Electronic Supplementary Information for:

Molecular Precursor-Directed Growth of Nanostructured SnS_2 for Memristive and Neuromorphic Electronics

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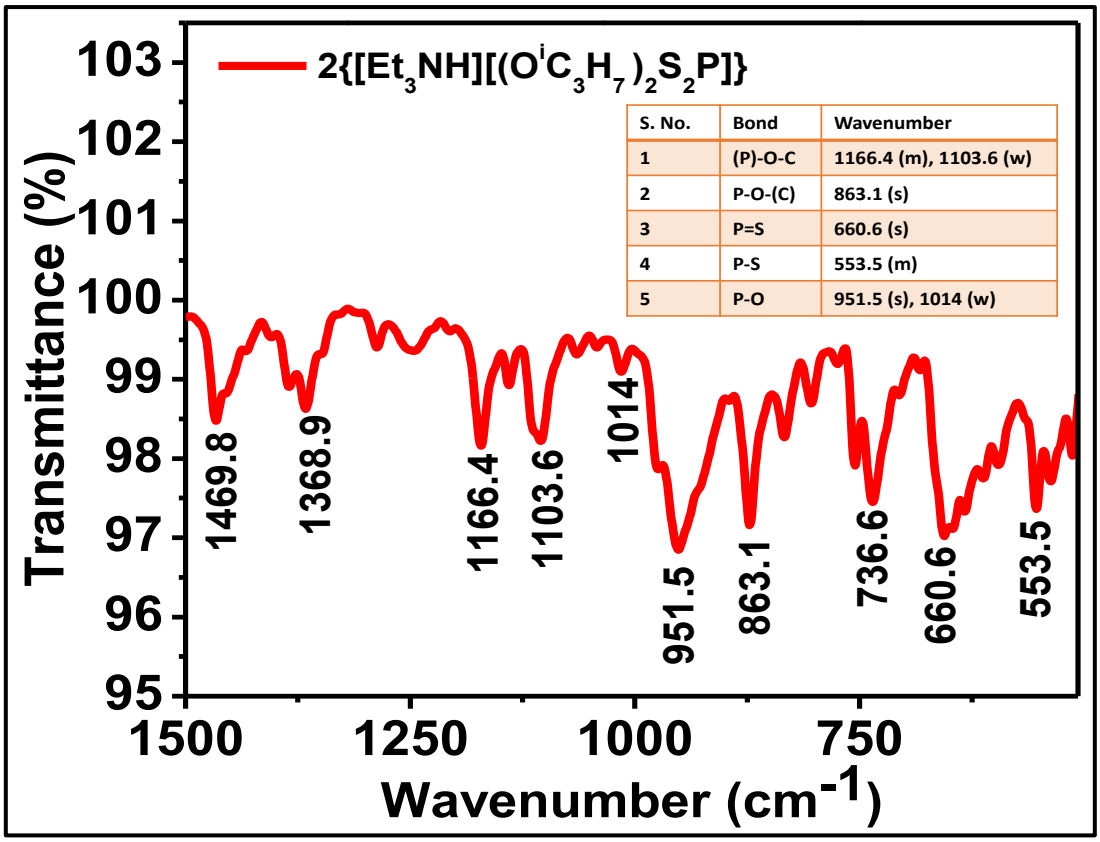

Figure S1. FT-IR spectrum of the $[Et_3NH][(O^iC_3H_7)_2S_2P]$ using KBr discs

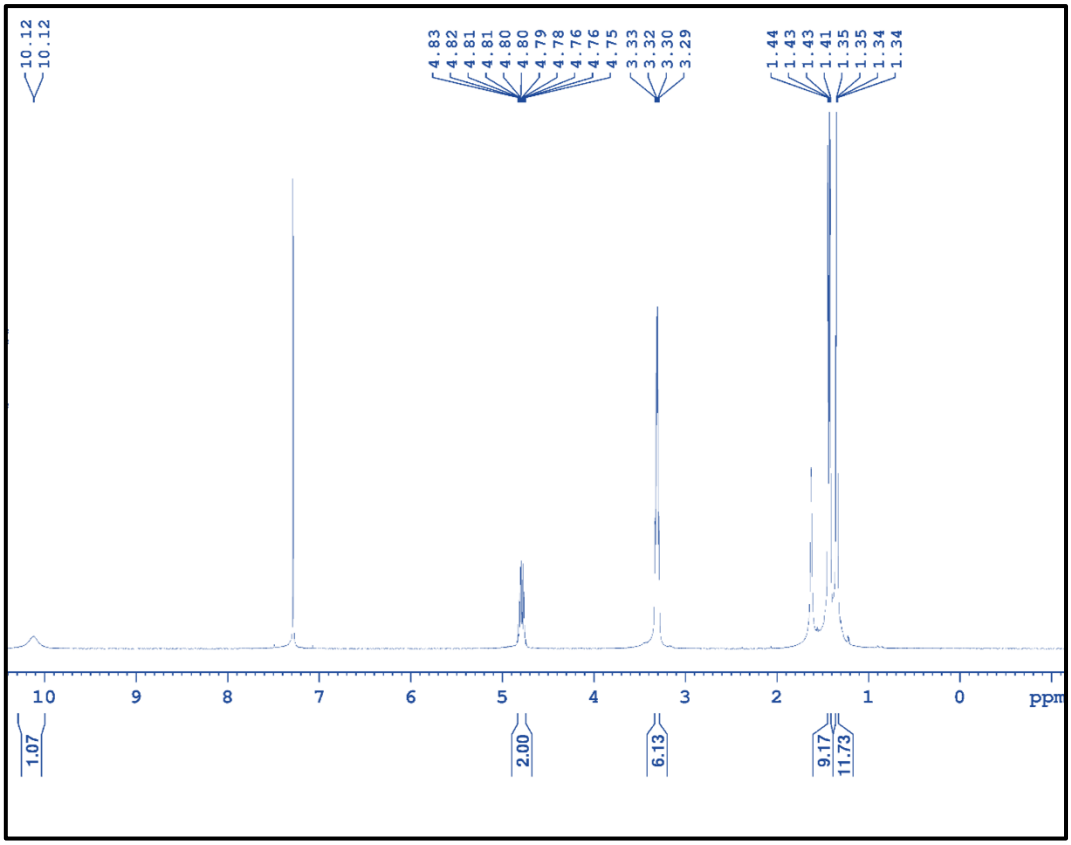

Figure S2. Room temperature $\{^1H\}$ NMR spectrum of $[Et_3NH][(O^iC_3H_7)_2S_2P]$ (in $CDCl_3$).

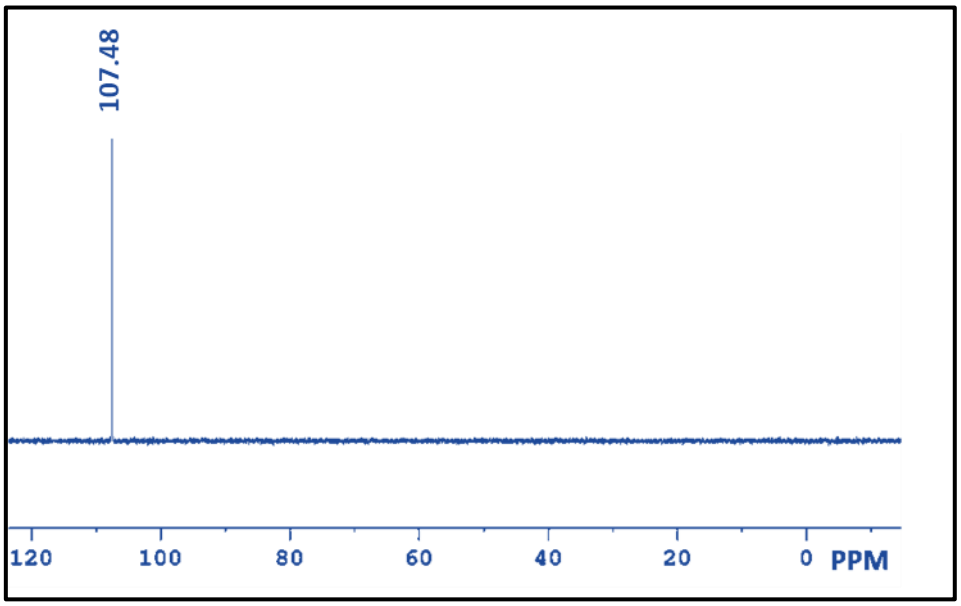

Figure S3. Room temperature $^{31}P\{^1H\}$ NMR spectrum of $[Et_3NH][(O^iC_3H_7)_2S_2P]$ (in $CDCl_3$).

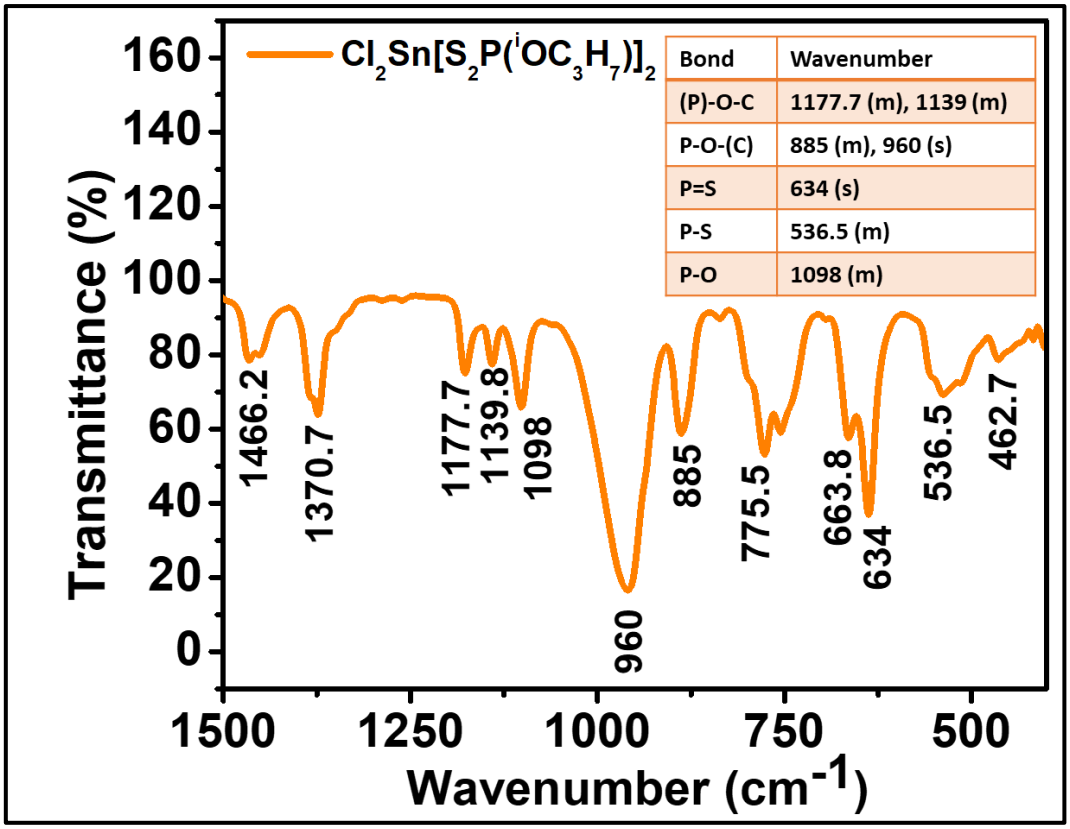

Figure S4. FT-IR spectrum of the $Cl_2Sn[S_2P(O^iC_3H_7)]_2$ complex using KBr discs

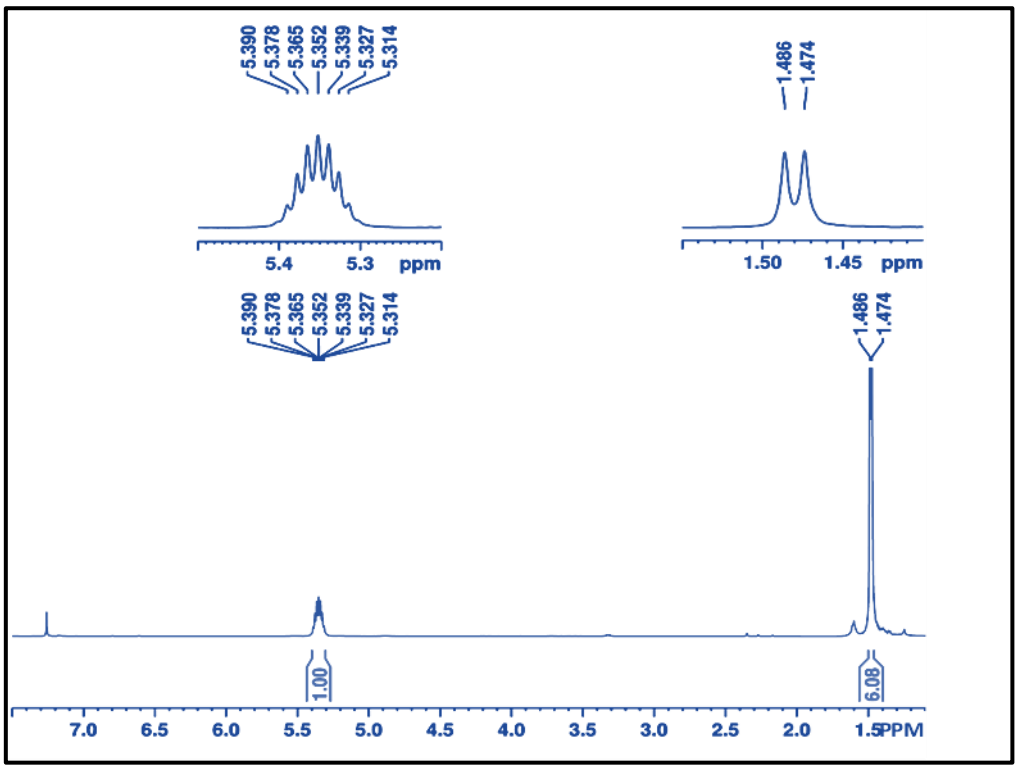

Figure S5. Room temperature $\{^1H\}$ NMR spectrum of $Cl_2Sn[S_2P(O^iC_3H_7)]_2$ complex (in $CDCl_3$).

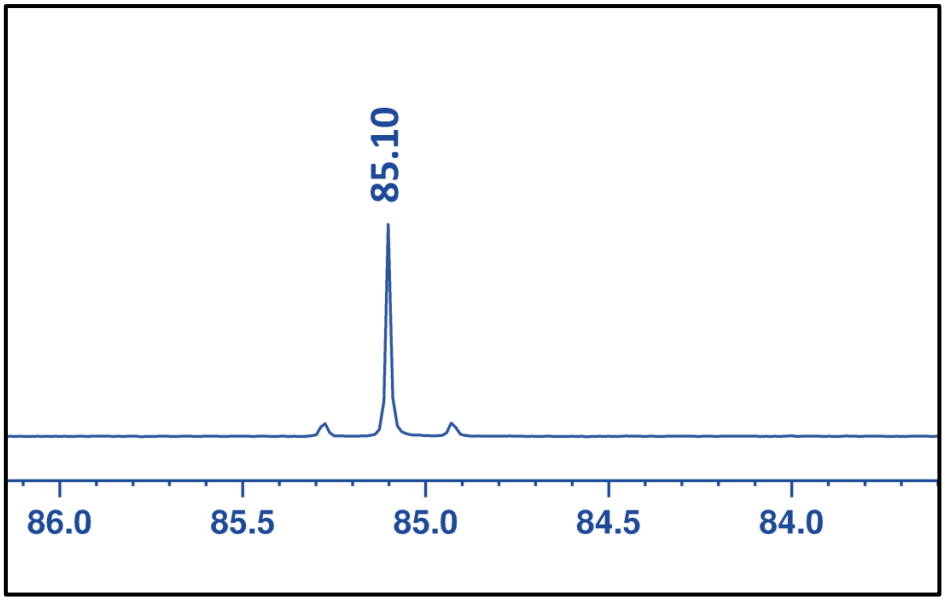

Figure S6. Room temperature $^{31}P\{^{1}H\}$ NMR spectrum of $Cl_2Sn[S_2P(O^iC_3H_7)]_2$ complex (in $CDCl_3$).

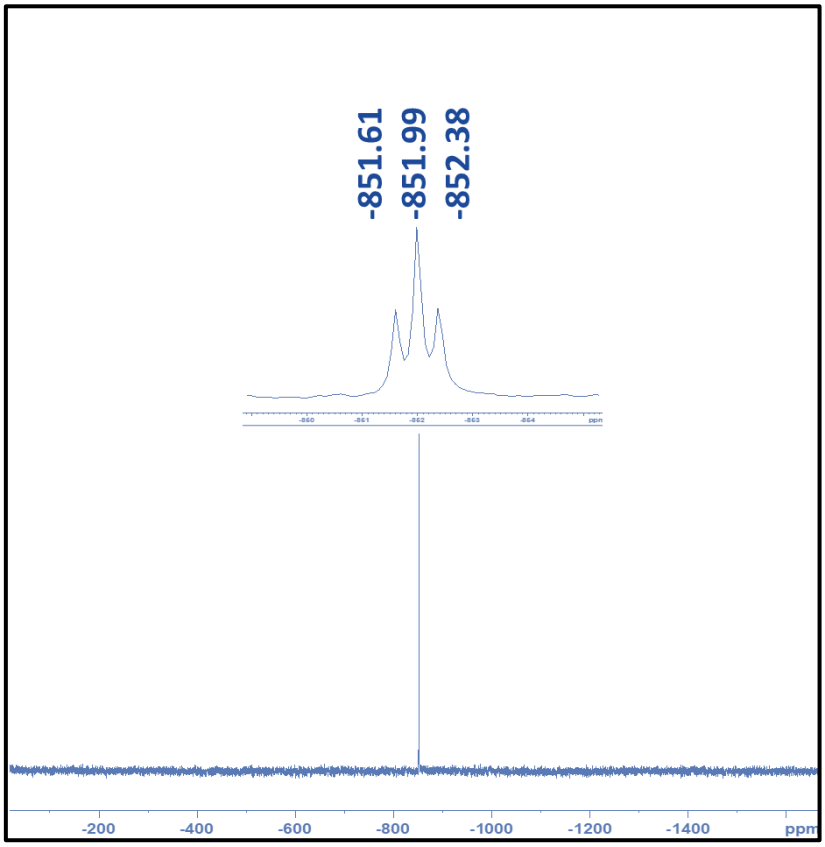

Figure S7. Room temperature $^{119}Sn\{^{1}H\}$ NMR spectrum of $Cl_2Sn[S_2P(O^iC_3H_7)]_2$ complex (in $CDCl_3$)

Table S1. Crystal data and structure refinement for $[Cl_2Sn[S_2P(O^iC_3H_7)]_2]$.

Parameter	Value
Empirical formula	$C_{12}H_{28}Cl_2O_4P_2S_4Sn$
Formula weight	616.11
Temperature (K)	156.0
Crystal system	Orthorhombic
Space group	C2221
a (Å)	9.9605(7)
b (Å)	18.5085(14)
c (Å)	28.902(2)
α (°)	90
β (°)	90
γ (°)	90
Volume (Å³)	5328.1(7)
Z	8
Density (ρcalc) (g/cm³)	1.536
μ (mm^{-1})	1.606
F(000)	2480.0
Crystal size (mm³)	0.23 × 0.221 × 0.221
Radiation	MoKα (λ = 0.71073 Å)
2θ range for data collection (°)	4.622 to 51.36
Index ranges	$-11 \le h \le 12$, $-22 \le k \le 21$, $-35 \le l \le 33$
Reflections collected	39408
Independent reflections	5069 [Rint = 0.0360, Rσ = 0.0231]
Data/restraints/parameters	5069 / 160 / 223
Goodness-of-fit on F^2	1.202
Final R indexes [$I \ge 2\sigma(I)$]	R_1 = 0.0387, wR_2 = 0.0944
Final R indexes [all data]	R_1 = 0.0401, wR_2 = 0.0952
Largest diff. peak/hole (e $Å^{-3}$)	0.81 / –0.66
Flack parameter	0.063(6)

Table S2: Bond lengths (Å) for $[Cl_2Sn[S_2P(O^iC_3H_7)]_2]$

Atom	Atom	Length (Å)	Atom	Atom	Length (Å)
Sn1	S2	2.5993(15)	P005	O1	1.556(4)
Sn1	S21	2.5994(15)	P006	S3	2.022(3)
Sn1	S1	2.5138(16)	P006	O4	1.561(5)
Sn1	S11	2.5138(16)	P006	O3	1.555(5)
Sn1	Cl1	2.3894(19)	O2	C4	1.475(7)
Sn1	Cl11	2.3894(19)	O1	C1	1.483(7)
Sn2	S4	2.5983(16)	O4	C10	1.472(11)
Sn2	S42	2.5983(16)	O3	C7	1.461(9)
Sn2	S32	2.526(2)	C7	C8	1.484(17)
Sn2	S3	2.526(2)	C7	C9	1.515(14)
Sn2	Cl2	2.373(2)	C1	C2	1.521(12)
Sn2	Cl22	2.373(2)	C1	C3	1.482(12)
S2	P005	2.004(2)	C4	C5	1.496(15)
S4	P006	2.003(2)	C4	C6	1.491(15)
P005	S1	2.022(2)	C12	C10	1.483(14)
P005	O2	1.555(5)	C11	C10	1.459(13)

Table S3: Bond angles (°) for $[Cl_2Sn[S_2P(O^iC_3H_7)]_2]$

Atom	Atom	Atom	Angle/°	Atom	Atom	Atom	Angle/°
S2	Sn1	S2[1]	88.14(7)	P006	S4	Sn2	86.52(7)
S1[1]	Sn1	S2[1]	78.65(6)	S2	P005	S1	107.23(9)
S1	Sn1	S2[1]	92.72(6)	O2	P005	S2	113.1(2)
S1[1]	Sn1	S2	92.72(6)	O2	P005	S1	112.2(2)
S1	Sn1	S2	78.65(6)	O2	P005	O1	98.4(2)
S1	Sn1	S1[1]	168.06(9)	O1	P005	S2	114.0(2)
Cl1	Sn1	S2	90.39(7)	O1	P005	S1	111.9(2)
Cl1	Sn1	S2[1]	168.59(6)	S4	P006	S3	107.06(11)
Cl1[1]	Sn1	S2[1]	90.39(7)	O4	P006	S4	113.0(2)
Cl1[1]	Sn1	S2	168.58(6)	O4	P006	S3	112.4(2)
Cl1	Sn1	S1[1]	90.12(7)	O3	P006	S4	112.8(2)
Cl1	Sn1	S1	98.09(7)	O3	P006	S3	112.8(3)
Cl1[1]	Sn1	S1[1]	98.09(7)	O3	P006	O4	98.8(3)
Cl1[1]	Sn1	S1	90.12(7)	P005	S1	Sn1	88.02(7)
Cl1	Sn1	Cl1[1]	93.23(12)	P006	S3	Sn2	88.08(8)
S4	Sn2	S4[2]	89.15(7)	C4	O2	P005	121.8(4)
S3[2]	Sn2	S4[2]	78.33(6)	C1	O1	P005	121.5(4)
S3[2]	Sn2	S4	90.92(6)	C10	O4	P006	122.0(6)
S3	Sn2	S4	78.33(6)	C7	O3	P006	122.9(5)
S3	Sn2	S4[2]	90.92(6)	O3	C7	C8	107.5(9)
S3	Sn2	S3[2]	164.97(10)	O3	C7	C9	106.1(8)
Cl2[2]	Sn2	S4	169.76(9)	C8	C7	C9	112.4(10)
Cl2	Sn2	S4	90.28(7)	O1	C1	C2	106.5(7)
Cl2[2]	Sn2	S4[2]	90.28(7)	C3	C1	O1	107.6(6)
Cl2	Sn2	S4[2]	169.76(9)	C3	C1	C2	113.0(7)
Cl2	Sn2	S3	98.98(9)	O2	C4	C5	106.5(7)
Cl2[2]	Sn2	S3	91.46(10)	O2	C4	C6	107.9(7)
Cl2[2]	Sn2	S3[2]	98.98(9)	C6	C4	C5	112.4(8)
Cl2	Sn2	S3[2]	91.46(10)	O4	C10	C12	107.0(9)
Cl2	Sn2	Cl2[2]	92.09(13)	C11	C10	O4	108.2(9)
P005	S2	Sn1	86.05(7)	C11	C10	C12	114.2(10)

Table S4. Comparative study of SSPs utilized for the deposition of SnS_2 thin films.

Precursor	Synthesis Method and Deposition Condition	Need for Additional Sulphur Source	Sulphur Deficient Tin Sulphide	Device Integration	Ref.
$^{n}Bu_2Sn(SnBu)_2$	AACVD + Annealing (440–460 °C)	No	Yes	Na-ion Battery	1
$SnCl_4\{^{n}BuS(CH_2)_3S^{n}Bu\}$	LPCVD (650 °C)	No	No	Not explored	2
$^{n}Bu_2Sn(SnBu)_2$	LPCVD (440–530 °C)	No	No	Thermoelectric	3
$Sn(SCH_2CF_3)_4$	APCVD (≥300 °C)	Yes	No	Not explored	4
$Sn(S_2CNEt_2)_4$	CVD (250–350 °C)	Yes	No	Not explored	5
$R_nSn[S_2CN(C_4H_9)CH_3]_{4-n}$	APCVD+ Annealing	Yes	No	Not explored	6
This work (DTP-based SSP)	One-step solvothermal (200 °C)	Not required	No	Memristor+ Neuromorphic	This work

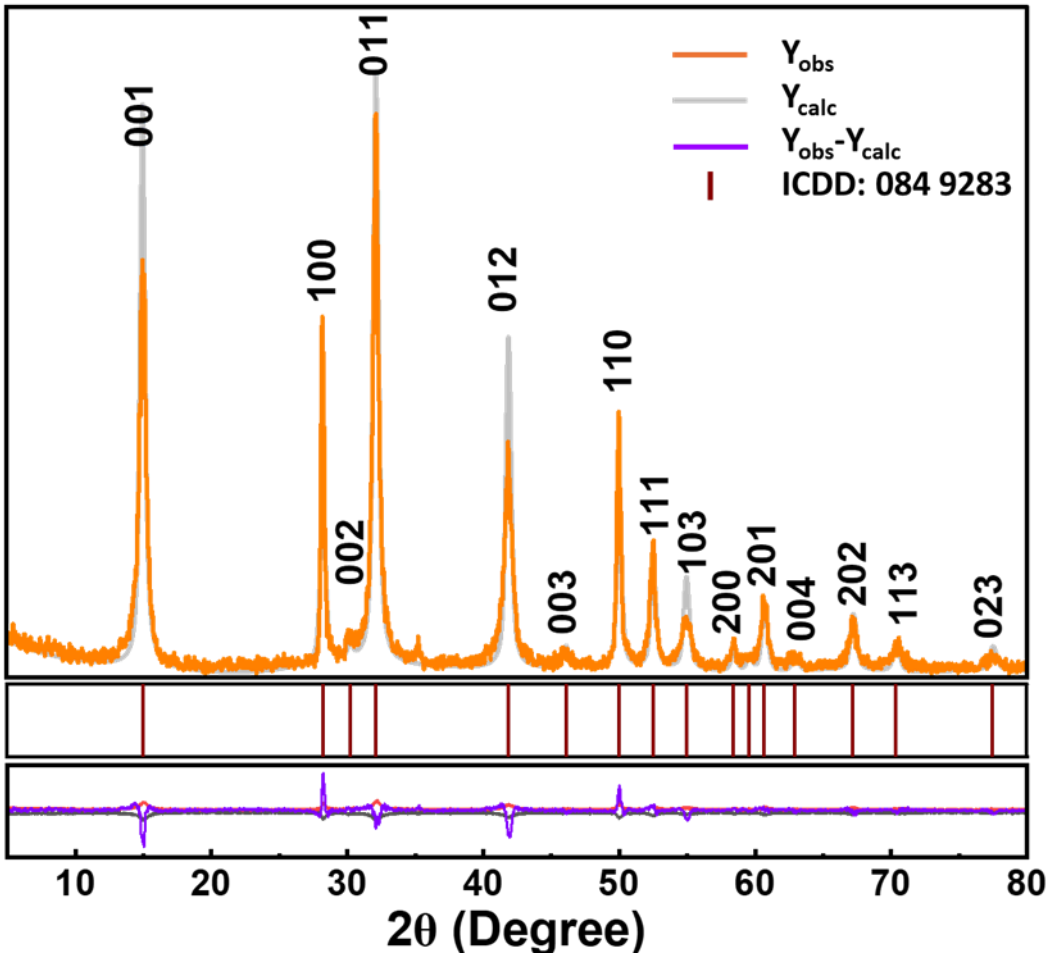

Figure S8: Rietveld refinement pattern of nanostructured SnS_2 thin film

Table S5: Microstrain (ε) values estimated from XRD peak broadening of SnS_2 thin film.

Peak (2θ)	FWHM (deg)	Microstrain (ε)
15.02	0.40422	0.0134
28.27	0.28947	0.0050
32.13	0.37345	0.0056
41.89	0.50812	0.0058
50.01	0.21850	0.0020

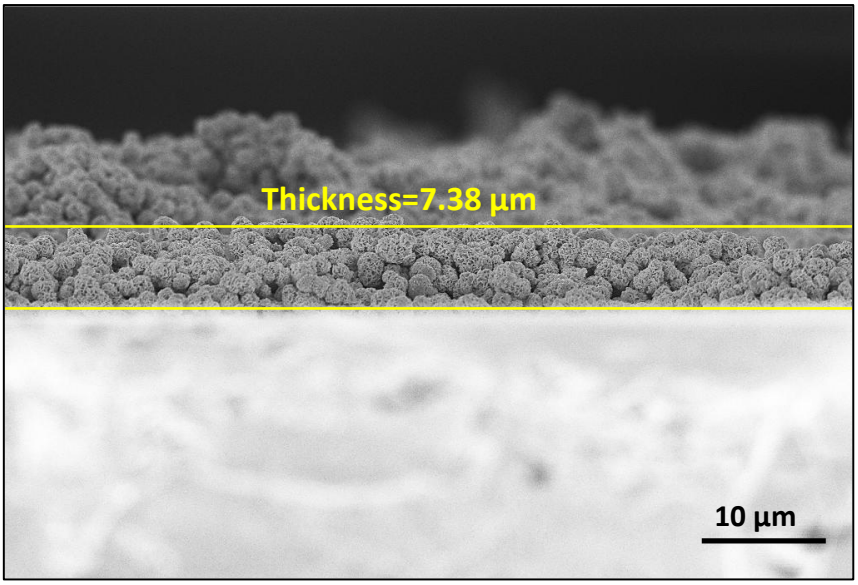

Figure S9. Cross-sectional micrograph of the SnS_2 nanostructured thin film, highlighting the film thickness

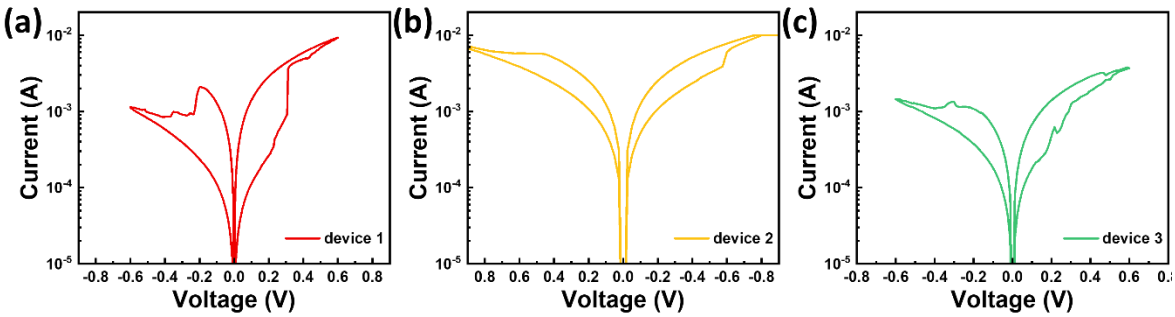

Figure S10 DC I–V characteristics of three representative Ag/SnS_2/ITO memristor devices, showing bipolar resistive switching behaviour with electroforming-free operation.

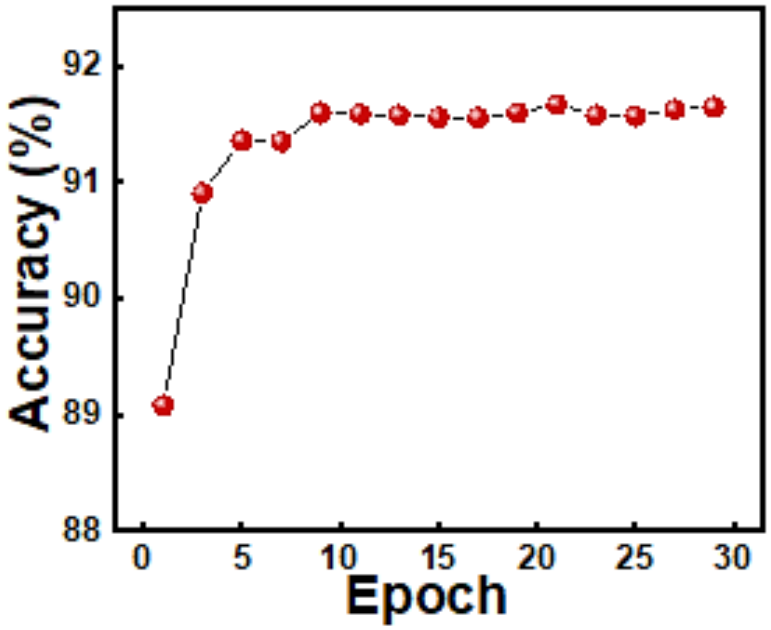

Figure S11. Validation accuracy as a function of training epoch.

Table S6. Comparison of the resistive switching performance of the Ag/SnS_2/ITO memristor in this work against other SnS_2-based memristors.

Device	**Steps in Synthesis**	**Temperature**	**Switching Voltage**	**Electro-forming**	**Synaptic Switching**	**MNIST Accuracy**	**Ref.**
SnO_x/SnS_2 Heterostructure	Multistep	250 °C	~1 V	Yes	Yes	90%	7
SnS_2 Quantum Dots	Multistep	160–200 °C	0.7-1 V	Yes	No	Not explored	8
SnS_2–rGO Composite	Multistep	180–200 °C	2 V	Yes	Yes	Not explored	9
Ca^{2+}-doped SnS_2	Multistep	180–220 °C	2-4 V	Yes	Yes	90%	10
Ag/SnS_2/ITO (This work)	Multistep	**~200 °C**	**0.6 V**	No	**Yes**	**92%**	This work

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