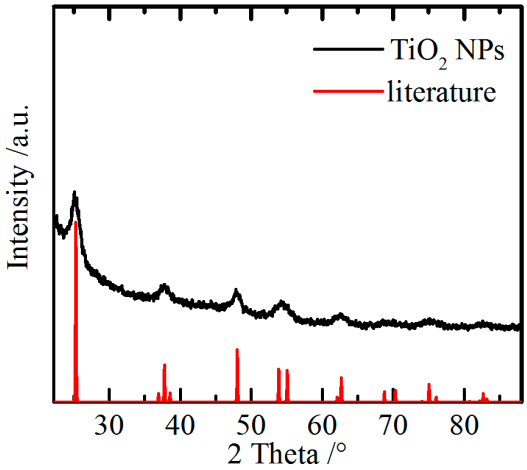
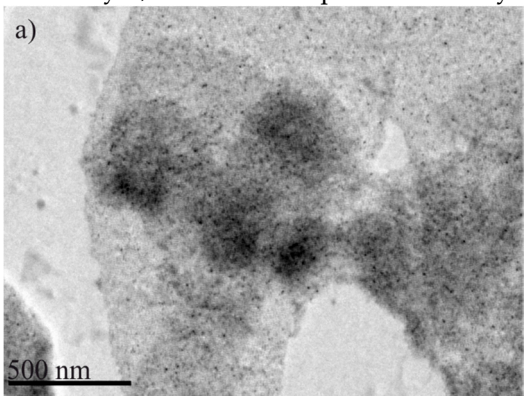
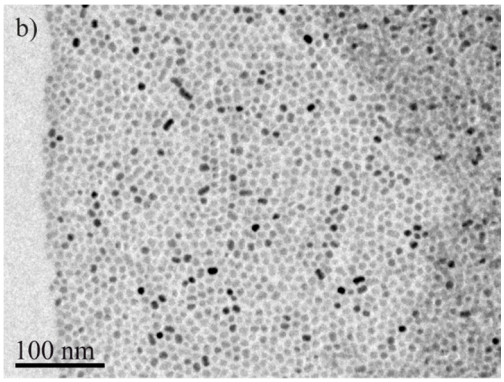



**Figure S2.** Exemplary TEM images of the synthesized $TiO_2$ NPs (a, b) and corresponding histograms of NPs' longitudinal (7.9 ± 2.2) nm and transversal (4.8 ± 0.8) nm (c, d), resulting in a mean particle diameter of (6.3 ± 1.9) nm. Powder XRD patterns of the NPs (black) and literature anatase data (red) (e) [38].

A self-assembled $TiO_2$ NP film was formed consisting of particles with a mean longitudinal of (9.5 ± 1.1) nm and mean transversal of (7.5 ± 0.9) nm and a spherical NP to non-spherical shaped NP ratio of 13:1. For TEM investigations, a small part of the self-assembled NP film was transferred onto a carbon coated TEM grid. The images revealed that mono-, bi- and multilayers were present as well as voids without any NPs (Figure S 3). For the one-step transfer method, the Pt/Ir substrate was gently brought into contact with the self-assembled film floating on the water surface (see Figure 2 d I and II in the main text) as compared the carbon grid. After evaporation of water residues, the $TiO_2$ NP film on the Pt/Ir surface was analyzed *via* AFM. As in the TEM images void spaces without any NP films were discernible in AFM images and multiple layers with various height differences were visible on the Pt/Ir surface (Figure S 4 c, d). A height profile was recorded along the white line in Figure S 4 d revealing a stepwise variation in height of approximately 8 nm. This height difference corresponds to the mean dimensions of the $TiO_2$ NPs of the mean longitudinal (9.5 ± 1.1) nm and mean transversal (7.5 ± 0.9) nm. Therefore, we assume that the first height step corresponds to a $TiO_2$ NP monolayer, the second step to a $TiO_2$ bilayer and so on.



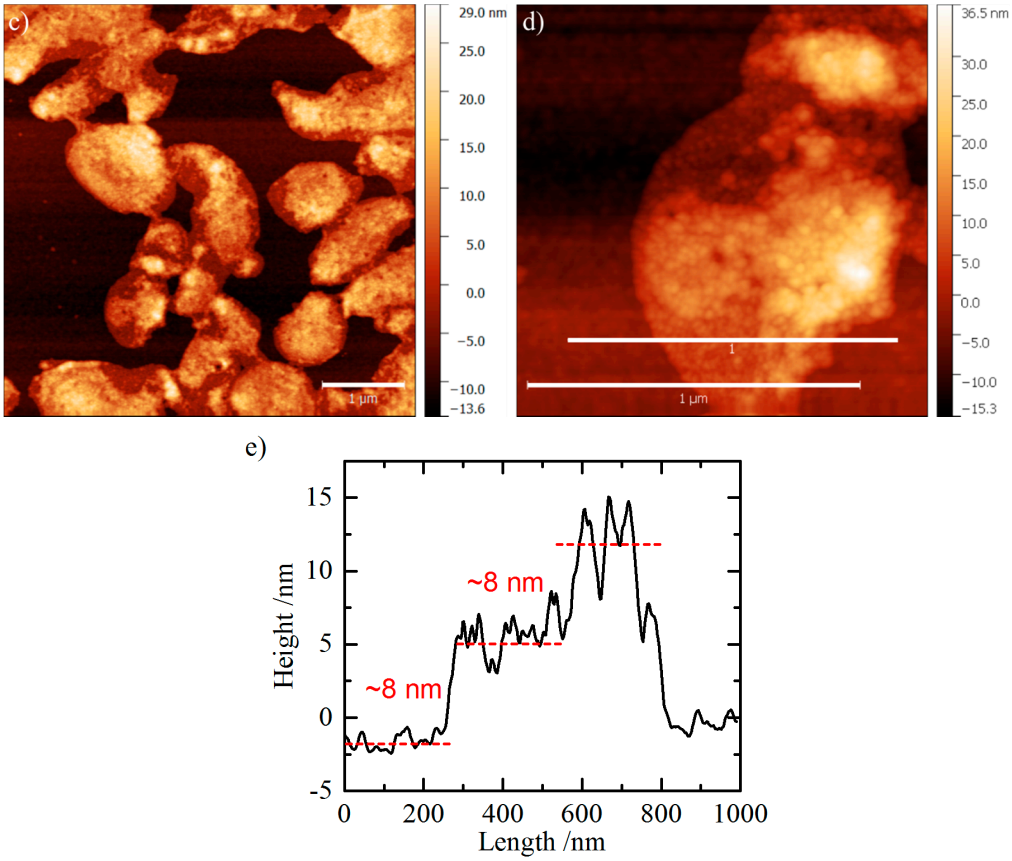



**Figure S3.** Exemplary TEM images of the self-assembled $TiO_2$ NP film (a, b). Tapping mode AFM images of the $TiO_2$ NP film transferred to a Pt/Ir surface by the one-step method. (c, d). Corresponding height profile (e) taken along the white line in (d) showing height differences of approximately 8 nm.

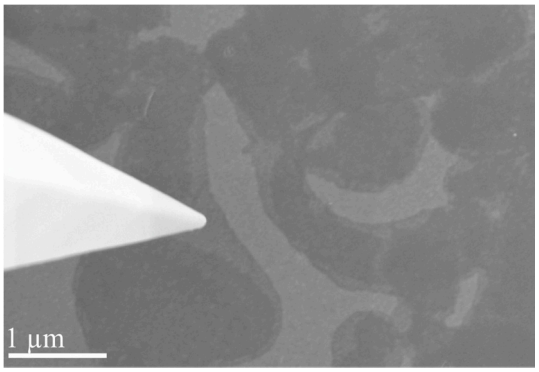



**Figure S4.** SEM image without enhanced contrast of a $TiO_2$ NP film on the Pt/Ir surface and on the left-hand side the Pt/Ir coated tip electrode is visible.

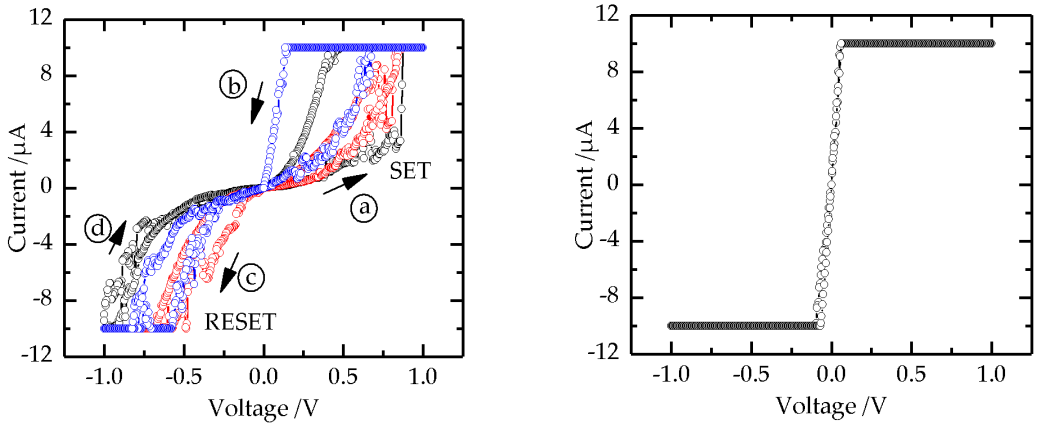



**Figure S5.** Three consecutive switching cycles recorded on a $TiO_2$ NP monolayer (a) and subsequent permanent LRS (b).

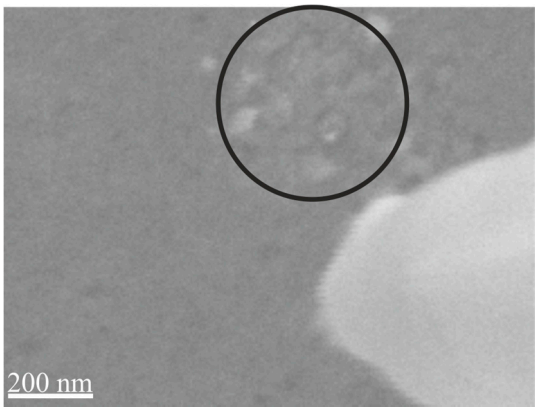



**Figure S6.** SEM image of a $TiO_2$ NP layer after a SET process. The tip was lifted off the $TiO_2$ NP layer, revealing a morphology change of the layer.