Supplementary Information

Artificial Nociceptor using an Ag/Ag_2S/Pt Atomic Switch

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Confirmation of gap-type configuration:

Figure S.I. 1a shows the current response for the first bias sweep 0 V→ 0.5V→0 V applied using C-AFM mode to evaluate the filament formation in nano-gap. Up to 200 mV, the response was a non-linear current of low values (nA order) followed by a sharp jump at 200 mV (to the 1 µA compliance). The initial resistance before the current jump, was calculated to be 1MΩ from the I-V spectrum. The z-position of the AFM tip also changed by 120 nm indicating a change in height as depicted in **Figure S.I. 1b**. From this, we understand that the filament has formed on the surface in the gap between tip and sample surface as pictured in Figure S.I. 1b inset. This was further confirmed by obtaining topography images before and after the application of bias. A stable and large precipitation is required to obtain the topography image, due to the high surface roughness and high mobility of Ag on the Ag_2S surface. Thus, five consecutive sweeps of 0 V→ 0.5V→0 V are applied, until the nature of the I-V response becomes linear. Topography images obtained before the application of any bias and after the stable filament formation is shown in **Figure S.I. 1c** and **Figure S.I. 1d**, respectively. In Figure S.I.1c the point of bias application is marked with an orange cross. The height profiles drawn across the point under the test before and after filament formation are compared in **Figure S.I. 1e**, which emphasizes the change in height. To confirm its metallic nature a -50mv to 50mv sweep was applied on the protrusion as shown in **Figure S.I. 1f**. The corresponding resistance was obtained to be 90.8 Ω from the current response that closely matches with metallic conductance property of Ag_2S[1][2]. These measurements ensure the presence of nano-gap between the tip and sample that allows the filament to form out of the surface of Ag_2S[3].

Sample characterization:

Figure S.I. 2a shows the FESEM image of the Ag_2S thin film grown on Ag substrate. The image revealed polycrystalline domains of sub-micron order size. **Figure S.I. 2b** reveals Ag-protrusions grew upon repeated scanning with a 10kV electron beam. The composition of the protrusion was confirmed to be silver from the EDS elemental mapping shown in **Figure S.I. 2c**. In addition, the detailed surface morphology was studied using AFM as shown in **Figure S.I. 2d**. This variation in morphology is expected to show some deviation in the repeated measurements within an acceptable range, which however does not affect the purpose of analogy and conclusions drawn in this work.

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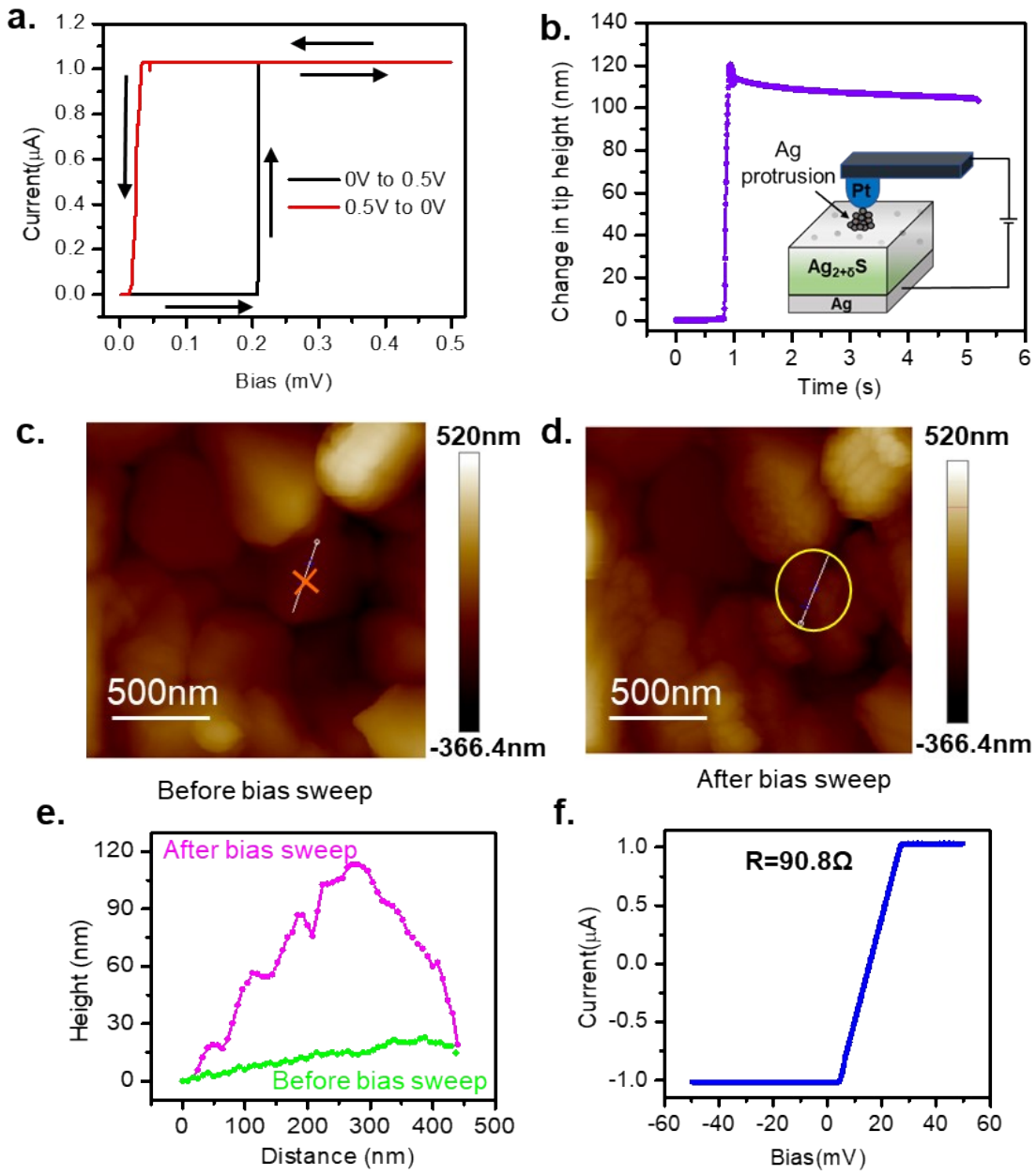

Figure S.I. 1: Filament formation process of the Ag/ Ag_2S /Pt system. (a) The current response to 0 V→0.5V→0 V sweeps applied to the system and (b) corresponding change in tip height. The topography image of the Ag_2S film filament formation process (c) before applying any bias and (d) after the stable filament formation. (e) The height profile across the point (orange cross in Figure c) of bias application before (green) and after (pink) protrusion. (f) The background currents as measured with a -50 mV→50 mV sweep on the filament reveal the metallic nature of the filament.

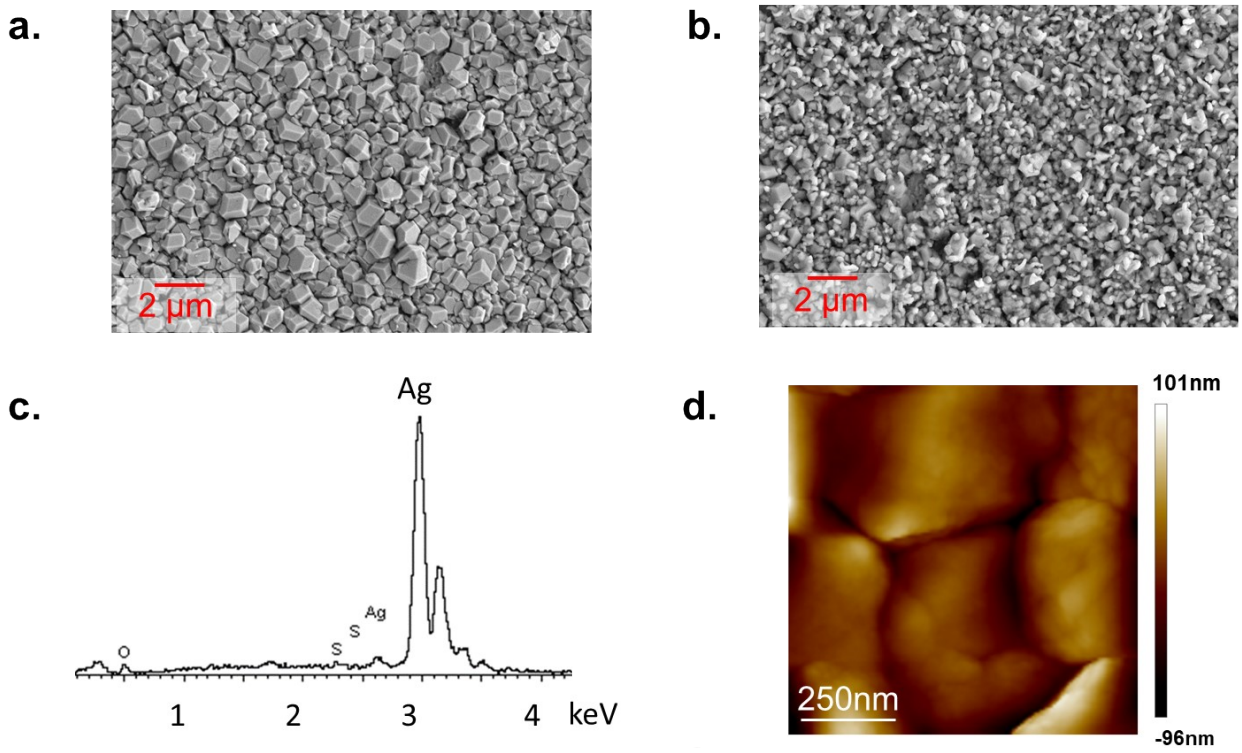

Figure S.I.2: (a) FESEM image of the Ag_2S surface taken with 10kV showing crystals of varying sizes. (b) The same area after repeated scanning showed bright whiskers growing on the surface. (c) EDS mapping confirmed that these bright whiskers are constitute of silver. (d) The AFM image of a small region showing crystal size less than 1µm.

References:

[1] M. Morales-Masis, S. J. van der Molen, W. T. Fu, M. B. Hesselberth, and J. M. van Ruitenbeek, "Conductance switching in Ag(2)S devices fabricated by in situ sulfurization.," *Nanotechnology*, vol. 20, no. 9, p. 95710, 2009, doi: 10.1088/0957-4484/20/9/095710.

[2] M. Kundu, K. Terabe, T. Hasegawa, and M. Aono, "Effect of sulfurization conditions and post-deposition annealing treatment on structural and electrical properties of silver sulfide films," *J. Appl. Phys.*, vol. 99, no. 10, 2006, doi: 10.1063/1.2199067.

[3] A. Suzuki, T. Tsuruoka, and T. Hasegawa, "Time-Dependent Operations in Molecular Gap Atomic Switches," *Phys. Status Solidi Basic Res.*, vol. 256, no. 8, pp. 1–10, 2019, doi: 10.1002/pssb.201900068.

