Electronic Supplementary Material (ESI) for Nanoscale.

Supplemental Information

Understanding the conductive channel evolution in Na:WO_{3-x}-based planar devices

Dashan Shang,*[a,b] Peining Li,[a] Tao Wang,[a] Egidio Carria,[a] Jirong Sun,[b] Baogen Shen,[b] Thomas Taubner,*[a] Ilia Valov,[c] Rainer Waser,[c,d] and Matthias Wuttig*[a,d]

[a] *I. Physikalisches Institut (IA), RWTH Aachen University, 52074 Aachen, Germany. E-mail: taubner@physik.rwth-aachen.de and wuttig@physik.rwth-aachen.de*

[b] *Beijing National Laboratory for Condensed Matter Physics and Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China. E-mail: shangdashan@iphy.ac.cn*

[c] *Institute für Werkstoffe der Elektrotechnik II, RWTH Aachen University, 52074 Aachen, Germany & Peter Grünberg Institute (PGI-7), Forschungszentrum Juelich, Juelich, Germany.*

[d] *JARA-FIT, Fundamentals of Future Information Technology, RWTH Aachen University, 52074 Aachen Germany.*

Tab. S1 Optimal fitting parameters for the FTIR spectroscopies.

ω_{TO} (cm^{-1})	Ω_p (cm^{-1})	Γ (cm^{-1})	ω_p (cm^{-1})	γ (cm^{-1})	ε_∞
1563	830	898	2524	110	6.2
1544	860	923	2505	110	6.2
1539	807	907	2438	110	6.2
1540	755	876	2395	110	6.2
1540	751	883	2378	110	6.2
1536	767	898	2385	110	6.2

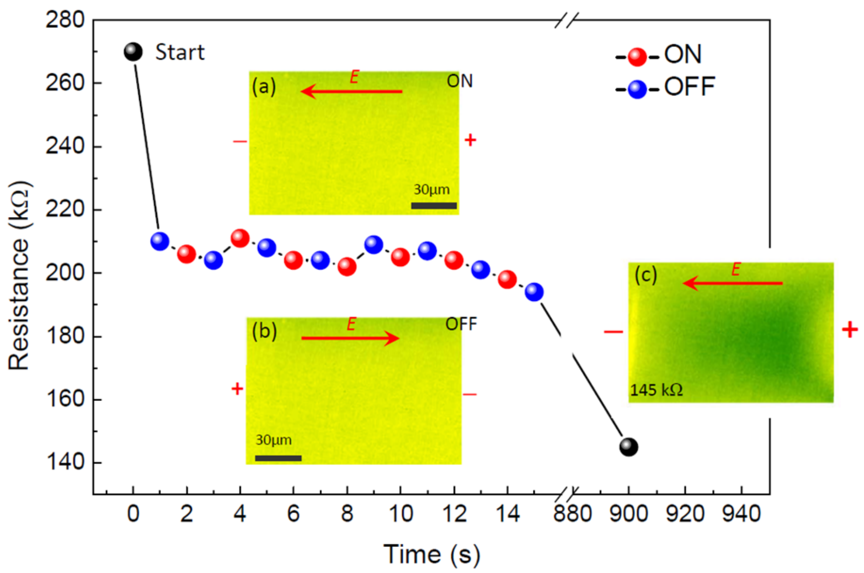

Fig. S1 Resistance change of the WO_{3-x} film deposited on quartz glass substrate. Inset (a) and (b) show the photo images taken after applying current pulse (+/-3 mA for 1 s). The device resistance almost changed little. No detectable color change can be distingushed between the ON and OFF states. Inset (c) shows the photo image after continuously applying +3 mA current for 900 seconds. The device resistance decreased to 145 kΩ and the film color became darker than before. However, this color change is irreversible when reversing the polarity of the electric field. The color change might be caused by the thermal annealling effect of the film. The arrows indicat the polarity of the applied electric field. The resistance is measured at 0.1 V after switching of the constant current. The device size is 100×150 μm^2.

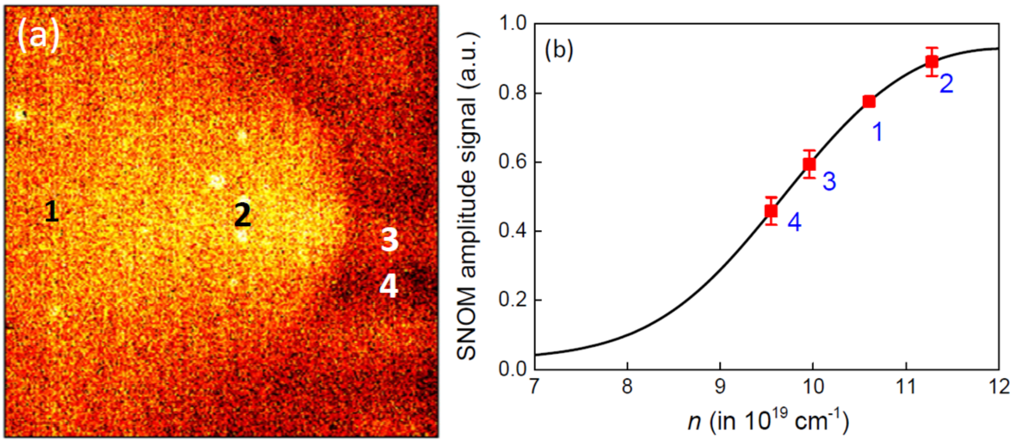

Fig. S2 (a) The s-SNOM image. (b) The calculated s-SNOM signal as a function of free-carrier concentration. The carrier densities of four typical positions marked in (c) are depicted. We calculate the s-SNOM signal as a function of free-carrier concentration by using a layered s-SNOM model,[1] and dielectric parameters obtained from the FTIR spectra. The calculated signal shows a monotonous dependence (solid line in the figure) on the free-carrier concentration.This relation links the recorded s-SNOM contrast and the local free-carrier concentration in the conductive channels.

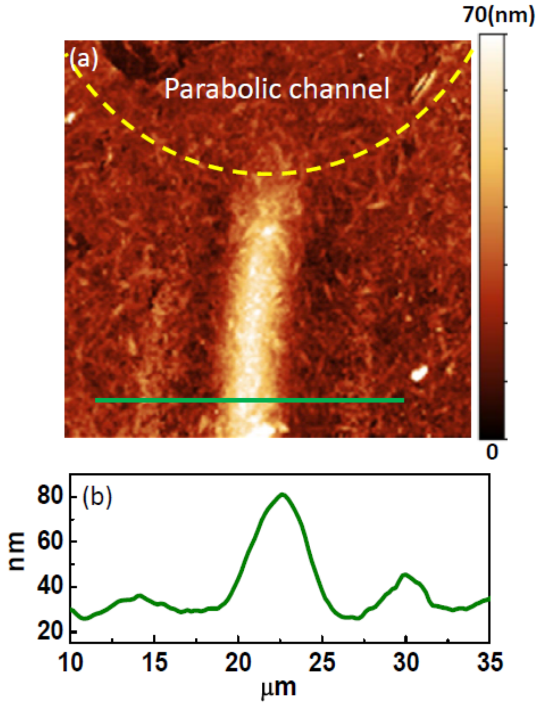

Fig. S3 (a) Topography of the film after keeping applying a constant current of 2 mA for 20 seconds. (b) Line-scan of the topography at the position in (a) (green line). A considerable bulge (~50 nm height) between the parabolic channel and the anode is observed. It should be noted that the bulged region always stopped at the top edge of the parabolic channel, further indicating that the bulge corresponds to the pre-formed channel. Moreover, two small convex regions on both sides of the bulge region can also be seen, which correspond to the other pre-formed channels observed in Fig. 6c. The device size is 100×150 μm^2.

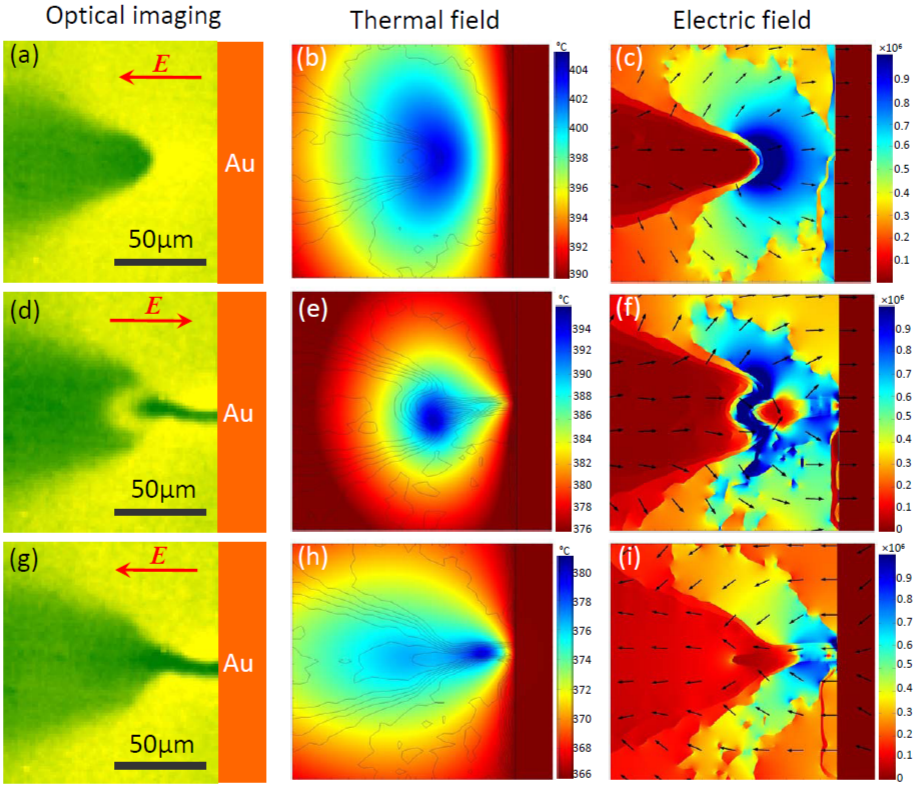

Fig. S4 Electric and thermal simulation using COMOSOL MULTIPHYSICS software. The AC/DC module has been used to reproduce the electric field and the electric potential distribution whereas the Electromagnetic Heat Modules has been coupled to include the Joule heating effect. The shape of the conductive channel was reproduced. Then, a COMSOL 2D model was used to obtain the simulations. Material properties used in the simulation are shown in Table S2.

Tab. S2 Material properties used in the computer simulation.

Layer	Thermal conductivity ($W \cdot m^{-1} \cdot K^{-1}$)	Heat capacity (10^6 $J \cdot m^{-3} \cdot K^{-1}$)	Density (g/cm^3)	Relative permittivity
WO_{3-x}	1.63[2]	2.28[2]	7.16[3]	6.2
glass	2.46	1.22	2.4	1.7

[1] B. Hauer, A. Engelhardt, T. Taubner, Opt. Express 2012, 20, 13173.
[2] H. Wang, Y. Xu, M. Goto, Y. Tanaka, M. Yamazaki, A. Kasahara, M. Tosa, *Materials Transactions*, **2006**, 47, 1894.
[3] C. G. Granqvist, *Handbook of Inorganic Electrochromic Materials*. Elsevier **2002**.