Supporting information

Ni-doped SnO_2 as electron transport layer by a low-temperature process in planar perovskite solar cells

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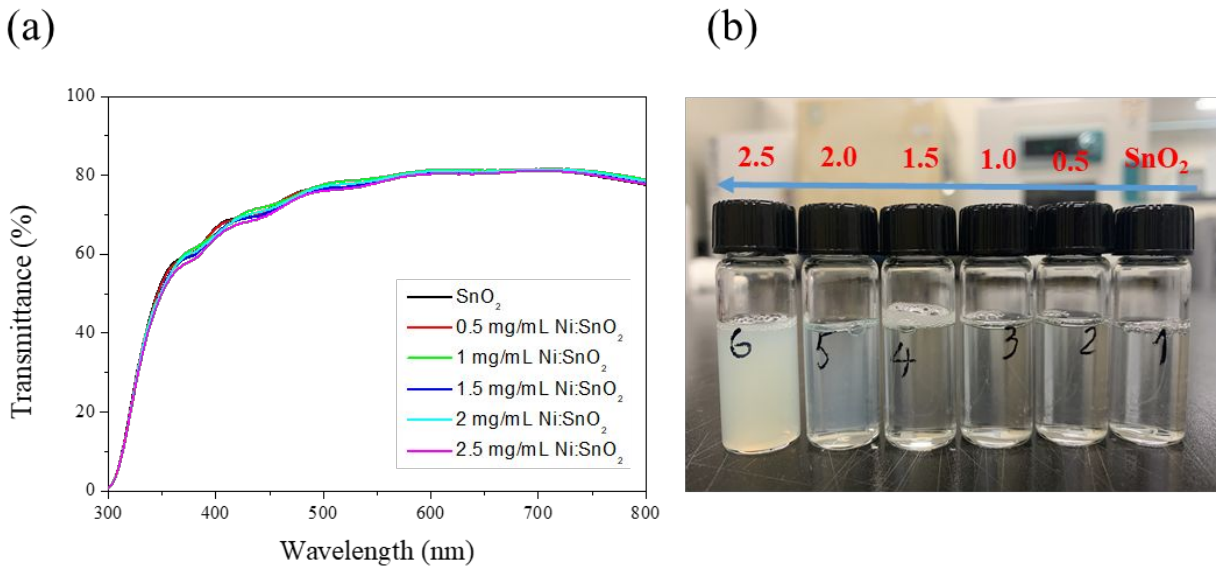

Figure S1. (a) Transmission spectra of 0, 0.5, 1, 1.5, 2, and 2.5 mg mL^{-1} SnO_2 films coated on FTO substrates. (b) Digital images of SnO_2 and different concentration of Ni-SnO_2 nanoparticle solutions.

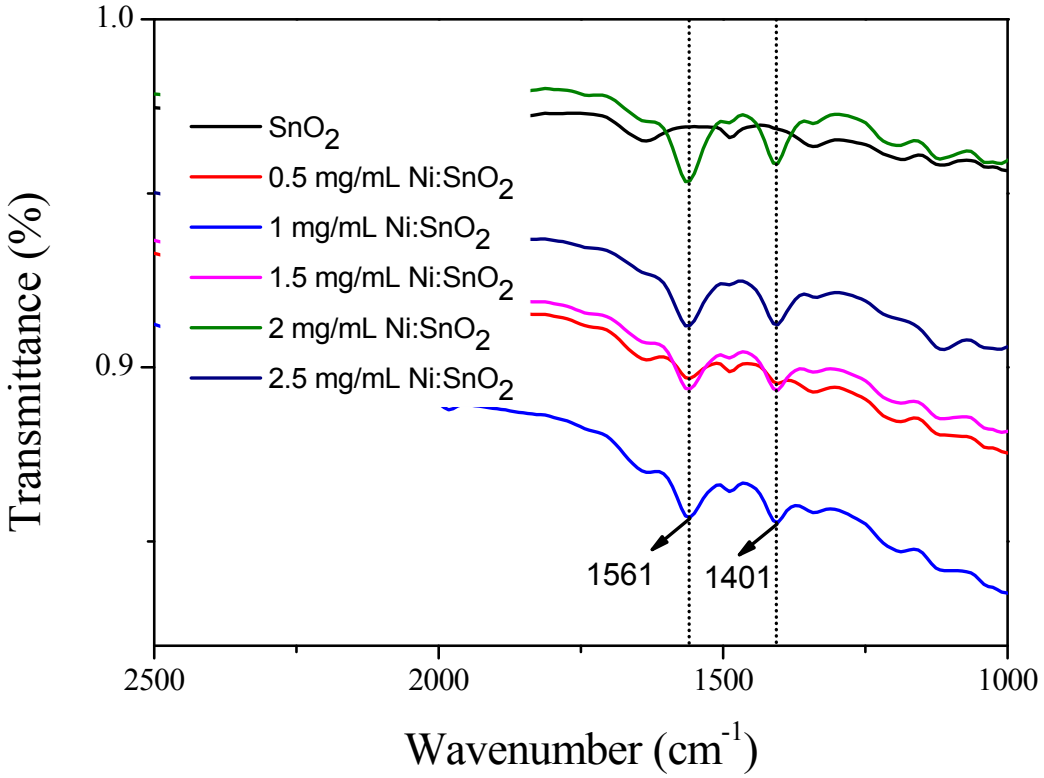

Figure S2. FTIR analysis of SnO_2 and Ni-doped SnO_2 layers at different concentrations.

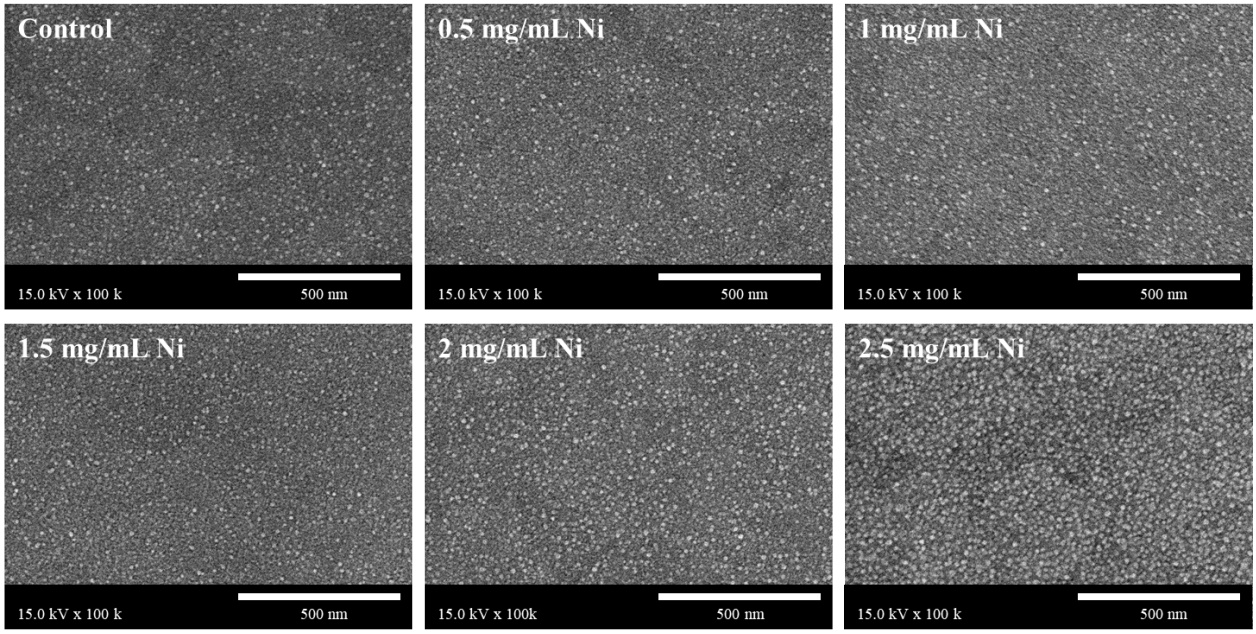

Figure S3. SEM images of SnO_2 and Ni:SnO_2 under different concentrations of Ni^+ doping levels.

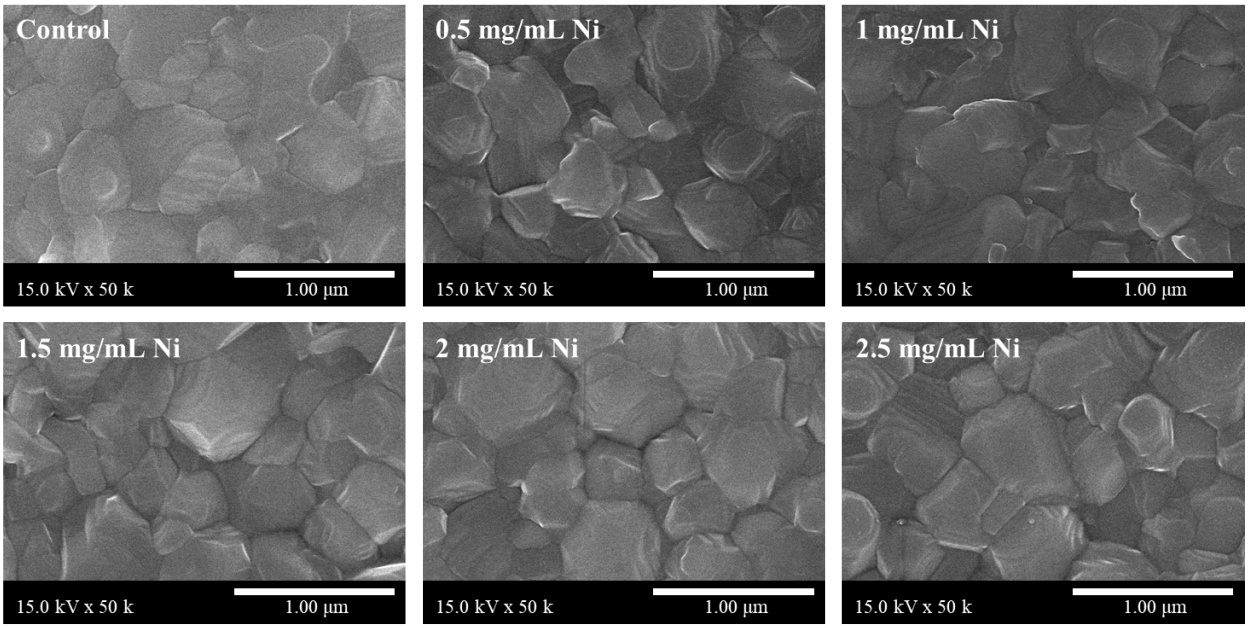

Figure S4. SEM images of perovskite films coated on Ni:SnO_2 films at different concentrations.

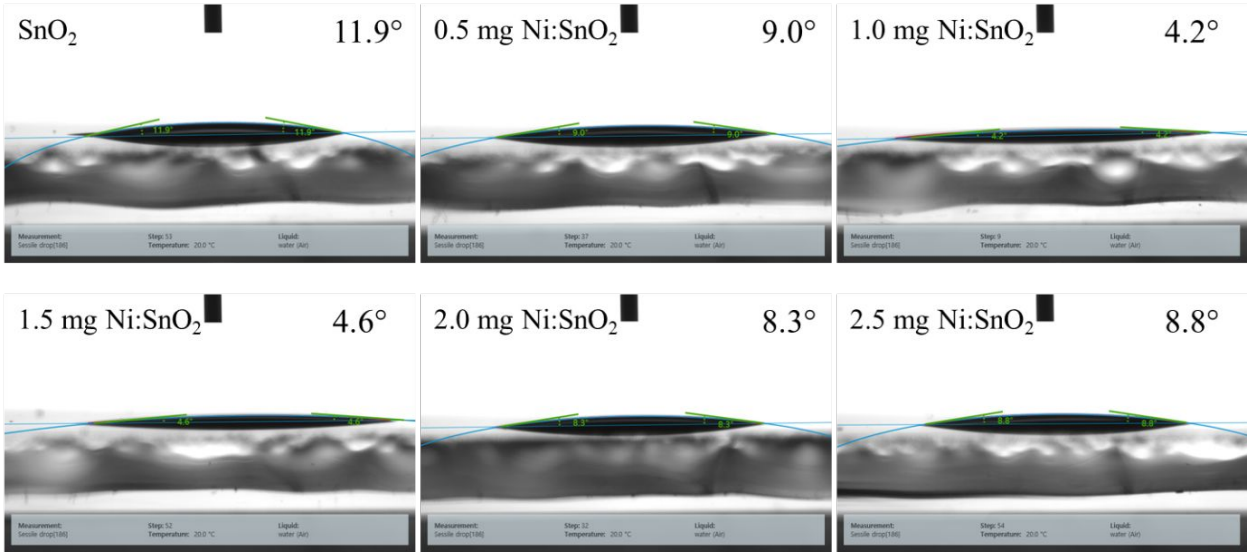

Figure S5. Contact angles of SnO_2 and Ni:SnO_2 films under different concentrations.

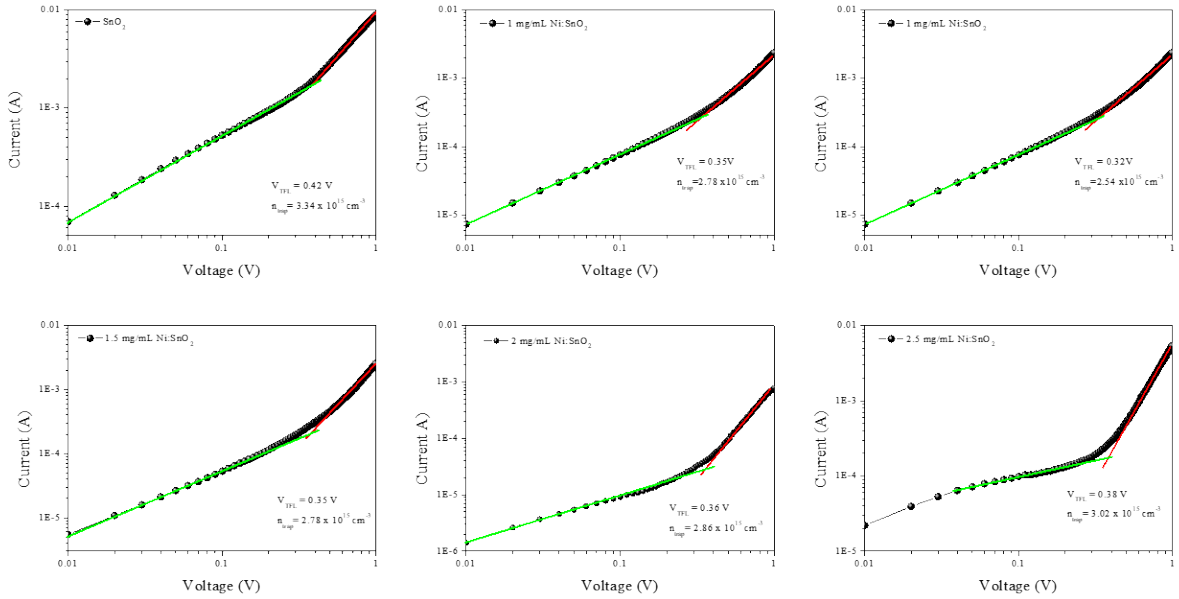

Figure S6. Dark *I-V* curves of the electron-only devices with different ETL.

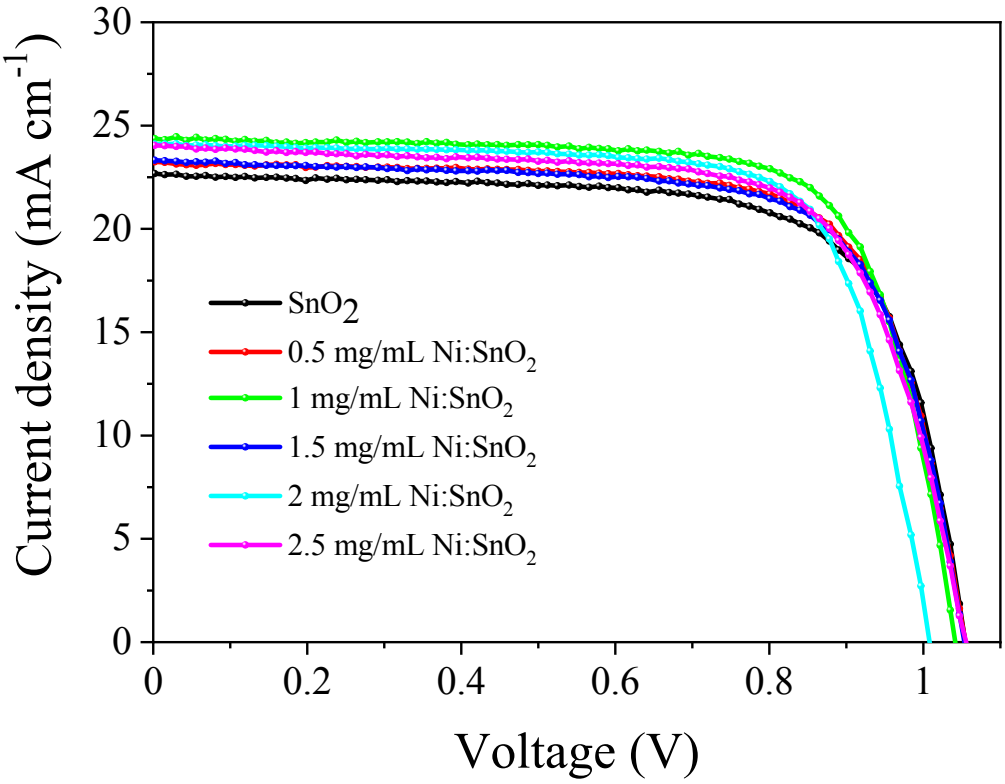

Figure S7. *J-V* curves of the PSCs with different ETLs substrates.

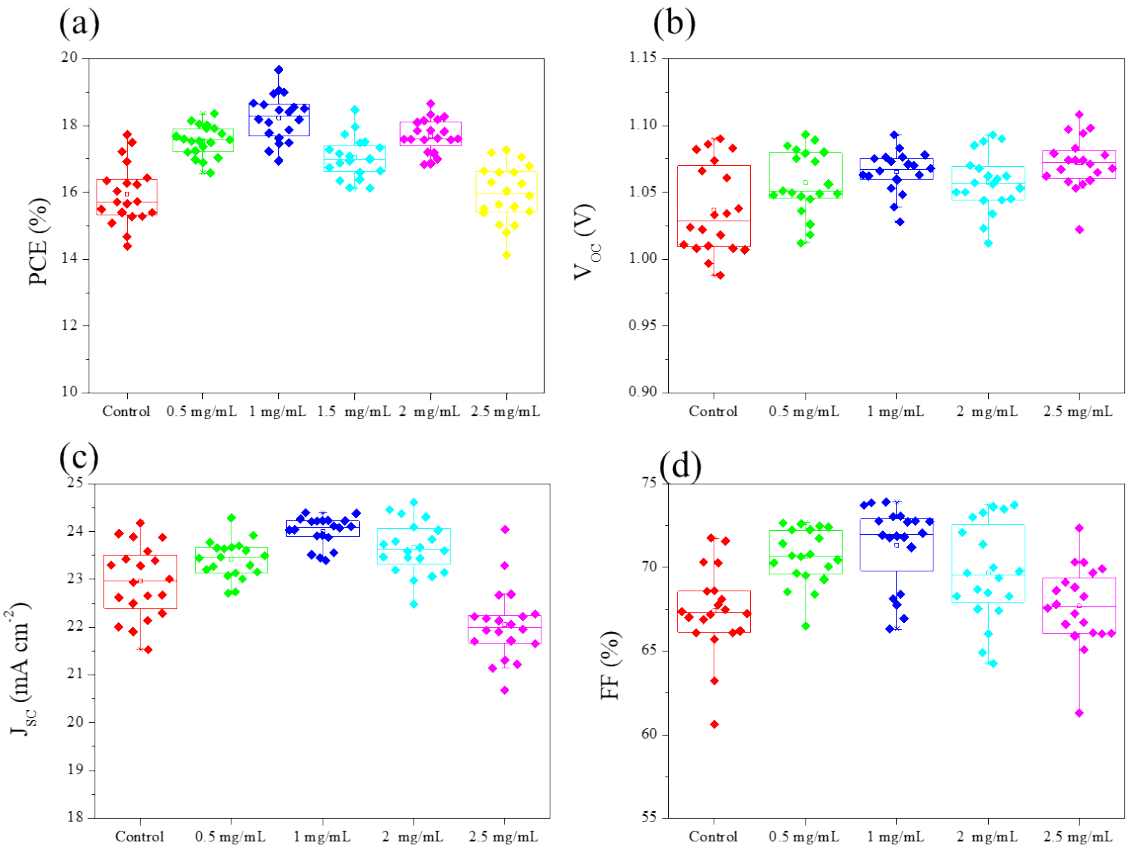

Figure S8. Effects of variation of Ni^{+} content on photovoltaic parameters including (a) PCE, (b) V_{OC}, (c) J_{SC}, and (d) FF.

Table S1. Photovoltaic parameters of the best performance devices based on the Ni:SnO_2 ETL with different Ni^+ contents.

	V_{OC} (V)	J_{SC} (mA cm^{-2})	FF	PCE (%)	Rs ($\Omega \cdot cm^2$)	Rsh ($k\Omega \cdot cm^2$)
Control	1.090	22.67	71.75	17.72	126.64	22529
0.5 mg/mL Ni:SnO_2	1.089	23.26	72.42	18.35	126.59	28803
1 mg/mL Ni:SnO_2	1.093	24.39	73.73	19.6	108.83	34398
2 mg/mL Ni:SnO_2	1.062	23.43	73.63	18.32	100.09	26229
2.5 mg/mL Ni:SnO_2	1.108	22.69	72.35	18.12	18.11	19004

Table S2. The parameters of PSCs on pristine SnO_2 and Ni:SnO_2 ETLs.

SnO_2	V_{OC} (V)	J_{SC} (mA cm^{-2})	FF	PCE (%)	Rs ($\Omega \cdot cm^2$)	Rsh ($k\Omega \cdot cm^2$)
1	1.018	23.284	68.62	16.27	14831	128.10
2	1.01	23.431	67.77	16.03	13870	134.94

3	1.033	23.393	67.18	16.23	14182	136.60
4	1.022	22.136	67.48	15.27	13499	127.28
5	1.034	22.651	66.87	15.65	15712	146.13
6	0.988	23.587	66.10	15.40	10428	136.64
7	1.008	22.944	66.09	15.28	10235	135.41
8	0.997	23.887	68.57	16.34	11319	119.59
9	1.008	23.881	70.28	16.92	13934	111.72
10	1.038	23.957	60.61	15.08	11073	206.64
11	1.007	24.18	63.24	14.39	10444	169.48
12	1.024	23.298	65.69	14.67	11547	152.23
13	1.011	23.008	66.20	15.40	8155	127.56
14	1.074	21.528	67.02	15.49	13628	146.03

15	1.09	22.671	71.75	17.73	22529	126.64
16	1.086	22.497	71.58	17.49	22904	123.35
17	1.083	22.618	70.31	17.22	23366	123.63
18	1.082	22.294	68.10	16.43	12195	118.08
19	1.066	21.911	67.25	15.70	13619	144.01
20	1.061	22.01	67.35	15.72	14432	145.76
Mean	**1.037**	**22.9583**	**67.40**	**15.94**	**14095**	**137.99**
Ni: SnO_2	**V_{OC} (V)**	**J_{SC} (mA cm^{-2})**	**FF**	**PCE (%)**	**Rs ($\Omega \cdot cm^2$)**	**Rsh ($k\Omega \cdot cm^2$)**
1	1.06	24.23	71.88	18.5	17343	106.14
2	1.073	24.23	73.05	19.0	20888	113.00
3	1.076	24.24	73.04	19.0	20869	109.03

4	1.076	24.21	72.72	18.9	17589	109.69
5	1.071	24.12	71.78	18.5	16497	114.90
6	1.066	24.40	67.75	17.6	14814	151.29
7	1.059	24.08	68.40	17.5	10812	116.34
8	1.07	24.27	66.32	17.2	8507	130.15
9	1.028	23.40	73.91	17.8	23172	106.17
10	1.083	23.92	71.83	18.6	31150	132.18
11	1.075	23.91	71.94	18.5	24940	122.15
12	1.063	23.89	71.21	18.1	18817	124.28
13	1.062	24.22	66.94	17.2	15006	150.73
14	1.078	23.45	72.78	18.4	25289	120.95
15	1.063	23.52	72.77	18.2	36216	126.60

16	1.053	23.56	72.04	17.9	23882	131.58
17	1.068	24.04	68.12	17.5	25302	172.27
18	1.048	24.11	73.87	18.7	27977	110.90
19	1.039	24.03	72.76	18.2	28958	117.52
20	1.093	24.38	73.74	19.7	34399	108.83
Mean	**1.065**	**24.01**	**71.34**	**18.25**	**22121**	**123.73**