Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supporting Information

Advanced artificial synaptic thin-film transistor based on doped potassium ions for neuromorphic computing via third-generation neural network

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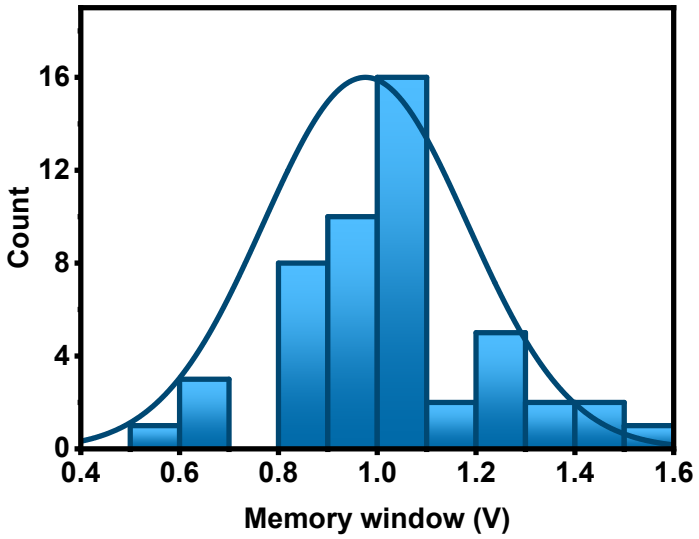

Figure S1. Distribution diagram of K^+ doped AlO_x artificial synaptic TFT memory window.

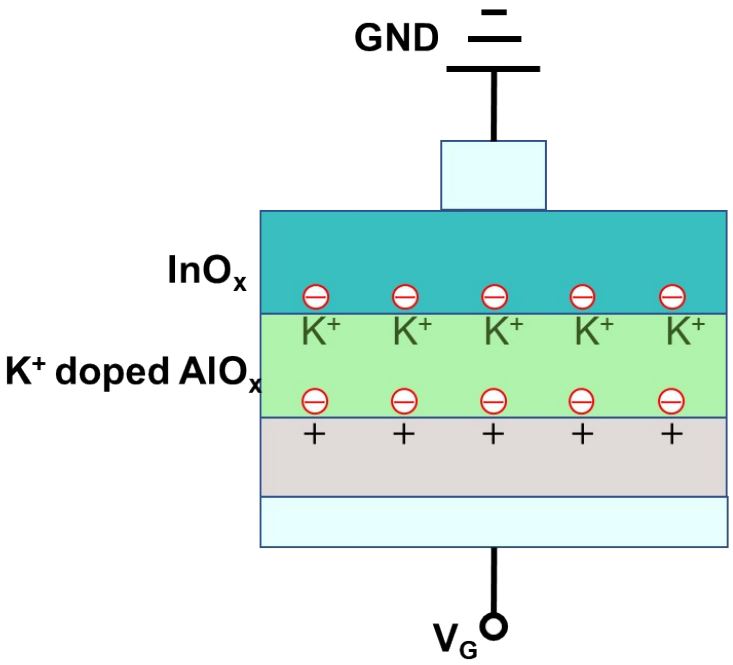

Figure S2. Schematic diagram of metal-insulated semiconductor structure.

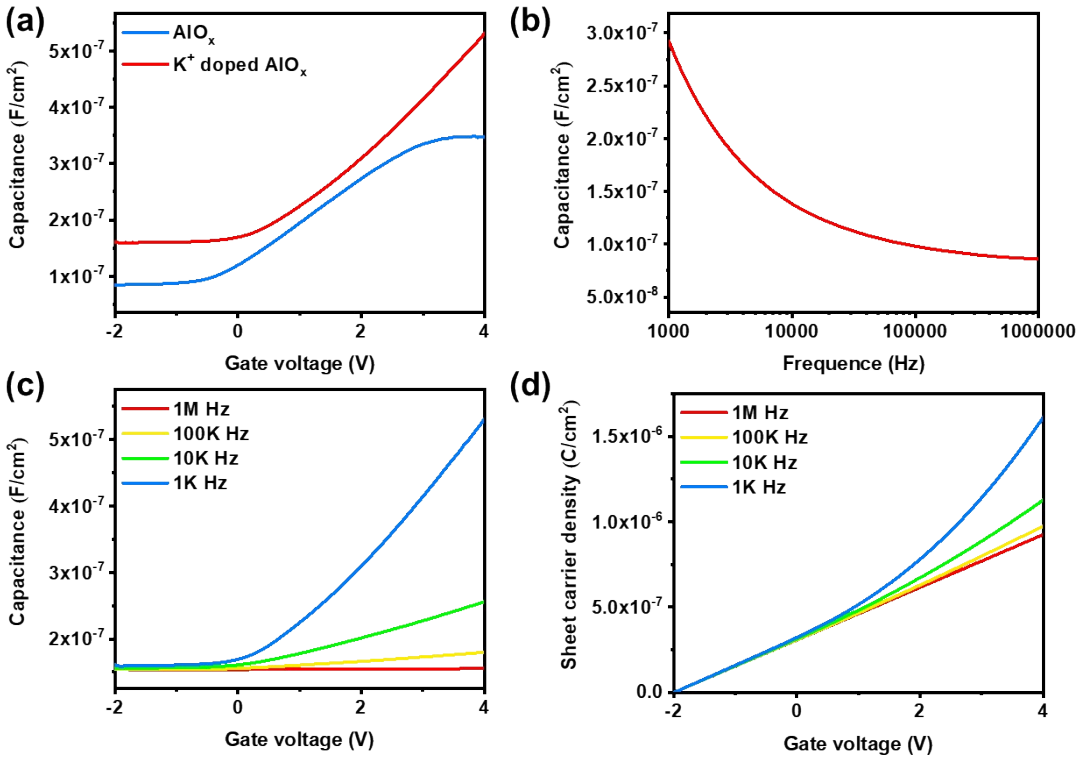

Figure S3. (a) C-V measurement comparison of metal-insulated semiconductor structure with and without K^+ doped TFT. (b) C-F measurement of metal-insulated semiconductor structure. (c) C-V relationship at different frequencies. (d) Comparison of sheet carrier density of the interface at a different frequency

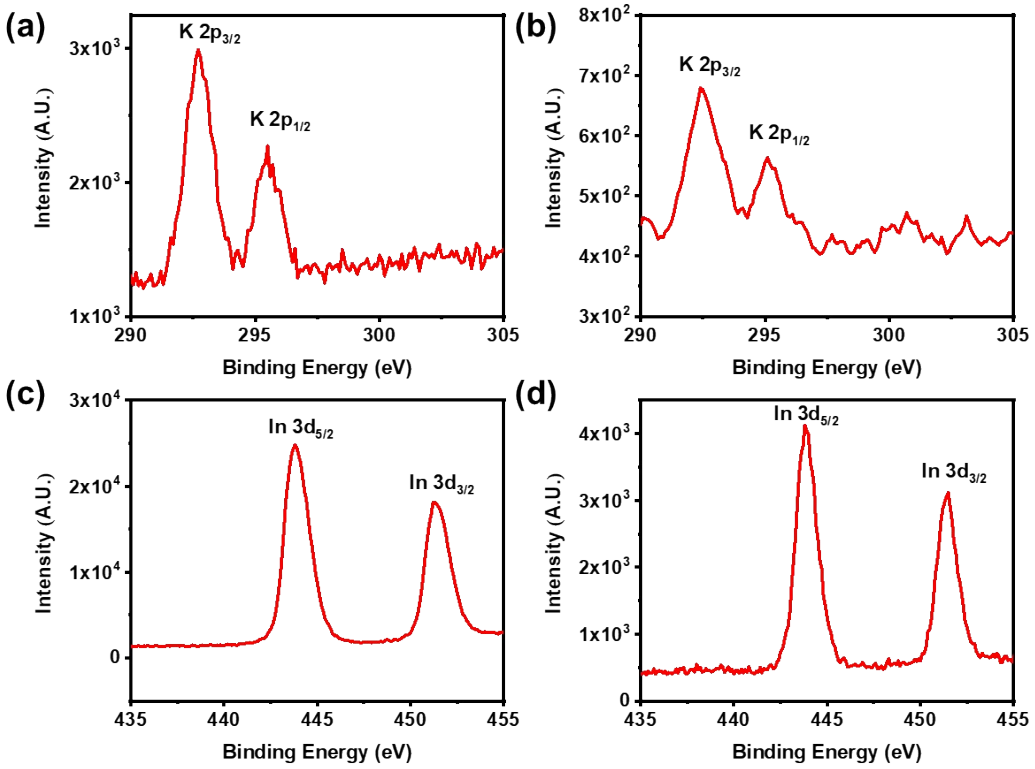

Figure S4. K 2p spectra detected on the InO_x surface (a) with no bias applied and (b) after strong bias. In 3d spectra detected on the InO_x surface (c) with no bias applied and (d) after strong bias

Table S1. In $3d_{5/2}$ and K $2p_{3/2}$ peaks area with/without strong bias and the ratios of In atom and K atom with/without strong bias.

Status	Element	Area	R.S.F	Ratio
No bias applied	In $3d_{5/2}$	39176.8	22.54	
No bias applied	K $2p_{3/2}$	2063.1	3.97	K/In = 29.89%
After strong bias	In $3d_{5/2}$	5031.6	22.54	
After strong bias	K $2p_{3/2}$	311.4	3.97	K/In = 35.13%

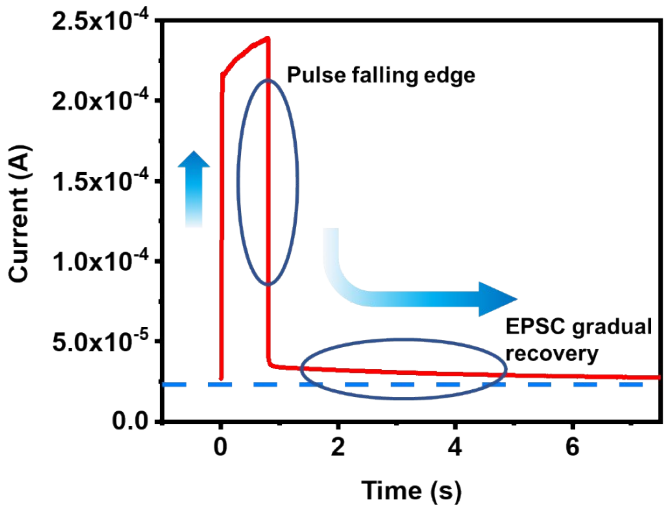

Figure S5. EPSC generated by the presynaptic spike (4 V, 1000 ms).

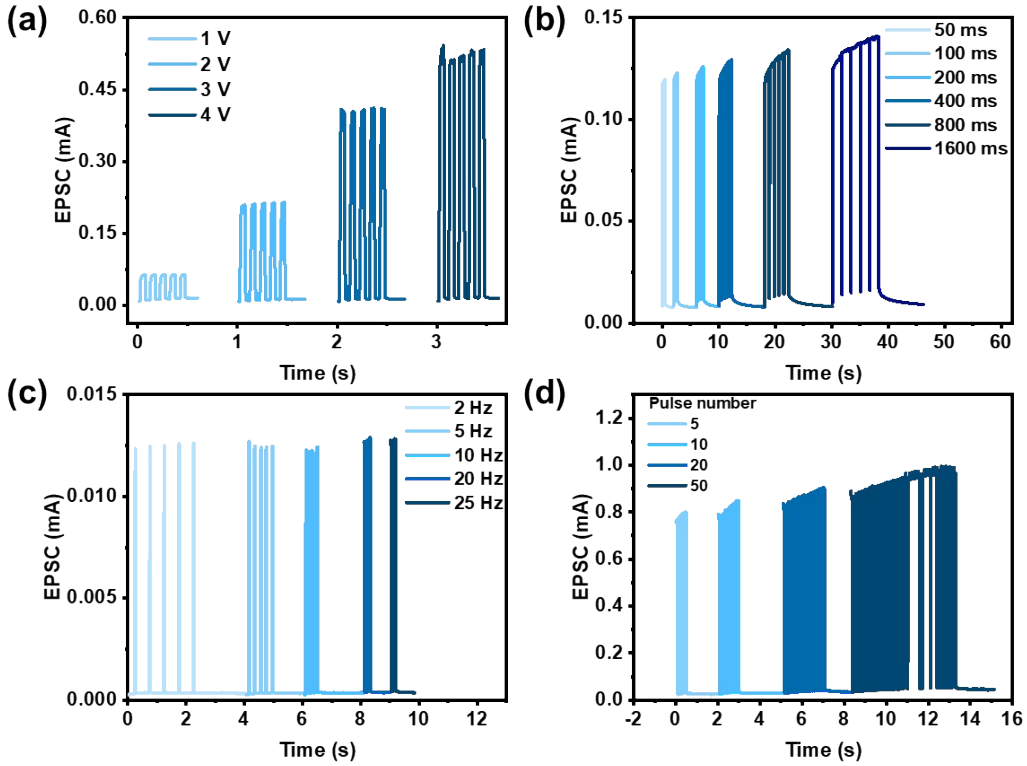

Figure S6. (a) EPSC generated by five presynaptic spikes (1 V to 4 V, 50 ms), Δt is 50 ms (V_{ds} = 2 V). (b) EPSC generated by five consecutive presynaptic pulses (2 V, 50 ms), the pulse time varies from 50 ms to 1600 ms (V_{ds} = 2 V). (c) EPSC (V_{ds} = 4 V) was generated by five presynaptic spikes (4 V, 30 ms) with different pulse frequencies (2 Hz-25 Hz). (d) EPSC generated by different numbers (5-50 times) of presynaptic spikes (4 V, 80 ms).

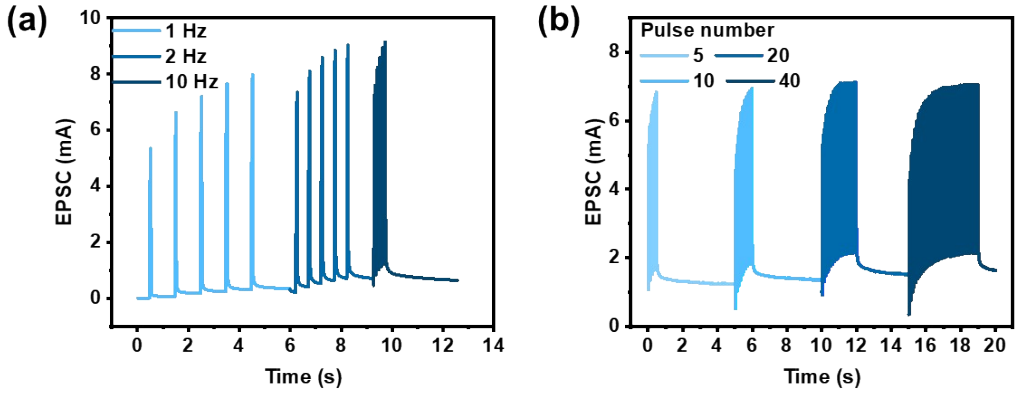

Figure S7. (a) EPSC (V_{ds} = 4 V) was generated by five presynaptic spikes (4 V, 30 ms) with different pulse frequencies (1 Hz-10 Hz). (b) EPSC is generated by different numbers (5-40 times) of presynaptic spikes (4 V, 80 ms).

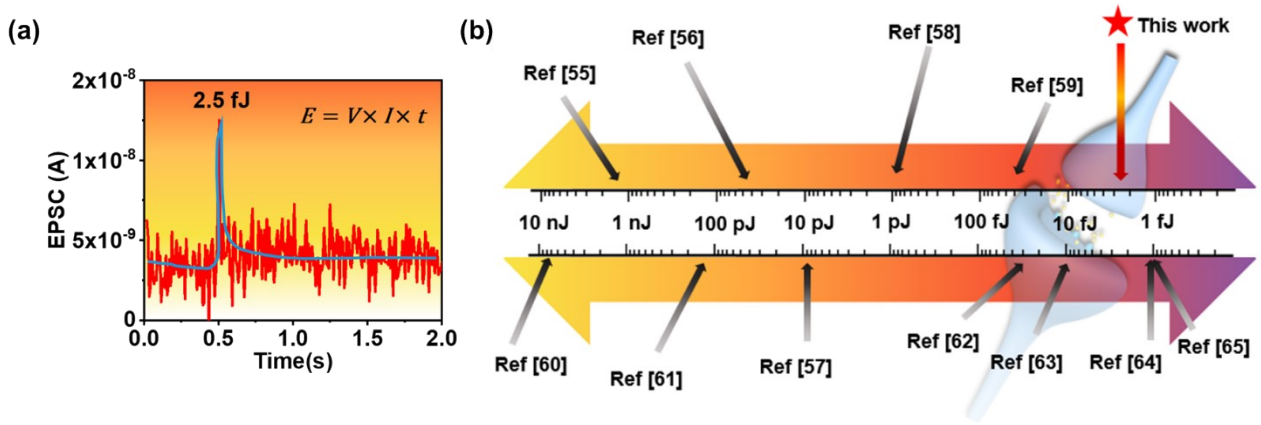

Figure S8. (a) EPSC stimulated by a single electrical spike (500 mV, 2 ms) at ultra-low drain voltage (V_{ds} = 160 μV). (b) The Comparison of the power consumption among the artificial synaptic transistors.

Table. S2. The function between nonlinearity NL and $A_{P/D}$

NL	A	NL	A	NL	A	NL	A	NL	A	NL	A	NL	A	NL	A
0.01	125.27	0.51	2.4702	1.01	1.2390	1.51	0.8195	2.01	0.6058	2.51	0.4748	3.01	0.3853	3.51	0.3194
0.02	63.134	0.52	2.4225	1.02	1.2257	1.52	0.8139	2.02	0.6025	2.52	0.4727	3.02	0.3838	3.52	0.3183
0.03	42.089	0.53	2.3755	1.03	1.2145	1.53	0.8083	2.03	0.5994	2.53	0.4705	3.03	0.3823	3.53	0.3171
0.04	31.556	0.54	2.3324	1.04	1.2026	1.54	0.8028	2.04	0.5952	2.54	0.4685	3.04	0.3808	3.54	0.316
0.05	25.253	0.55	2.2897	1.05	1.191	1.55	0.7974	2.05	0.5931	2.55	0.4665	3.05	0.3793	3.55	0.3148
0.06	21.044	0.56	2.2485	1.06	1.1795	1.56	0.7921	2.06	0.59	2.56	0.4644	3.06	0.3779	3.56	0.3137
0.07	18.038	0.57	2.2090	1.07	1.1683	1.57	0.7858	2.07	0.5859	2.57	0.4624	3.07	0.3764	3.57	0.3125
0.08	15.782	0.58	2.1707	1.08	1.1572	1.58	0.7815	2.08	0.5838	2.58	0.4604	3.08	0.3749	3.58	0.3115
0.09	14.029	0.59	2.1337	1.09	1.1454	1.59	0.7765	2.09	0.5808	2.59	0.4584	3.09	0.3735	3.59	0.3104
0.1	12.626	0.6	2.0979	1.1	1.1357	1.6	0.7714	2.1	0.5778	2.6	0.4564	3.1	0.372	3.6	0.3093
0.11	11.478	0.61	2.0533	1.11	1.1253	1.61	0.7654	2.11	0.5749	2.61	0.4544	3.11	0.3705	3.61	0.3082
0.12	10.521	0.62	2.0298	1.12	1.115	1.62	0.7615	2.12	0.5719	2.62	0.4524	3.12	0.3692	3.62	0.3071
0.13	9.7116	0.63	1.9973	1.13	1.1049	1.63	0.7555	2.13	0.569	2.63	0.4505	3.13	0.3678	3.63	0.306
0.14	9.0177	0.64	1.9559	1.14	1.095	1.64	0.7517	2.14	0.5661	2.64	0.4485	3.14	0.3664	3.64	0.3049
0.15	8.4163	0.65	1.9354	1.15	1.0853	1.65	0.7459	2.15	0.5633	2.65	0.4466	3.15	0.365	3.65	0.3038
0.16	7.8901	0.66	1.9059	1.16	1.0757	1.66	0.7422	2.16	0.5604	2.66	0.4447	3.16	0.3635	3.66	0.3028
0.17	7.4257	0.67	1.8772	1.17	1.0663	1.67	0.7375	2.17	0.5576	2.67	0.4428	3.17	0.3622	3.67	0.3017
0.18	7.0130	0.68	1.8494	1.18	1.057	1.68	0.7329	2.18	0.5548	2.68	0.4409	3.18	0.3608	3.68	0.3005
0.19	6.6437	0.69	1.8224	1.19	1.0479	1.69	0.7284	2.19	0.5521	2.69	0.439	3.19	0.3594	3.69	0.2996
0.2	6.3113	0.7	1.7951	1.2	1.039	1.7	0.7239	2.2	0.5493	2.7	0.4372	3.2	0.3581	3.7	0.2985
0.21	6.0105	0.71	1.7705	1.21	1.0302	1.71	0.7194	2.21	0.5466	2.71	0.4353	3.21	0.3567	3.71	0.2975
0.22	5.7371	0.72	1.7458	1.22	1.0215	1.72	0.715	2.22	0.5439	2.72	0.4335	3.22	0.3554	3.72	0.2964
0.23	5.4874	0.73	1.7217	1.23	1.013	1.73	0.7105	2.23	0.5413	2.73	0.4317	3.23	0.3541	3.73	0.2954
0.24	5.2585	0.74	1.6982	1.24	1.0045	1.74	0.7053	2.24	0.5385	2.74	0.4299	3.24	0.3527	3.74	0.2944
0.25	5.0480	0.75	1.6753	1.25	0.9953	1.75	0.7021	2.25	0.535	2.75	0.4281	3.25	0.3514	3.75	0.2933
0.26	4.8535	0.76	1.6531	1.26	0.9882	1.76	0.6979	2.26	0.5334	2.76	0.4263	3.26	0.3501	3.76	0.2923
0.27	4.5737	0.77	1.6314	1.27	0.9802	1.77	0.6937	2.27	0.5308	2.77	0.4245	3.27	0.3488	3.77	0.2913
0.28	4.5055	0.78	1.6102	1.28	0.9723	1.78	0.6895	2.28	0.5283	2.78	0.4228	3.28	0.3475	3.78	0.2903
0.29	4.3509	0.79	1.5895	1.29	0.9645	1.79	0.6855	2.29	0.5257	2.79	0.421	3.29	0.3462	3.79	0.2893
0.3	4.2057	0.8	1.5695	1.3	0.9569	1.8	0.6815	2.3	0.5232	2.8	0.4193	3.3	0.3449	3.8	0.2883
0.31	4.0598	0.81	1.5499	1.31	0.9494	1.81	0.6775	2.31	0.5207	2.81	0.4175	3.31	0.3436	3.81	0.2873
0.32	3.9424	0.82	1.5308	1.32	0.942	1.82	0.6735	2.32	0.5183	2.82	0.4159	3.32	0.3424	3.82	0.2863
0.33	3.8227	0.83	1.5122	1.33	0.9347	1.83	0.6696	2.33	0.5158	2.83	0.4142	3.33	0.3411	3.83	0.2853
0.34	3.7101	0.84	1.4939	1.34	0.9257	1.84	0.6658	2.34	0.5134	2.84	0.4125	3.34	0.3398	3.84	0.2843
0.35	3.6038	0.85	1.4761	1.35	0.9204	1.85	0.6619	2.35	0.511	2.85	0.4108	3.35	0.3386	3.85	0.2833
0.36	3.5035	0.86	1.4588	1.36	0.9134	1.86	0.6582	2.36	0.5085	2.86	0.4091	3.36	0.3373	3.86	0.2823
0.37	3.4085	0.87	1.4418	1.37	0.9055	1.87	0.6544	2.37	0.5062	2.87	0.4075	3.37	0.3361	3.87	0.2814
0.38	3.3187	0.88	1.4252	1.38	0.8997	1.88	0.6507	2.38	0.5038	2.88	0.4058	3.38	0.3349	3.88	0.2804
0.39	3.2334	0.89	1.4089	1.39	0.893	1.89	0.647	2.39	0.5015	2.89	0.4042	3.39	0.3336	3.89	0.2794
0.4	3.1523	0.9	1.3931	1.4	0.8854	1.9	0.6434	2.4	0.4992	2.9	0.4025	3.4	0.3324	3.9	0.2785
0.41	3.0752	0.91	1.3775	1.41	0.8799	1.91	0.6398	2.41	0.4969	2.91	0.4009	3.41	0.3312	3.91	0.2775
0.42	3.0018	0.92	1.3523	1.42	0.8735	1.92	0.6353	2.42	0.4945	2.92	0.3993	3.42	0.33	3.92	0.2766
0.43	2.9318	0.93	1.3475	1.43	0.8672	1.93	0.6327	2.43	0.4923	2.93	0.3977	3.43	0.3288	3.93	0.2756
0.44	2.8549	0.94	1.3329	1.44	0.8609	1.94	0.6292	2.44	0.4901	2.94	0.3961	3.44	0.3275	3.94	0.2747
0.45	2.8010	0.95	1.3187	1.45	0.8548	1.95	0.6258	2.45	0.4879	2.95	0.3946	3.45	0.3264	3.95	0.2737
0.46	2.7399	0.96	1.3047	1.46	0.8487	1.96	0.6224	2.46	0.4856	2.96	0.393	3.46	0.3252	3.96	0.2728
0.47	2.6814	0.97	1.2910	1.47	0.8427	1.97	0.619	2.47	0.4835	2.97	0.3914	3.47	0.324	3.97	0.2719
0.48	2.6253	0.98	1.2776	1.48	0.8358	1.98	0.6156	2.48	0.4813	2.98	0.3899	3.48	0.3229	3.98	0.2709
0.49	2.5715	0.99	1.2645	1.49	0.8309	1.99	0.6123	2.49	0.4791	2.99	0.3884	3.49	0.3217	3.99	0.27
0.5	2.5199	1	1.2517	1.5	0.8252	2	0.609	2.5	0.477	3	0.3868	3.5	0.3205	4	0.2691