Electronic Supplementary Material (ESI) for Nanoscale.
This journal is © The Royal Society of Chemistry 2023

Supplementary Information

Synthesis of large area ReS_2 thin film by CVD for in-depth investigation of resistive switching: effect of metal electrode, channel width and noise behaviour

Pallavi Aggarwal[1,3], Hardhyan Sheoran[1], Prashant Bisht[1], Om Kumar Prasad[3], Chin-Han Chung[3], Edward Yi Chang[3], Bodh Raj Mehta[1,4], and Rajendra Singh*[1,2]

*Corresponding author

E-mail: rsingh@physics.iitd.ac.in

1 Department of Physics, Indian Institute of Technology Delhi, New Delhi-110016, India

2 Department of Electrical Engineering, Indian Institute of Technology Delhi, New Delhi-110016, India

3 International College of Semiconductor Technology, National Yang Ming Chiao Tung University, Hsinchu City-300093, Taiwan

4 Directorate of Research, Innovation and Development, Jaypee Institute of Information technology, Noida (U.P.), 201309, India

Section S1

XPS Fitting

X-ray photoelectron spectroscopy (XPS) was performed using the PHI Versa probe III system with a monochromatic X-ray source of Al Kα (hν = 1486.6 eV). XPS data was obtained over a 500 x 500 μm^2 area and with an analyser pass energy of 20 eV. All the XPS spectra were fitted in CasaXPS software after subtraction of a Shirley background. The spectra have been calibrated for the charging effect with respect to C 1s peak at 284.5 eV, obtained from small amount adventitious carbon present over the film. Gaussian-Lorentzian peak shapes with a 70/30 mix were used for all peaks. Spin-orbit splitting for the Re 4f core level is set to 2.43 eV and for the S 2p core level to 1.18 eV. An area constraint of 4:3 is used for all the peaks corresponding to Re-4$f_{7/2}$:Re-4$f_{5/2}$. Atomic ratio, Re:S is calculated from the Re-4f and S-2p peaks corresponding to ReS_2 in the high resolution scan of Re-4f and S-2p peaks.

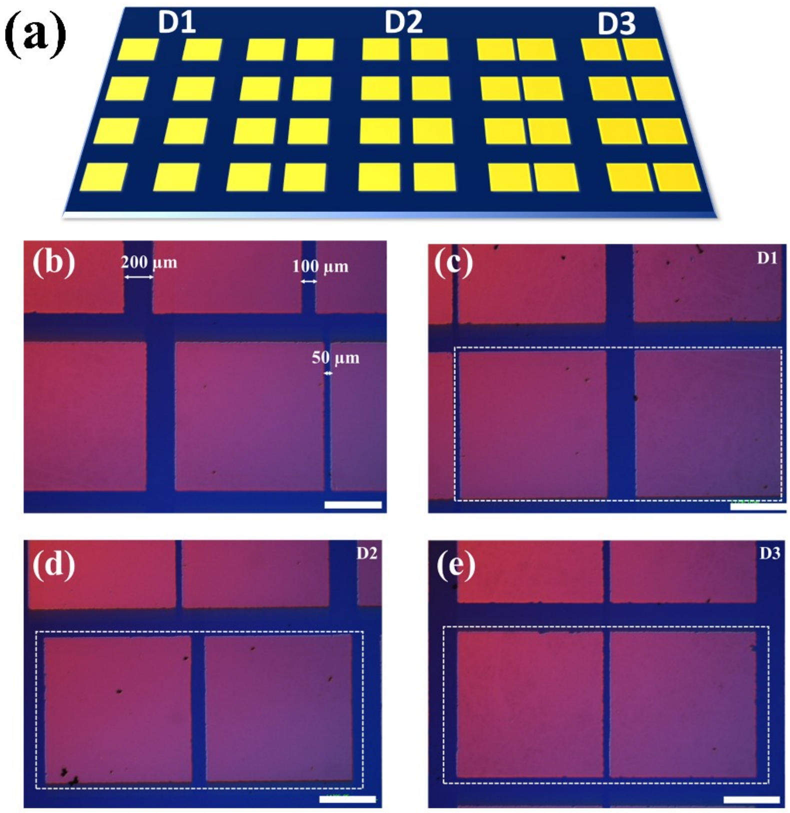

Figure S1

Fig. S1 (a) Schematic of the device architecture. (b) Optical microscopic image depicting overview of the device. It shows presence of devices with 200, 100, and 50 µm channel width all together. Optical microscopic image of (c) D1, (d) D2, and (e) D3. The scale provided in each figure is 400 µm.

Figure S2

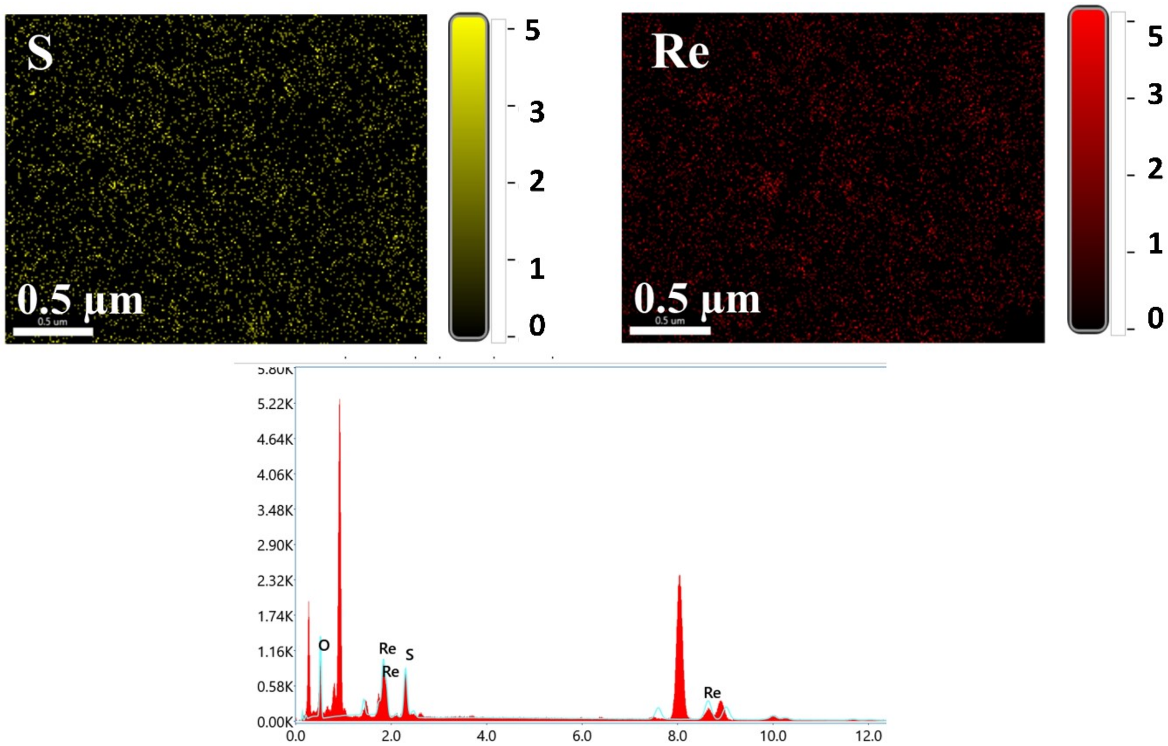

Fig. S2 EDAX spectra of the as-grown ReS_2 film showing peak signals from Re and S and depicting the atomic ratio, Re:S equal to 1:1.9, thereby indicating the formation of stochiometric film.

Figure S3

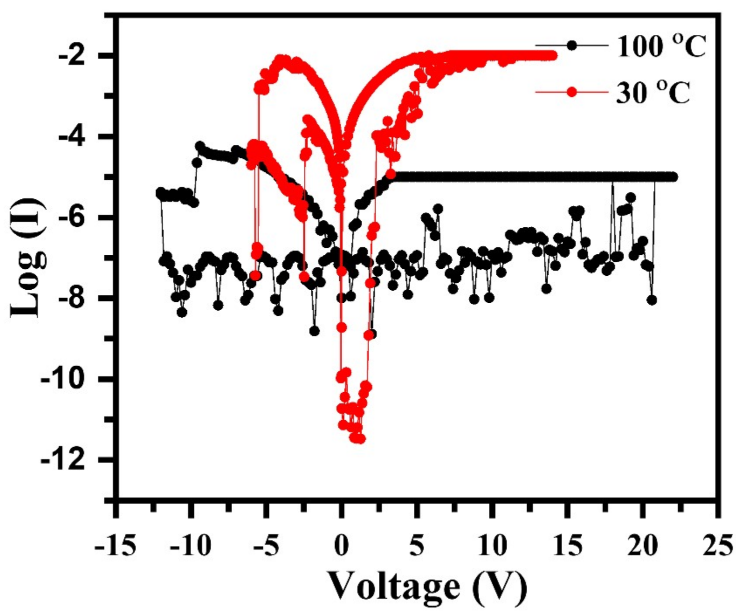

Fig. S3 Resistive switching cycle for device D2 at 30 and 100 °C. A change in HRS/LRS resistance ratio from 10^8 to 10^3 is observed which has been attributed to the weakening of Ag filament followed by which the current is dominated by defect mediated charge transport.

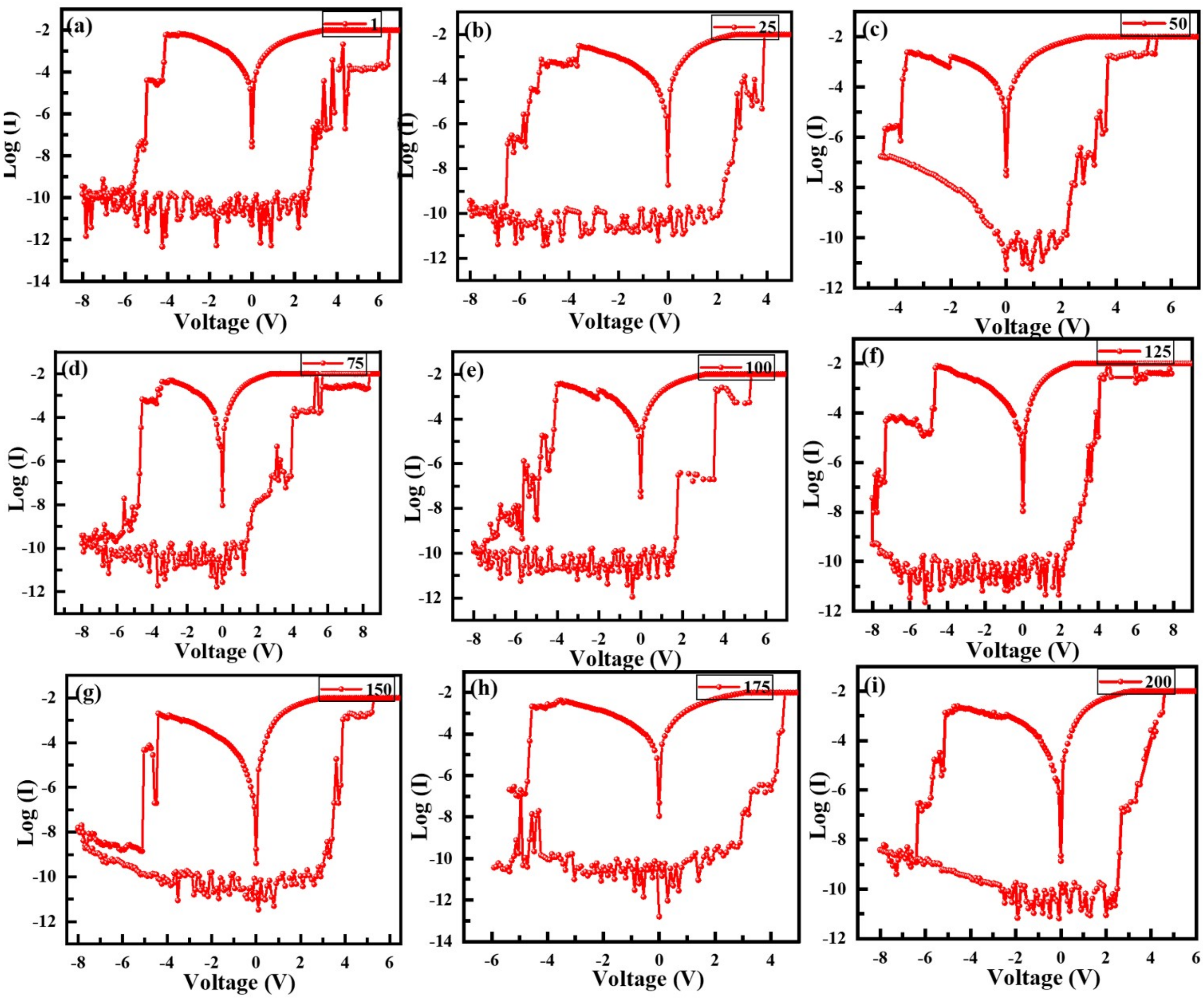

Figure S4

Fig. S4 RS cycles for D1 at the interval of 25 cycles. (a) 1st cycle, (b) 25th cycle, (c) 50th cycle, (d) 75th cycle, (e) 100th cycle, (f) 125th cycle, (g) 150th cycle, (h) 175th cycle, and (i) 200th cycle.

Figure S5

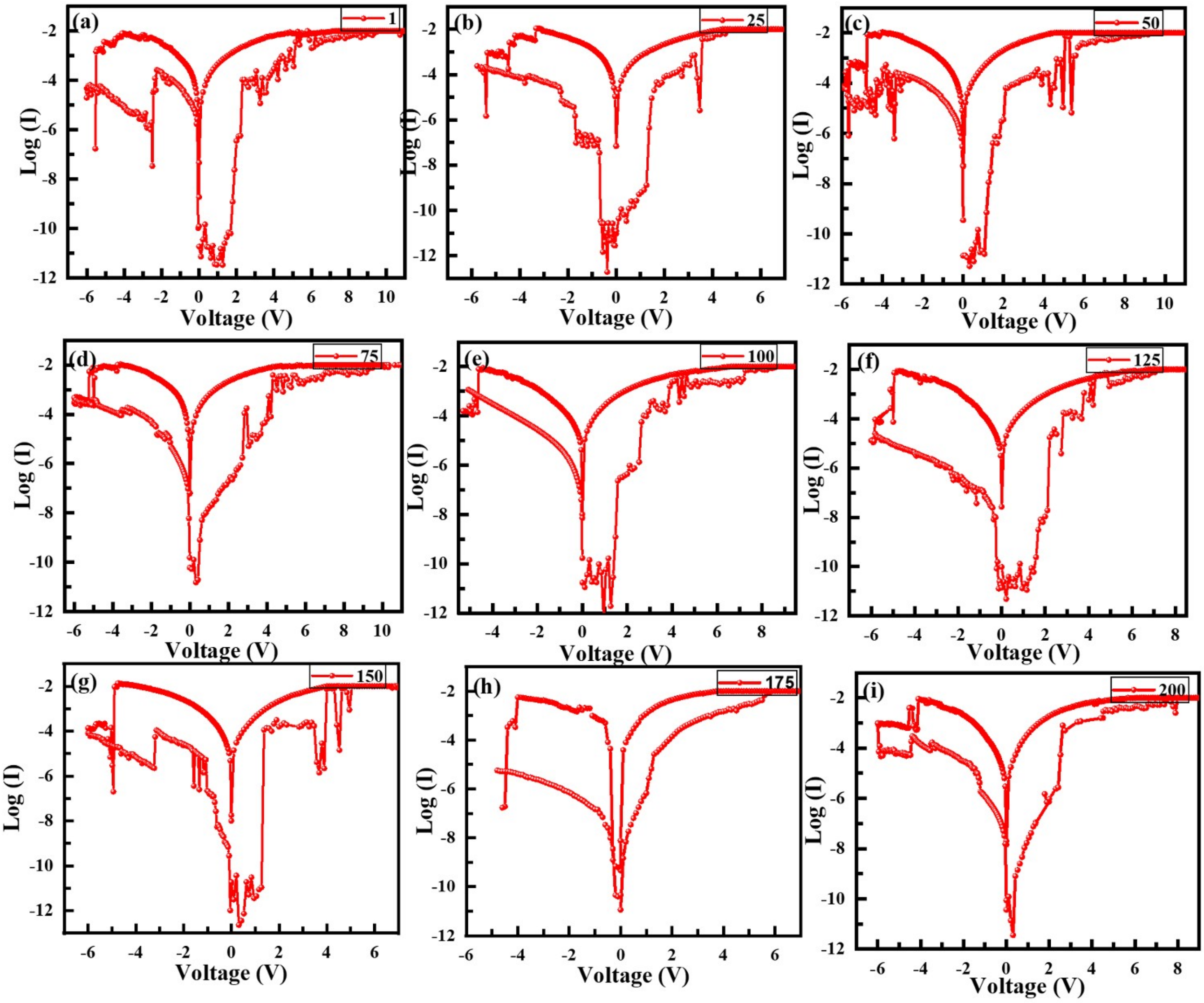

Fig. S5 RS cycles for D2 at the interval of 25 cycles. (a) 1st cycle, (b) 25th cycle, (c) 50th cycle, (d) 75th cycle, (e) 100th cycle, (f) 125th cycle, (g) 150th cycle, (h) 175th cycle, and (i) 200th cycle.

Figure S6

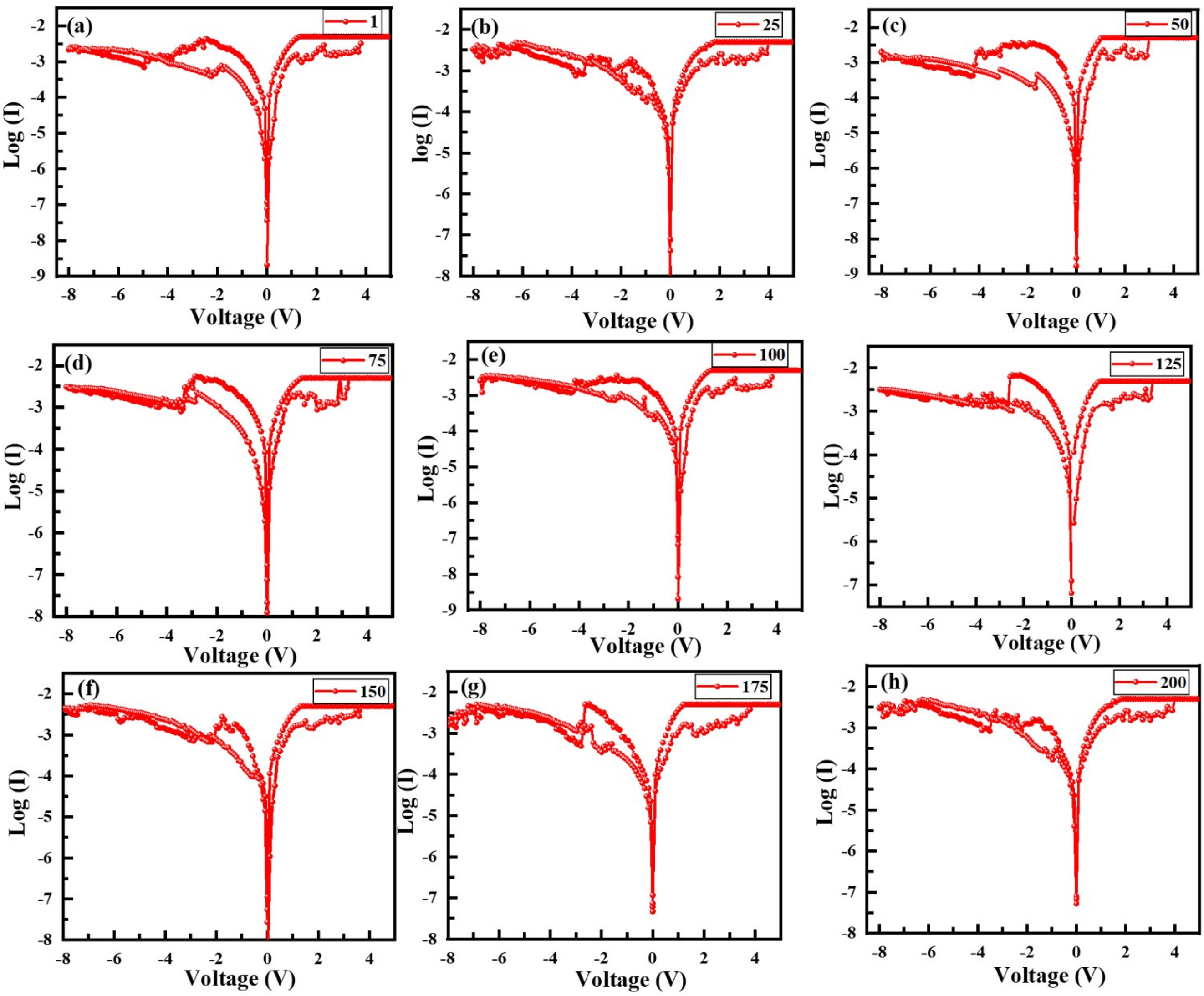

Fig. S6 RS cycles for D3 at the interval of 25 cycles. (a) 1st cycle, (b) 25th cycle, (c) 50th cycle, (d) 75th cycle, (e) 100th cycle, (f) 125th cycle, (g) 150th cycle, (h) 175th cycle, and (i) 200th cycle.

Figure S7

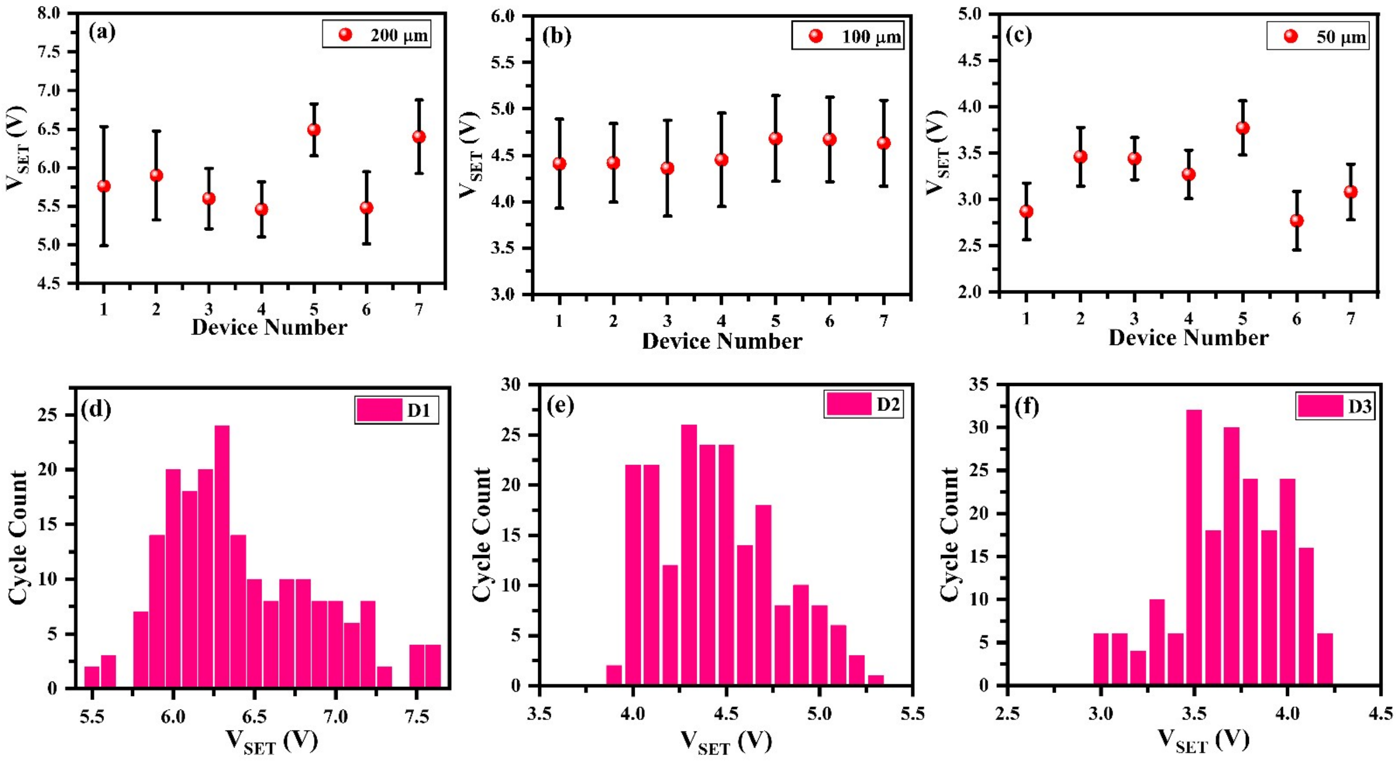

Fig. S7 Device statistics depicting average of the SET voltage, V_{SET}, for the tested seven devices with channel length of (a) 200 µm, (b) 100 µm, and (c) 50 µm. Plots clearly indicate increase in V_{SET} with channel width, which matches with the results reported in the manuscript. Histogram plot representing distribution of V_{SET} over 200 cycles for (d) D1, (e) D2, and (f) D3. V_{SET} is 6.55 ± 0.63 V for D1, 4.6 ± 0.5 V for D2, and 3.6 ± 0.3 V. This small value of standard deviation represents device repeatability and stability over multiple cycles.

Table T1

Table T1. Comparison table containing reported R_{HRS}/R_{LRS} resistance ratio of memristors fabricated on 2DMs.

S.No	Contact Metal	Material	Geometry	R_{HRS}/R_{LRS}	Ref
1	Ti/Au	ReS_2	Lateral	50	[1]
2	Ti/Au	ReS_2	Vertical	10^6	[2]
3	Au	ReS_2	Lateral	10^5	[3]
4	Au Ag/Au	MoS_2	Vertical	- 10^2	[4]
5	Cu/$ReSe_2$/graphene	ReS_2	Lateral	10^5	[5]
6	Ag, Cu	WS_2	Vertical	4.2×10^4	[6]
7	Al	MoS_2-MoO_x	Vertical	10^8	[7]
8	Au, Cr/Au	hBN	Vertical	10^7	[8]
9	**Ag/Au** **Pt/Au**	**ReS_2**	**Lateral**	**10^8** **10^2**	**This Work**

Reference

1 X. Wu, Y. Gu, R. Ge, M. I. Serna, Y. Huang, J. C. Lee and D. Akinwande, *npj 2D Mater. Appl. 2022 61*, 2022, **6**, 1–12.

2 M. E. Pam, S. Li, T. Su, Y. C. Chien, Y. Li, Y. S. Ang and K. W. Ang, *Adv. Mater.*, 2022, **34**, 2202722.

3 C. Ke, F. Huang, Z. Zhang, X. Li, Z. Wu, C. Zhang, F. Xu, Y. Wu and J. Kang, *Appl. Phys. Express*, , DOI:10.35848/1882-0786/ACC8B6.

4 K. Ranganathan, M. Fiegenbaum-Raz and A. Ismach, *Adv. Funct. Mater.*, 2020, **30**, 2005718.

5 S. Rehman, H. Kim, M. F. Khan, J. H. Hur, J. Eom and D. kee Kim, *J. Alloys Compd.*, , DOI:10.1016/j.jallcom.2020.157310.

6 Q. Cao, P. Zou, P. Li, L. Xiong, H. Bi and J. Wu, *J. Mater. Sci. Mater. Electron.*, , DOI:10.1007/S10854-022-09612-9.

7 D. Son, S. I. Chae, M. Kim, M. K. Choi, J. Yang, K. Park, V. S. Kale, J. H. Koo, C. Choi, M. Lee, J. H. Kim, T. Hyeon and D. H. Kim, *Adv. Mater.*, 2016, **28**, 9326–9332.

8 X. Wu, R. Ge, P. A. Chen, H. Chou, Z. Zhang, Y. Zhang, S. Banerjee, M. H. Chiang, J. C. Lee and D. Akinwande, *Adv. Mater.*, , DOI:10.1002/ADMA.201806790.