Electronic Supplementary Information for:

A large-volume manufacturing of multi-crystalline silicon solar cells with 18.8% efficiency incorporating practical advanced technologies

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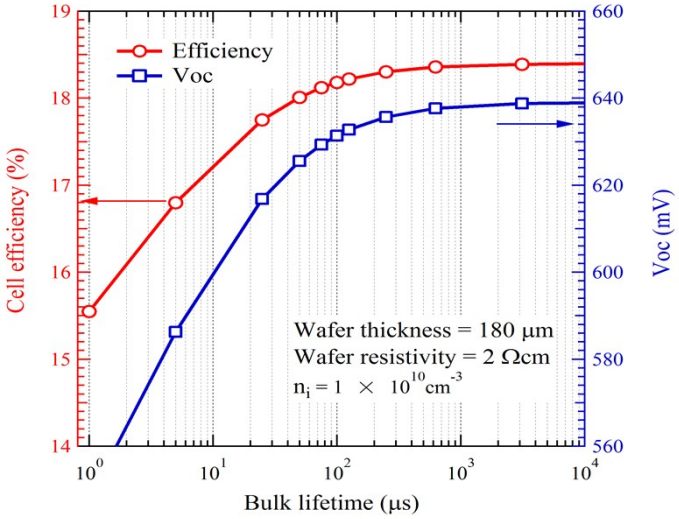

Figure S1. Simulated cell efficiency and V_{oc} as a function of bulk lifetime for conventional solar cells with Al-BSF.

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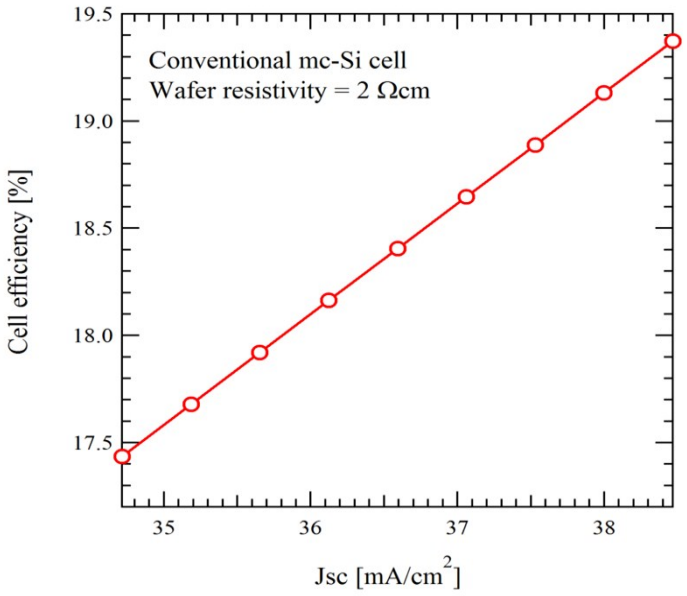

Figure S2. Simulated cell efficiency for conventional mc-Si solar cells as a function of J_{sc}.

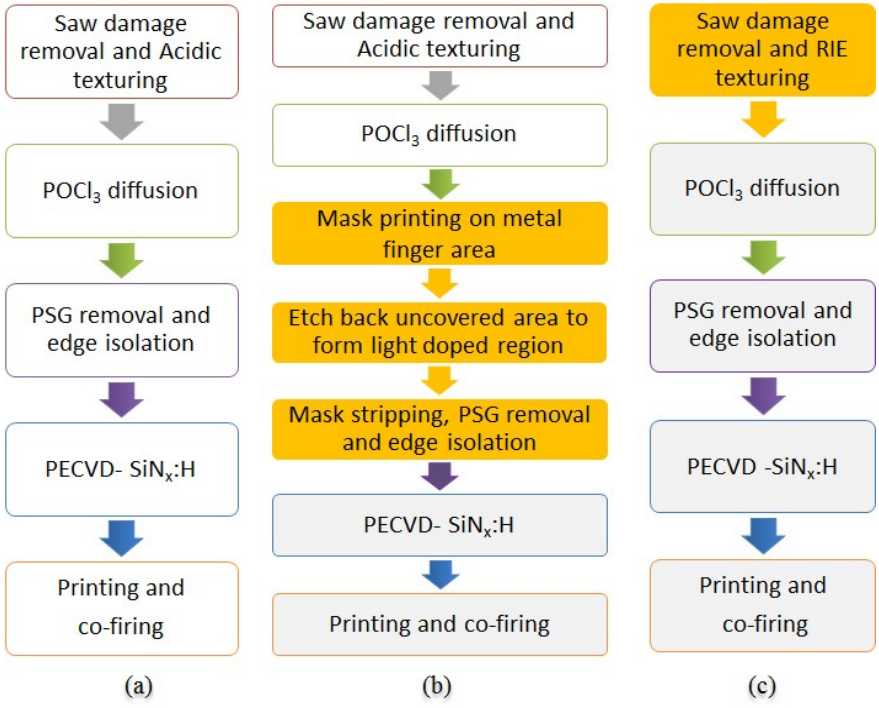

Figure S3. Different cell fabrication processes (a) standard cells,(b) cells with SE structure and (c) cells with RIE texture.

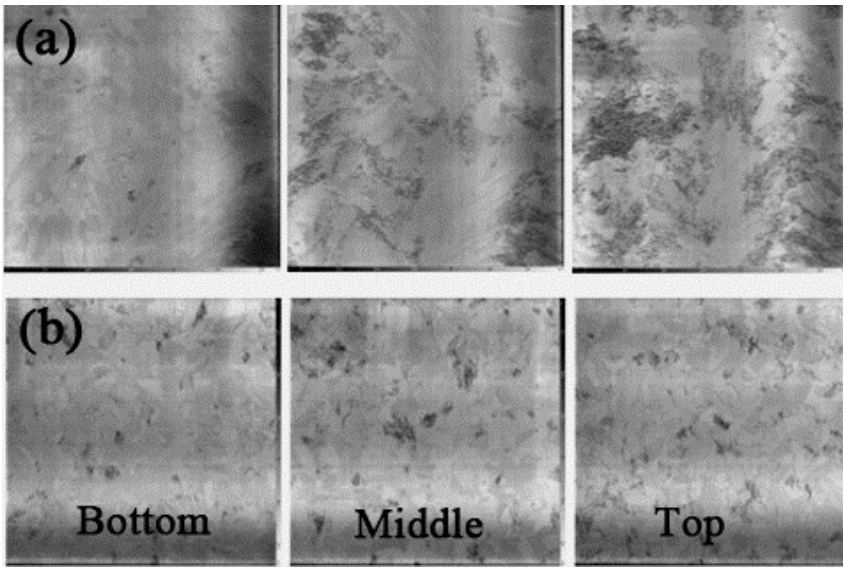

Figure S4. PL mapping of the mc-Si wafers at different positions of the ingots from (a) conventional and (b) grain-size controlled growth.

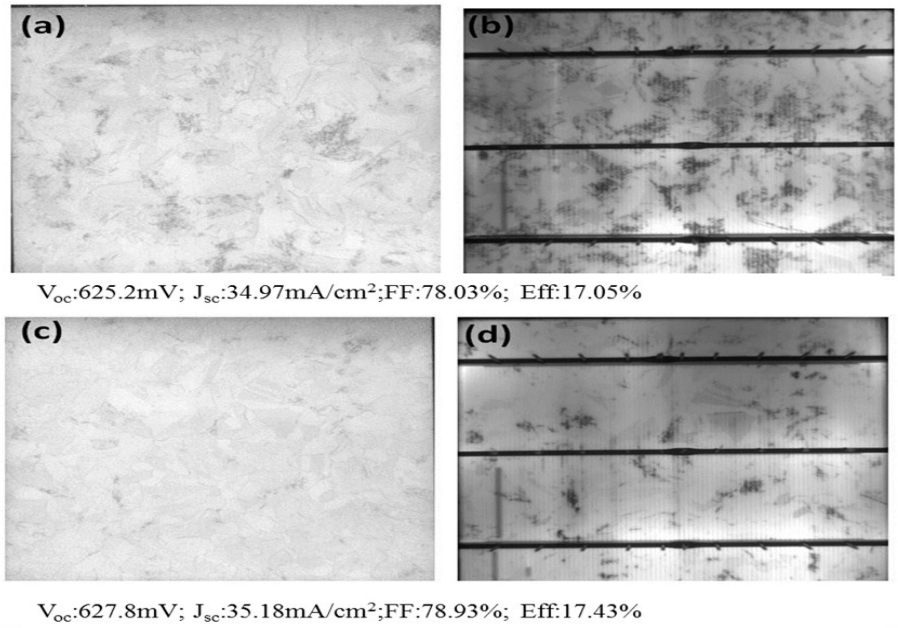

Figure S5. PL and EL images of mc-Si wafer and cell: (a) represents the PL image of a standard wafer, (b) is the EL image of the same wafer after cell processing, (c) represents the PL image of a wafer fabricated with the grain-size controlled growth and (d) is the EL image of the same wafer after solar cell fabrication.

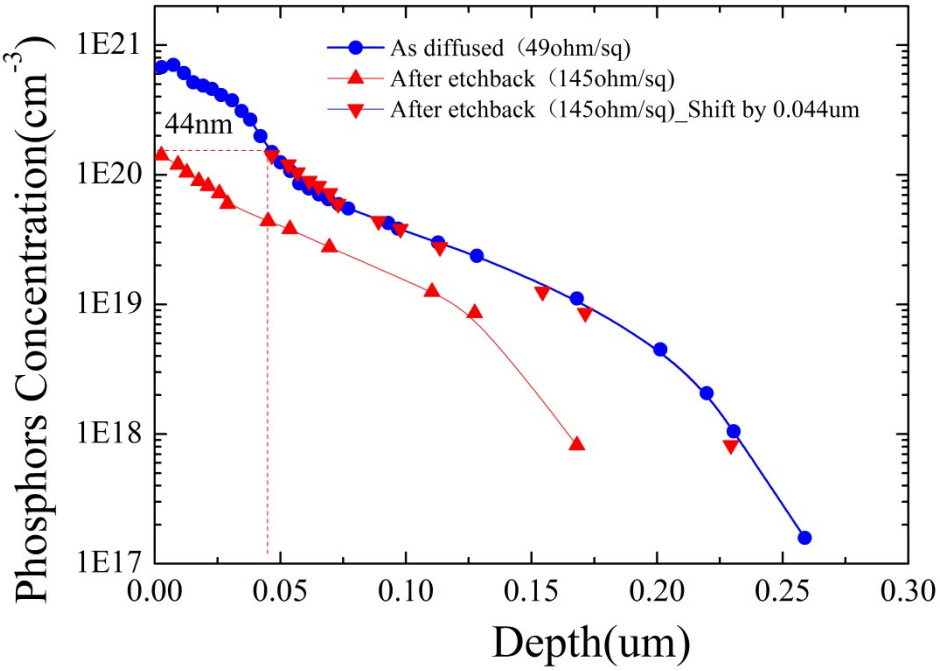

Figure S6. Phosphorus dopant concentration as a function of depth for as doped (blue) and after etch back (red) by ECV with non-textured monocrystalline wafer.

Table S1. The average electrical performance of solar cells with different wafer types.

Wafer source	Samples	J_{sc}(mA/cm^2)		V_{oc} (mv)		*FF*(%)		*Eff.*(%)	
		Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
Standard mc-Si	465	34.96	0.0792	621.9	0.00404	78.37	0.326	17.05	0.331
Grain-size controlled mc-Si	470	35.18	0.056	627.8	0.00249	78.83	0.317	17.43	0.182

Table S2. Cell electrical parameters vs. initial sheet resistance.

Initial sheet resistance(Ω/□)	Samples	J_{sc}(mA/cm^2)		V_{oc} (mv)		*FF*(%)		*Eff.*(%)	
		Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
40	893	35.84	0.035	630	0.0023	78.31	0.248	17.69	0.144
50	974	36	0.034	631.3	0.0022	78.33	0.237	17.83	0.138
60	890	35.88	0.044	631.1	0.0027	78.34	0.297	17.74	0.178

Table S3. Cell parameters vs. post-etchback sheet resistance.

Post-etchback sheet resistance(Ω/□)	Samples	J_{sc}(mA/cm^2)		V_{oc} (mv)		*FF*(%)		*Eff.*(%)	
		Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
90	472	35.95	0.0318	630.1	0.0019	78.76	0.207	17.85	0.119
110	458	35.97	0.0323	631.5	0.0023	78.49	0.345	17.83	0.139
130	478	36.01	0.0334	631.7	0.0023	78.36	0.367	17.825	0.135

Table S4. Comparison of cell performance between homogeneous and selective emitter.

Emitter Type	Samples	J_{sc}(mA/cm^2)		V_{oc} (mv)		*FF*(%)		*Eff.*(%)	
		Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
Homogeneous emitter	482	35.18	0.056	627.8	0.00249	78.83	0.317	17.43	0.182
Selective emitter	473	35.79	0.0469	631.1	0.00237	78.92	0.3271	17.78	0.1639

Table S5. Efficiency of RIE without DRC vs. acid texturing.

Texturing conditions	Samples	J_{sc}(mA/cm^2)		V_{oc}(mv)		*FF*(%)		*Eff.*(%)	
		Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
Standard Acid Texturing	493	34.52	0.0832	619.3	0.00413	78.6	0.346	16.67	0.3405
RIE without DRC	485	34.95	0.0853	617.3	0.00421	79.1	0.302	16.89	0.3323

Table S6. The impact of different reflectances on cell parameter.

Texturing conditions	Samples	J_{sc}(mA/cm^2)		V_{oc} (mv)		*FF*(%)		*Eff.*(%)	
		Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
Standard Acid Texturing	199	34.25	0.0882	615.2	0.0041	78.2	0.316	16.47	0.324
Reflectance 9% with RIE	220	35.17	0.0734	614.8	0.0038	77.9	0.282	16.85	0.278
Reflectance 6% with RIE	216	35.26	0.0846	615.4	0.0038	78.0	0.269	16.92	0.288
Reflectance 4% with RIE	222	35.34	0.0935	615.9	0.004	78.1	0.3	16.93	0.32

Table S7. The impact of DRC time.

Texturing conditions	Samples	J_{sc}(mA/cm^2)		V_{oc} (mv)		*FF*(%)		*Eff.*(%)	
		Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
Standard Acid Texturing	175	34.11	0.1092	617.1	0.005	78.3	0.518	16.48	0.369
Reflectance 11% after DRC 20sec	159	35.22	0.1034	617.5	0.0047	78.6	0.42	17.09	0.376
Reflectance 15% after DRC 35sec	148	35.21	0.1086	617.8	0.0044	78.6	0.574	17.1	0.372
Reflectance 18% after DRC 50sec	158	35.15	0.0968	618.9	0.0049	78.6	0.414	17.11	0.347
Reflectance 19.3% after DRC 70sec	160	35.01	0.1165	618.2	0.0051	78.3	0.58	16.96	0.411

Table S8. Cell parameters with integration of multiple technologies.

Process conditions	Samples	J_{sc}(mA/cm^2)		V_{oc} (mv)		*FF*(%)		*Eff.*(%)	
		Average	STDEV	Average	STDEV	Average	STDEV	Average	STDEV
Standard solar cells	9951	35.01	0.0821	621.5	0.00394	78.6	0.321	17.07	0.3111
Multiple technologies	9794	36.32	0.0512	638.7	0.0024	80.37	0.2532	18.65	0.1435
Multiple technologies	Maxium	36.67	-	639.5	-	80.31	-	18.84	-