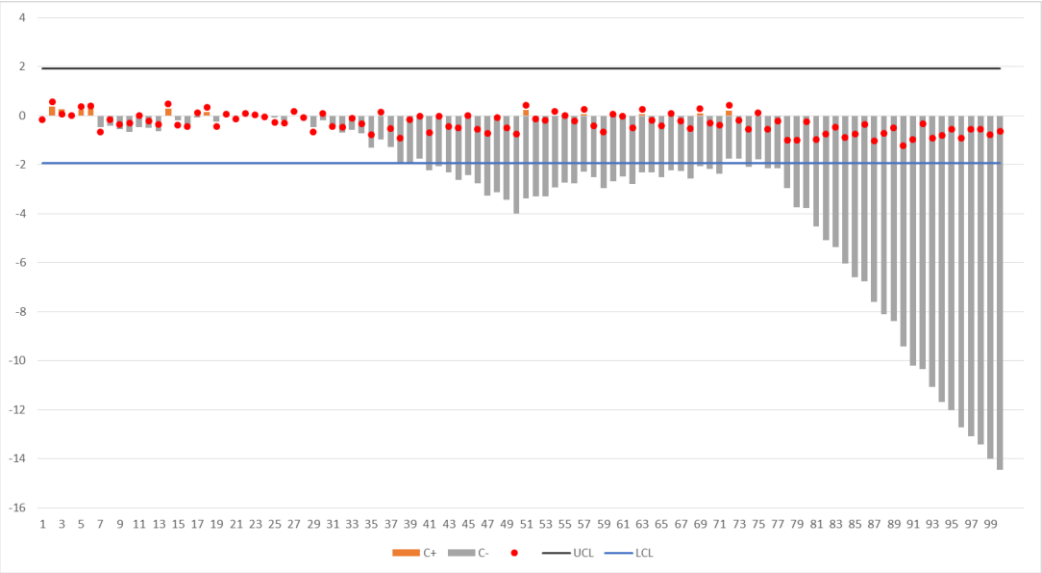
1.

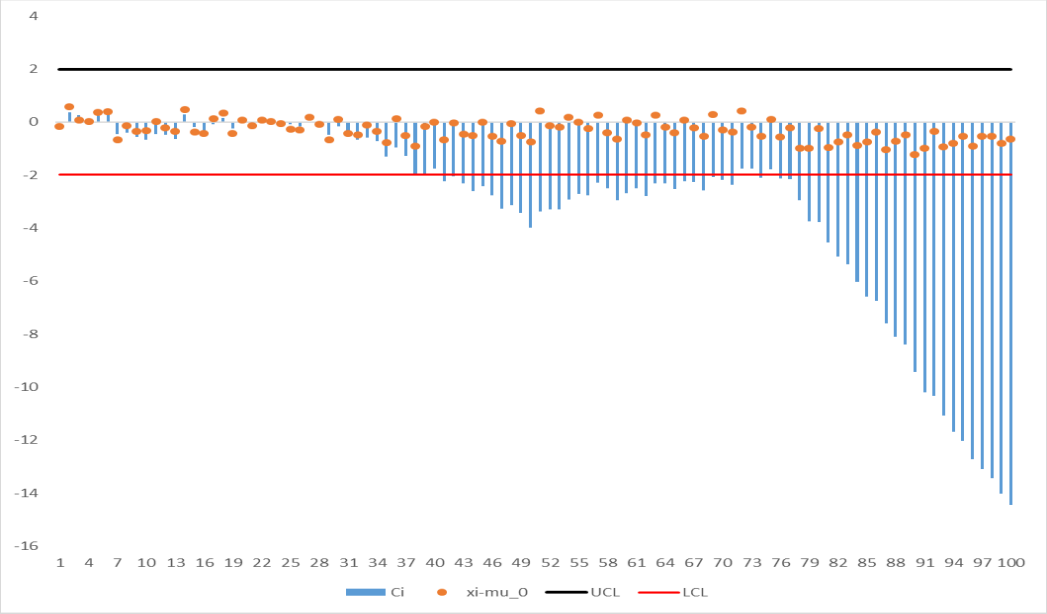
(i) 由於在(ii)中需要比較 CD_site3 的分布狀況，且設定$\mu_0 = 59.5$，因此在這個題目中也以同樣的設定進行後續的數據處理。已知$\mu_0 = 59.5$，$\sigma_{CD\ site3} = 0.39688$的設定下，在最佳化的 optimal Tabular CUSUM 的參數設計中，當$ARL_0 = 400$，偏移量$\delta = 1\sigma$，可得到$k^* = 0.5$、$h^* = 4.8428$、K=0.19844、H=1.92203。討論不同偏移量對 ARL 的影響整理於下表：

shift	ARL
0*sigma	400
0.5*sigma	16.3949
1*sigma	10.0225
1.5*sigma	7.123
2*sigma	5.5088
2.5*sigma	4.4871
3*sigma	3.7836

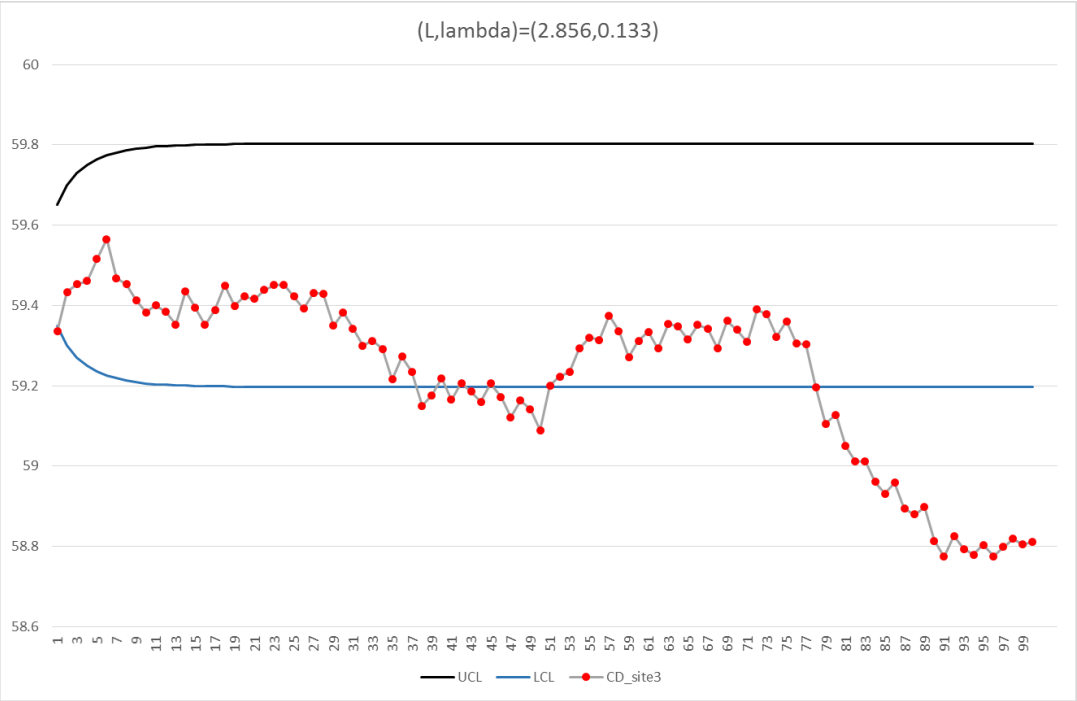
(ii) 承(i)，根據(i)中的參數設計上下界，可得 UCL=1.92203、LCL=-1.922，所繪出的 optimal graphical Tabular CUSUM chart of CD_site3 如下圖所示：

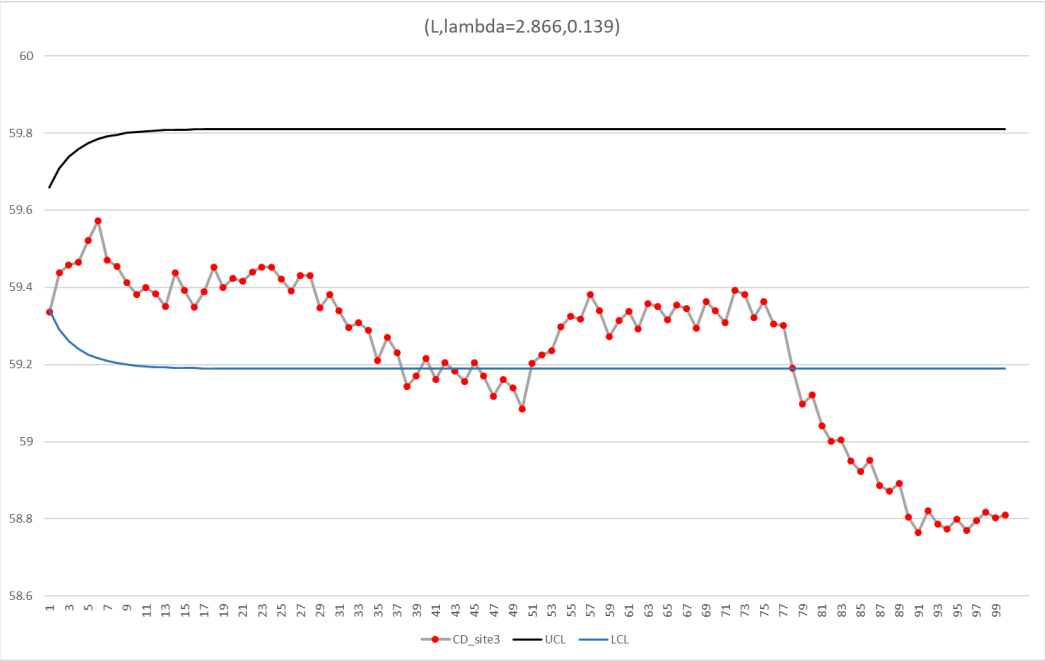


與 HW7-2-vii 相比，該圖的參數 K=0.5σ = 0.19844，H=1.984405，與 optmal 的 CUSUM 相近，因此圖形差距並不大，敏感度相似。

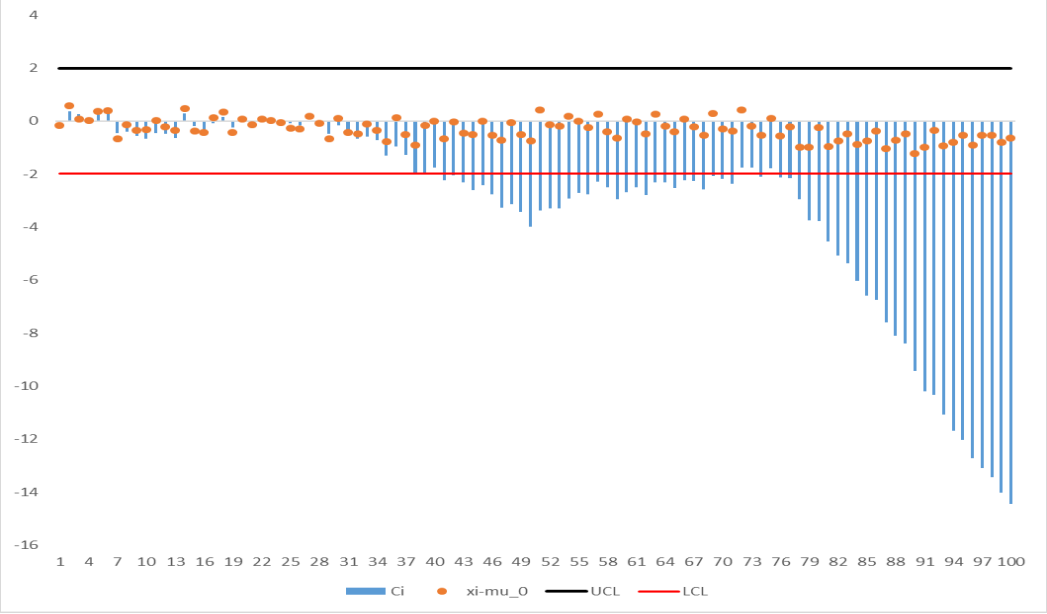


(iii) 當$\mu_0 = 59.5$，當(L,λ)=(2.856, 0.133)時，可求出 UCL=59.6508，LCL=59.3492，及$(L,\lambda) = (2.866, 0.139)$，可求出 UCL=59.65810、LCL=59.3419。將 CD_site3 以$Z_i = \lambda Z_i + (1-\lambda)Z_{i-1}$處理後，匯出 EWMA 如下圖：





比較兩組 EWMA 與 HW_7-2-(vii)，會發現 EWMA 的敏感度較 CUSM 來的低，且由於對於記憶的長度較短，叫先的數據會被權重所調整到較小，因此會超出上下界的 sample 數較少。

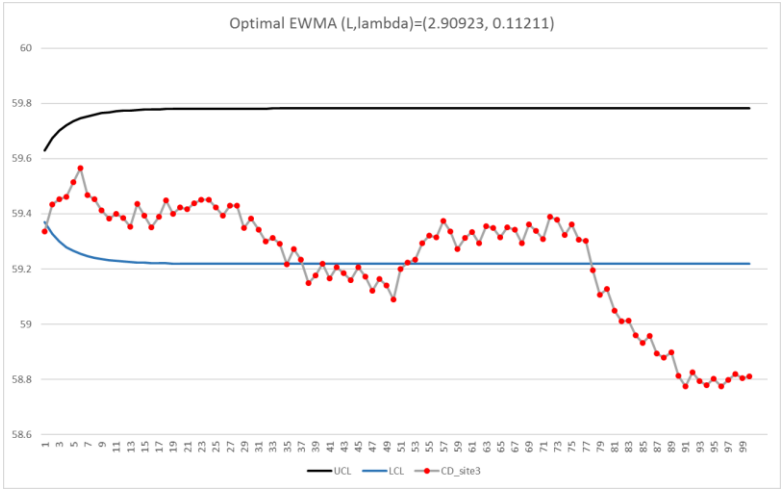


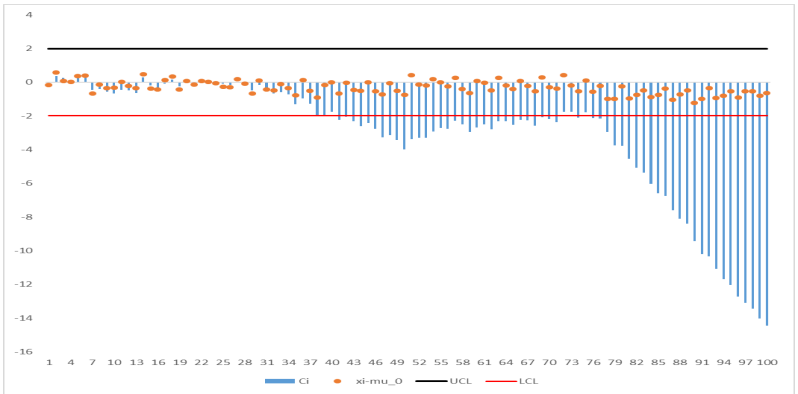
(iv) 將偏移量同為δ = 1σ、ARL_0=400 的 optimal CUSUM 與 EWMA 在不同偏移量的 ARL 進行比較，可得到結果如下：

shift	ARL(CUSUM)	ARL(EWMA)	CUSUM/EWMA
0*sigma	400	400	1
0.5*sigma	16.3949	35.27048	0.464833
1*sigma	10.0225	9.150579	1.095286
1.5*sigma	7.123	4.31356	1.651304
2*sigma	5.5088	2.620604	2.102111
2.5*sigma	4.4871	1.837006	2.442615
3*sigma	3.7836	1.411349	2.68084

如表所示，可以看到 EWMA 除了在偏移量為0.5σ時 ARL_1 較長，其餘的偏移量中 ARL_1 皆較短。

(v) 比較 optimal EWMA 與(ii)中所得到的結果，如下圖所示:





如圖所示，EWMA 對於同一筆資料的判定，出界的機會較小，可見敏感度較 CUSUM 來的低。

2.

(i) 考量 target value=60，specific window=(58,61)，針對所有晶元的 CD_site 的統計結果，可得 mean=59.77544、$\sigma = 0.537814$，求出對應的所求如下：

Cp	0.92969
Cpk	0.75897
Cpm	0.85791
Cpm*	0.57194

若要使$C_p = 2.0$，及表示在工程規格不變情況下，樣本的標準差需要變小。考量製程的流程，可以考慮加速晶圓在爐中的旋轉，使每個方向的加熱爐子在溫度控制上的偏差對每個 CD site 厚度的偏差影響最小。

(ii) 考量每個 CD site 的分布狀態，可將所需參數整理於下表：

	CD site 1	CD site 2	CD site 3	CD site 4	CD site 5
mean	60.270114	59.8406	59.1976	60.0325	59.5364
std.s	0.36578622	0.29582	0.39688	0.52637	0.29799
Cp	1.36691864	1.69023	1.25982	0.94991	1.6779
Cpk	0.66512985	1.30648	1.51381	0.61266	1.63718
Cpm	1.09960209	1.48788	0.55854	0.9481	0.90726
Cpm*	0.73306806	0.99192	0.37236	0.63207	0.60484
P>UXL	0.0230002	4.4E-05	2.8E-06	0.03303	4.5E-07
P<LSL	2.7154E-10	2.5E-10	0.00127	5.6E-05	1.3E-07
out of spec(%)	2.30002046	0.00444	0.12771	3.30886	5.8E-05

若要使$C_p = 2.0$，及表示在工程規格不變情況下，樣本的標準差需要變小。考量製程的流程，可以調整三個方向的爐子的垂直溫度分部，使每個方向的加熱爐子在溫度上的偏差對同一個 CD site 厚度的偏差影響最小。

(iii) 考量每個 wafer 內的 CD site 分布狀態，可將所需參數整理於下

表：

	CD_site1	CD_site2	CD_site3	CD_site4	CD_site5	mean	sigma	**Cp**	**Cpk**	**Cpm**	**Cpm***	sigma tilda
1	60.5162	59.837	59.3353	60.6154	59.5903	59.97884	0.565506	**0.884163**	**0.601915**	**0.883545**	**0.58903**	0.565902163
2	61.1069	60.2251	60.0777	61.0384	60.07	60.50362	0.523675	**0.95479**	**0.315959**	**0.688188**	**0.458792**	0.726546001
3	60.4273	60.0916	59.5779	59.667	59.6652	59.8858	0.362945	**1.377619**	**1.023296**	**1.314104**	**0.876069**	0.380487405
4	60.4573	60.1561	59.511	60.5301	59.5017	60.03124	0.49926	**1.001483**	**0.646798**	**0.999528**	**0.666352**	0.50023606
5	61.0794	60.097	59.8724	61.0229	60.1698	60.4483	0.561491	**0.890487**	**0.327521**	**0.695893**	**0.463928**	0.718501684
6	60.7286	60.6621	59.8892	60.1159	60.0329	60.28574	0.383337	**1.304335**	**0.621089**	**1.045772**	**0.697181**	0.478115802
7	60.1703	59.4637	58.8379	60.2597	59.6426	59.67484	0.577414	**0.865929**	**0.764996**	**0.754519**	**0.503013**	0.662673754
8	60.5165	59.7269	59.3544	60.4725	59.7791	59.96988	0.506377	**0.987406**	**0.678098**	**0.985664**	**0.657109**	0.507272379
9	60.2833	60.0219	59.1502	59.5856	59.3892	59.68604	0.46229	**1.081572**	**0.947428**	**0.894738**	**0.596492**	0.558822794
10	60.2231	59.8091	59.1907	60.5211	59.821	59.913	0.501728	**0.996556**	**0.722171**	**0.981903**	**0.654602**	0.509215112
11	60.6078	59.689	59.5104	60.4594	59.6853	59.99038	0.503853	**0.992353**	**0.667933**	**0.992172**	**0.661448**	0.503944914
12	60.0584	60.0024	59.2832	59.548	59.4336	59.66512	0.34699	**1.440963**	**1.282342**	**1.036848**	**0.691232**	0.482230989
13	60.3702	59.9263	59.147	60.4912	59.7085	59.92864	0.541035	**0.924154**	**0.660068**	**0.916219**	**0.610813**	0.545721122
14	60.7709	60.0212	59.9744	60.8368	59.7676	60.27418	0.493397	**1.013383**	**0.490356**	**0.885802**	**0.590535**	0.564460126
15	60.2213	59.9153	59.1201	59.5834	59.6324	59.6945	0.410002	**1.219507**	**1.061377**	**0.977892**	**0.651928**	0.511303936
16	60.1331	59.7331	59.0737	60.5905	60.0352	59.91312	0.561064	**0.891164**	**0.645725**	**0.880668**	**0.587112**	0.56775084
17	60.8244	60.132	59.6342	60.7432	59.7215	60.21106	0.556338	**0.898735**	**0.472699**	**0.840297**	**0.560198**	0.595027555
18	60.595	60.5702	59.8446	60.2178	60.0275	60.25102	0.330318	**1.513693**	**0.755817**	**1.205183**	**0.803455**	0.414874755
19	60.1519	59.4849	59.0719	60.2875	59.4354	59.68632	0.514593	**0.971641**	**0.85095**	**0.829653**	**0.553102**	0.602661907
20	60.7326	59.9997	59.5767	60.8255	60.1118	60.24926	0.52421	**0.953817**	**0.477379**	**0.861396**	**0.574264**	0.580453418
21	60.4442	60.2798	59.3721	59.8496	59.6713	59.9234	0.439086	**1.138729**	**0.817304**	**1.121787**	**0.747858**	0.445717506
22	60.558	60.2308	59.5891	60.6294	59.5795	60.11736	0.509306	**0.981729**	**0.577675**	**0.956659**	**0.637772**	0.522652535
23	60.5452	59.663	59.5301	60.4405	59.7173	59.97922	0.475242	**1.052096**	**0.715973**	**1.051092**	**0.700728**	0.475695749
24	60.1812	60.1585	59.455	59.8311	59.5849	59.84214	0.328336	**1.522832**	**1.175484**	**1.372446**	**0.914964**	0.364313097

25	60.4656	59.7521	59.2296	60.3784	59.5816	59.88146	0.529089	**0.945021**	**0.704696**	**0.92216**	**0.614773**	0.542205523
26	60.2171	59.7928	59.1992	60.1462	59.4706	59.76518	0.43511	**1.149136**	**0.945984**	**1.011266**	**0.674177**	0.494429787
27	60.679	60.0312	59.676	60.6946	59.7498	60.16612	0.493478	**1.013217**	**0.563268**	**0.960268**	**0.640179**	0.520687955
28	60.2856	60.5364	59.4284	59.7468	59.9994	59.99932	0.435926	**1.146983**	**0.765175**	**1.146981**	**0.764654**	0.435926891
29	60.1287	59.5274	58.8267	60.1089	59.3138	59.5811	0.552696	**0.904657**	**0.855745**	**0.720975**	**0.48065**	0.693505548
30	60.3301	59.6917	59.6014	60.3998	59.7271	59.95002	0.382335	**1.307752**	**0.915409**	**1.29672**	**0.86448**	0.385588287
31	60.0879	60.0963	59.0748	59.5287	59.5093	59.6594	0.434702	**1.150213**	**1.027984**	**0.905396**	**0.603597**	0.552244728
32	60.0727	59.9255	59.0265	60.2185	59.3554	59.71972	0.507199	**0.985806**	**0.841405**	**0.862828**	**0.575219**	0.5794895
33	60.498	59.7675	59.3883	60.5243	59.7895	59.99352	0.498806	**1.002395**	**0.672593**	**1.00231**	**0.668207**	0.498847644
34	59.4544	60.016	59.1644	59.3925	59.5823	59.52192	0.314996	**1.587322**	**1.564126**	**0.873327**	**0.582218**	0.572523313
35	60.1139	59.6413	58.7204	60.1391	59.1041	59.54376	0.624545	**0.800583**	**0.777227**	**0.646461**	**0.430974**	0.773441294
36	60.522	60.1795	59.6401	60.5544	59.8519	60.14958	0.403626	**1.238772**	**0.702318**	**1.161573**	**0.774382**	0.430450652
37	59.7652	59.8195	58.9894	59.1156	59.3309	59.40412	0.375339	**1.33213**	**1.24698**	**0.709986**	**0.473324**	0.704238746
38	59.9665	59.4009	58.5957	59.9417	59.2954	59.44004	0.56218	**0.889395**	**0.853843**	**0.63014**	**0.420093**	0.793474385
39	60.315	59.7813	59.3492	60.4984	59.5098	59.89074	0.499901	**1.000197**	**0.739653**	**0.977131**	**0.651421**	0.511702106
40	60.2152	60.5287	59.4928	59.5033	59.5491	59.85782	0.482709	**1.03582**	**0.788729**	**0.993615**	**0.66241**	0.503212956
41	59.9982	59.458	58.8212	60.1166	59.4356	59.56592	0.518014	**0.965226**	**0.922807**	**0.739817**	**0.493211**	0.675842836
42	60.5297	59.932	59.4729	60.5895	59.8498	60.07478	0.475697	**1.051089**	**0.648326**	**1.038338**	**0.692225**	0.481538872
43	60.144	59.9978	59.0518	59.4021	59.5434	59.62782	0.44531	**1.122815**	**1.027136**	**0.861533**	**0.574355**	0.580360685
44	60.122	59.8533	58.9922	60.1449	59.6087	59.74422	0.474094	**1.054643**	**0.882933**	**0.928175**	**0.618783**	0.538691475
45	60.4647	59.7804	59.5009	60.3826	59.597	59.94512	0.449167	**1.113172**	**0.782842**	**1.104955**	**0.736637**	0.452507184
46	59.9181	60.1042	58.9603	59.3132	59.7741	59.61398	0.46803	**1.068307**	**0.98713**	**0.824154**	**0.549436**	0.606682567
47	60.1301	59.6912	58.7914	60.1733	59.1663	59.59046	0.604043	**0.827756**	**0.777837**	**0.68513**	**0.456754**	0.72978815
48	60.5612	60.0876	59.4339	60.4631	59.6897	60.0471	0.485475	**1.029919**	**0.654273**	**1.025106**	**0.683404**	0.487754472
49	59.909	59.9883	58.9976	59.3183	59.5051	59.54366	0.412806	**1.211224**	**1.175969**	**0.812547**	**0.541698**	0.61534916

50	59.9923	59.6489	58.7464	59.9598	59.1805	59.50558	0.535207	**0.934219**	**0.930744**	**0.686222**	**0.457482**	0.728626896
51	61.1043	60.2049	59.9318	60.8897	60.1532	60.45678	0.509389	**0.981567**	**0.355471**	**0.730784**	**0.487189**	0.684196993
52	60.2295	60.1278	59.3683	59.8139	59.856	59.8791	0.335534	**1.49016**	**1.113547**	**1.40193**	**0.93462**	0.356651223
53	60.7804	59.8067	59.3023	60.5773	59.8628	60.0659	0.604888	**0.826599**	**0.514751**	**0.821737**	**0.547824**	0.608467472
54	60.75	59.8935	59.6791	60.8414	59.7007	60.17294	0.575502	**0.868806**	**0.479036**	**0.83205**	**0.5547**	0.600925384
55	60.4551	60.2238	59.5004	59.8055	59.6599	59.92894	0.398451	**1.254859**	**0.89602**	**1.235367**	**0.823578**	0.404737985
56	60.3195	59.6306	59.271	60.451	59.2571	59.78584	0.5692	**0.878425**	**0.711032**	**0.822158**	**0.548105**	0.608155925
57	60.9673	59.9522	59.7689	60.7041	60.0878	60.29606	0.513948	**0.972861**	**0.456557**	**0.842997**	**0.561998**	0.593122135
58	59.9257	59.8448	59.0864	59.4422	59.4461	59.54904	0.341099	**1.46585**	**1.417927**	**0.88428**	**0.58952**	0.565432051
59	60.1783	59.433	58.8502	60.1406	59.2821	59.57684	0.573399	**0.871993**	**0.827323**	**0.70162**	**0.467747**	0.712636709
60	60.2875	59.8001	59.5783	60.5469	59.4142	59.9254	0.478247	**1.045484**	**0.748985**	**1.032992**	**0.688661**	0.484030794
61	60.4904	60.0207	59.4813	59.6934	59.8112	59.8994	0.383737	**1.302974**	**0.956036**	**1.260383**	**0.840255**	0.396704859
62	60.0325	59.7698	59.0168	59.8108	59.2889	59.58376	0.417107	**1.198734**	**1.131797**	**0.848514**	**0.565676**	0.589265357
63	60.8831	60.1294	59.7628	60.6326	59.7229	60.22616	0.518194	**0.96489**	**0.49778**	**0.884335**	**0.589557**	0.565396461
64	60.0526	59.936	59.3005	59.5552	59.4016	59.64918	0.330424	**1.513209**	**1.362715**	**1.0375**	**0.691666**	0.481927883
65	60.4184	59.5606	59.1009	60.2908	59.467	59.76754	0.564574	**0.885623**	**0.727663**	**0.818922**	**0.545948**	0.610558703
66	60.5155	59.5419	59.5877	60.4365	59.4063	59.89758	0.532952	**0.938171**	**0.689506**	**0.921313**	**0.614209**	0.542703702
67	60.3555	60.0847	59.2878	59.5964	59.5282	59.77052	0.43674	**1.144847**	**0.938378**	**1.013462**	**0.675641**	0.493358467
68	60.0512	59.545	58.9763	60.0855	59.2136	59.57432	0.494299	**1.011533**	**0.961415**	**0.766483**	**0.510988**	0.652330414
69	60.9248	59.976	59.8016	60.6645	60.0629	60.28596	0.482661	**1.035925**	**0.493128**	**0.891247**	**0.594165**	0.56101184
70	60.239	59.9498	59.1938	59.7456	59.7487	59.77538	0.382492	**1.307218**	**1.06723**	**1.127219**	**0.751479**	0.44356972
71	60.4456	59.7708	59.1142	60.2215	59.2748	59.76538	0.577814	**0.86533**	**0.712236**	**0.801756**	**0.534504**	0.623631379
72	60.6727	60.0168	59.9152	60.6345	59.4723	60.1423	0.509855	**0.98067**	**0.560747**	**0.944571**	**0.629714**	0.529340821
73	60.5072	60.1296	59.3034	59.618	59.9506	59.90176	0.463521	**1.078699**	**0.78978**	**1.055258**	**0.703505**	0.473817692
74	60.2762	59.4334	58.9596	60.2533	59.3352	59.65154	0.587101	**0.851642**	**0.765603**	**0.73236**	**0.48824**	0.682724271

75	60.9508	60.3853	59.6117	60.3875	60.0287	60.2728	0.495513	**1.009054**	**0.48919**	**0.883948**	**0.589299**	0.565644261
76	59.8491	59.6467	58.9508	59.123	59.1721	59.34834	0.380676	**1.313454**	**1.180655**	**0.662513**	**0.441676**	0.754701761
77	60.2239	59.6311	59.2793	60.1797	59.4519	59.75318	0.428291	**1.167431**	**0.970384**	**1.011489**	**0.674326**	0.494320872
78	59.994	59.3402	58.5014	59.7491	59.2316	59.36326	0.571702	**0.874581**	**0.794854**	**0.584293**	**0.389529**	0.855734413
79	59.5612	59.709	58.5154	58.8833	59.323	59.19838	0.493366	**1.013447**	**0.809663**	**0.531193**	**0.354128**	0.94127797
80	60.3696	59.7175	59.2709	60.0944	59.5912	59.80872	0.430432	**1.161624**	**0.922547**	**1.061527**	**0.707685**	0.471019634
81	59.7699	59.4244	58.5411	59.8016	58.9836	59.30412	0.539406	**0.926945**	**0.805898**	**0.567886**	**0.37859**	0.880459131
82	59.7536	59.806	58.7597	58.9801	59.2243	59.30474	0.46413	**1.077284**	**0.93705**	**0.598126**	**0.398751**	0.835944538
83	60.0592	59.6332	59.0211	59.9445	59.4503	59.62166	0.414076	**1.207507**	**1.10957**	**0.891437**	**0.594291**	0.560892431
84	60.0366	59.518	58.6203	59.765	59.2901	59.446	0.538943	**0.927742**	**0.894343**	**0.646914**	**0.431276**	0.772900812
85	59.5807	59.7527	58.7463	59.1109	59.1525	59.26862	0.400907	**1.247173**	**1.054792**	**0.599483**	**0.399655**	0.834052131
86	60.5753	59.6743	59.1347	60.0801	59.4845	59.78978	0.5561	**0.899119**	**0.725421**	**0.841032**	**0.560688**	0.594507881
87	59.8815	59.428	58.4741	59.7458	59.032	59.31228	0.571499	**0.874892**	**0.765402**	**0.559167**	**0.372778**	0.894186768
88	60.0775	59.9759	58.786	59.2211	59.6387	59.53984	0.538254	**0.928929**	**0.904257**	**0.706073**	**0.470716**	0.708141712
89	60.0875	59.4436	59.0125	59.9681	59.2138	59.5451	0.468202	**1.067916**	**1.035807**	**0.765932**	**0.510621**	0.652799261
90	59.7463	59.347	58.2705	59.5506	58.9196	59.1668	0.587379	**0.851239**	**0.662151**	**0.49047**	**0.32698**	1.019429402
91	59.5332	59.732	58.5158	58.9822	59.3506	59.22276	0.482106	**1.037117**	**0.84543**	**0.546676**	**0.364451**	0.914618918
92	60.3067	59.4645	59.1637	60.1212	59.2823	59.66768	0.514253	**0.972285**	**0.863596**	**0.816614**	**0.544409**	0.612284447
93	59.7129	59.1805	58.58	59.6866	59.0019	59.23238	0.479225	**1.043351**	**0.857203**	**0.552529**	**0.368353**	0.904929468
94	59.7244	59.7689	58.6896	59.0174	59.0607	59.2522	0.473887	**1.055105**	**0.880802**	**0.564774**	**0.376516**	0.885309711
95	59.9654	59.4688	58.9586	59.9129	59.1808	59.4973	0.442443	**1.130089**	**1.128055**	**0.746632**	**0.497755**	0.669673861
96	59.8161	59.5173	58.5898	59.5514	59.0994	59.3148	0.479664	**1.042397**	**0.913695**	**0.597795**	**0.39853**	0.836406872
97	59.8729	59.8817	58.9525	59.1254	59.1892	59.40434	0.440362	**1.135431**	**1.06302**	**0.67498**	**0.449987**	0.740762532
98	60.4039	59.6124	58.954	60.0036	59.5727	59.70932	0.54028	**0.925446**	**0.796303**	**0.81498**	**0.54332**	0.613512094
99	59.7383	59.3571	58.7117	59.7572	58.9452	59.3019	0.468071	**1.068215**	**0.927139**	**0.594887**	**0.396591**	0.840496202

100	59.9693	59.9316	58.8586	59.1436	59.5216	59.48494	0.485867	**1.029087**	**1.018755**	**0.706151**	**0.470768**	0.708063508

若要使$C_p = 2.0$，及表示在工程規格不變情況下，樣本的標準差需要變小。考量製程的流程，可以考慮加速晶圓在爐中的旋轉，使每個方向的加熱爐子在溫度控制上的偏差對每個 CD site 厚度的偏差影響最小。