HWABAEK
ENGINEERING CO., LTD.

(주)화백엔지니어링

ETCHING TECHNOLOGY

㈜ 화백 엔지니어링 홍 석 표 부장

ETCHING TECHNOLOGY

DEFINITION

ETCHING 이란 ?

반도체나 PCB 등과 같은 기판상에 어떠한 패턴 (마스크)에 의해 필요한 소자를 배치하는 가공을 할 때, 필요 없는 부분을 부식 등으로 제거하는 기술

- WET ETCHING : 강산에 의한 화학적 작용, 등방성 ETCHING
- DRY ETCHING : 플라즈마 중의 이온의 작용, 이방성 ETCHING

ETCHING TECHNOLOGY

ETCHING 의 구성 요소

EQUIPMENT

ETCHANT

ETCHANT CONTROLLER

SUBSTRATE

ETCHING TECHNOLOGY

ETCHANT 의 종류

- 염 화 동 (CuCl2) : 동 및 동 합금 소재 부식
  - 과산화 수소 (H2O2) TYPE
  - 염소산 나트륨 (NaClO3) TYPE
- 염 화 철 (FeCl3) : 동 및 동 합금, 철 및 철 합금 소재 부식
- 기 타 : Alkaline Ammonia
  Sulfuric Acid – Hydrogen Peroxide
  Persulfates (Ammonium, Sodium)....

ETCHING TECHNOLOGY

ETCHANT 의 특성 비교

염 화 동	염 화 철
■ 낮은 RUNNING COST	■ 빠른 ETCHING SPEED
■ 넓은 PROCESS WINDOW	■ 높은 ETCHING FACTOR
■ 유지관리 용이	■ 넓은 소재 선택폭

ETCHING TECHNOLOGY

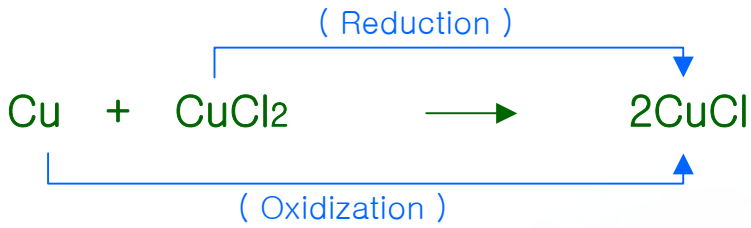
ETCHANT CONTROLLER

SENSOR에 의한 관리방식	비색 법에 의한 관리방식
■ SENSOR 에 의한 액 상태 관리 (ORP, pH, mS, Specific ion sensor)	■ 반영구적 COLOR SENSOR 사용
■ SENSOR의 불안정성	■ 정교한 액 관리
■ 저 염산농도에서의 부 정확성	■ 염 화 동 / 염 화 철 모두 적용가능

ETCHING TECHNOLOGY

염 화 동 ETCHANT

Major Reaction (Electro Chemical Reaction)



Regeneration

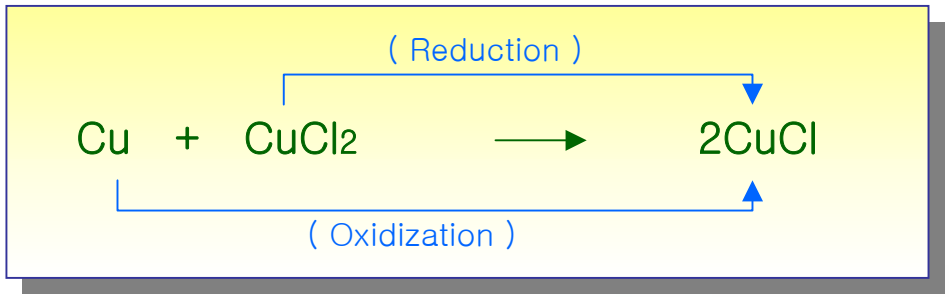
$$6CuCl + NaClO_3 + 6HCl \rightarrow 6CuCl_2 + NaCl + 3H_2O$$

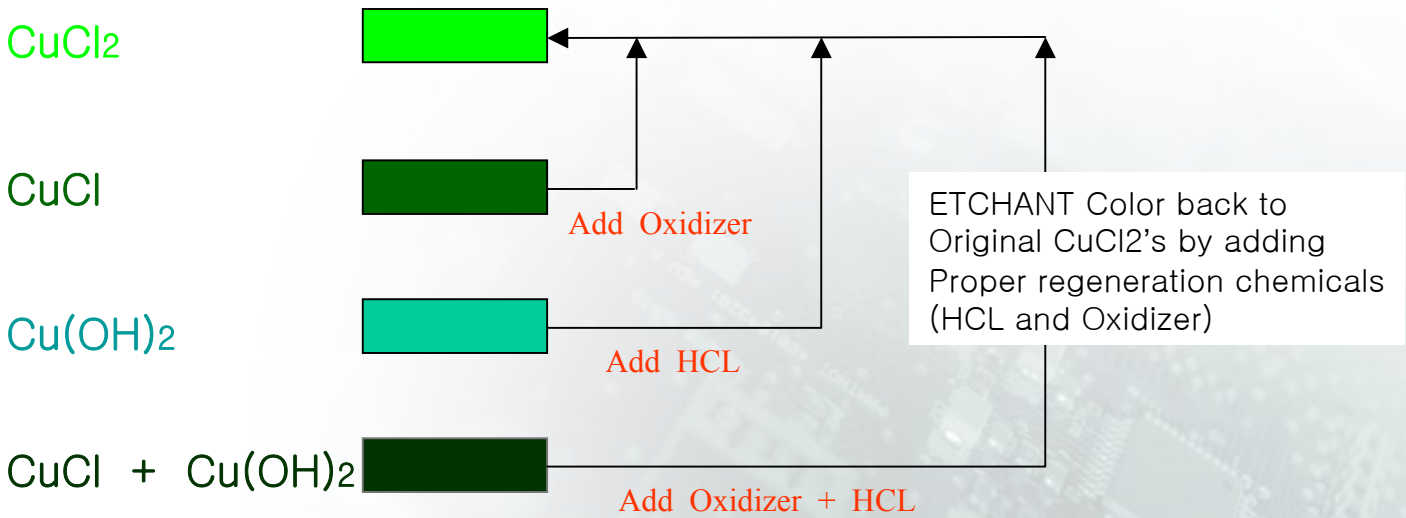
$$3Cu + NaClO_3 + 6HCl \rightarrow 3CuCl_2 + NaCl + 3H_2O$$

$$Cu(OH)_2 + 2HCl \rightarrow CuCl_2 + 2H_2O$$

ETCHING TECHNOLOGY

Major Reaction (Electro Chemical Reaction)





ETCHING TECHNOLOGY

Regeneration

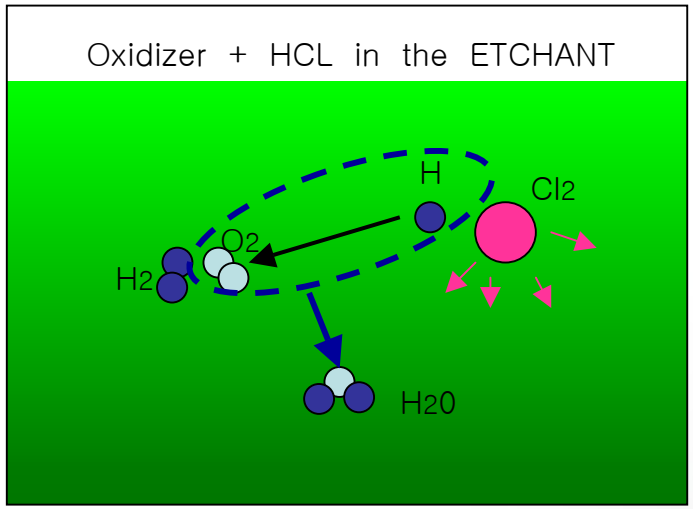
$$2CuCl + Cl_2\,(G) \longrightarrow 2CuCl_2$$

$$2CuCl + H_2O_2 + 2HCl \longrightarrow 2CuCl_2 + 2H_2O$$

$$6CuCl + NaClO_3 + 6HCl \longrightarrow 6CuCl_2 + NaCl + 3H_2O$$

ETCHING TECHNOLOGY

Function of Oxidizer (H_2O_2, $NaClO_3$)



O_2 took the H from the HCL to release the Cl_2 gas for regeneration and the remaining H and O become water.

ETCHANT with H_2O_2 is very UNSTABLE !

HCL Normality does not read accurately < 0.5N

An excess of free acid in the ETCHANT is required.
(ORP FLUCTUATION)

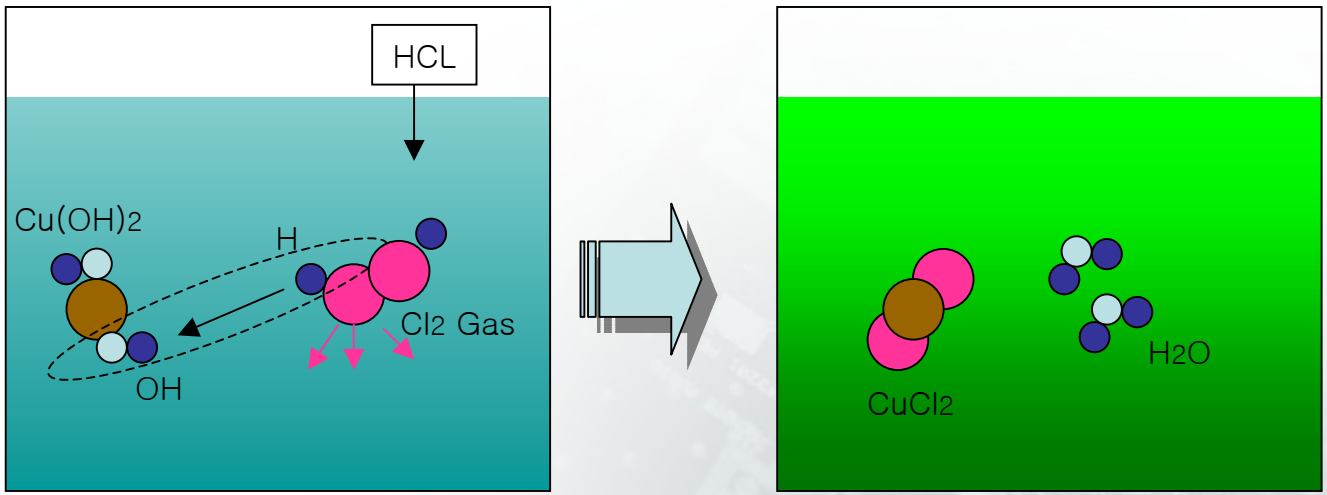
A slight miscalculation, then the release of Cl_2 !
(SAFETY ISSUE)

$NaClO_3$ keeps the HCL Normality very low !!! (0 – 0.04N)

ETCHING TECHNOLOGY

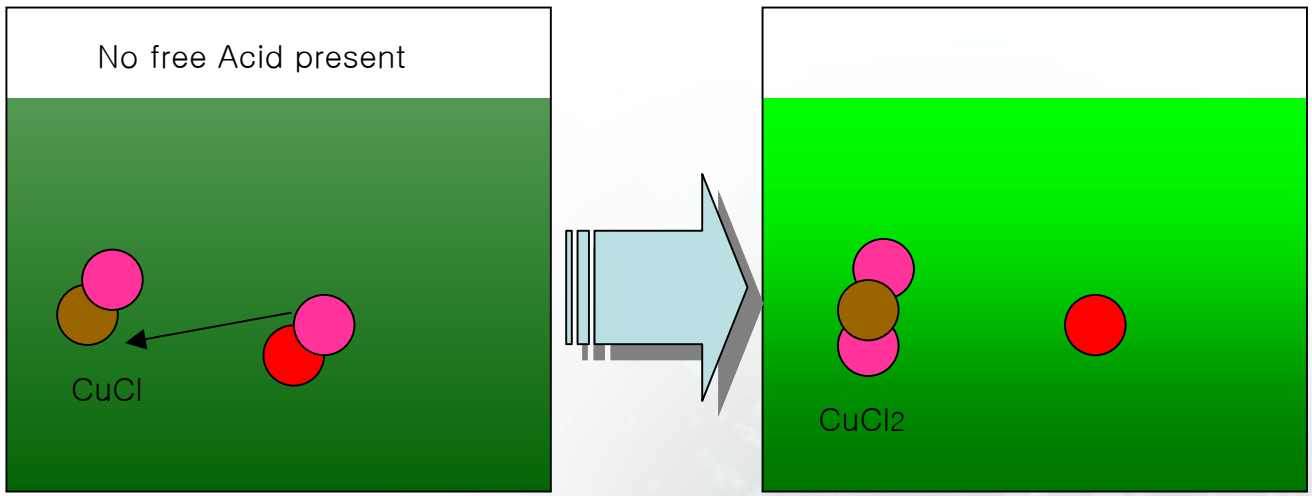
Copper Hydroxide ($Cu(OH)_2$)

$$Cu(OH)_2 + 2HCl \longrightarrow CuCl_2 + 2H_2O$$



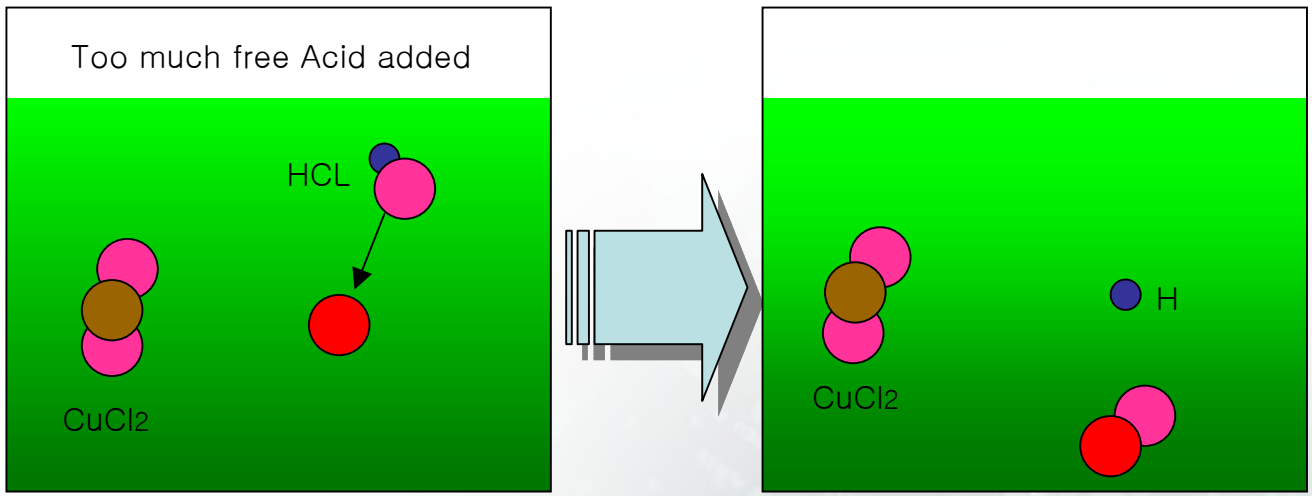
ETCHING TECHNOLOGY

- Regeneration with $NaClO_3$ at 0 HCL



ETCHING TECHNOLOGY

Regeneration with $NaClO_3$ at too much HCL



ETCHING TECHNOLOGY

염 화 철 ETCHANT

< FeCl3 for Cu >

Major Reaction

$$FeCl_3 + Cu \longrightarrow FeCl_2 + CuCl \quad (1)$$

$$FeCl_3 + CuCl \longrightarrow FeCl_2 + CuCl_2 \quad (2)$$

$$CuCl_2 + Cu \longrightarrow 2CuCl \quad (3)$$

Hydrolysis Reaction

$$FeCl_3 + 3H_2O \longrightarrow Fe(OH)_3 + 3HCl$$

ETCHING TECHNOLOGY

< FeCl3 for Fe-Alloy >

Major Reaction

$$2FeCl_3 + Fe \longrightarrow 3FeCl_2 \quad (1)$$

$$2FeCl_3 + Ni \longrightarrow 2FeCl_2 + NiCl_2 \quad (2)$$

Hydrolysis Reaction

$$FeCl_3 + 3H_2O \longrightarrow Fe(OH)_3 + 3HCl$$

ETCHING TECHNOLOGY

Regeneration

$2FeCl_2 + Cl_2 \longrightarrow 2FeCl_3$

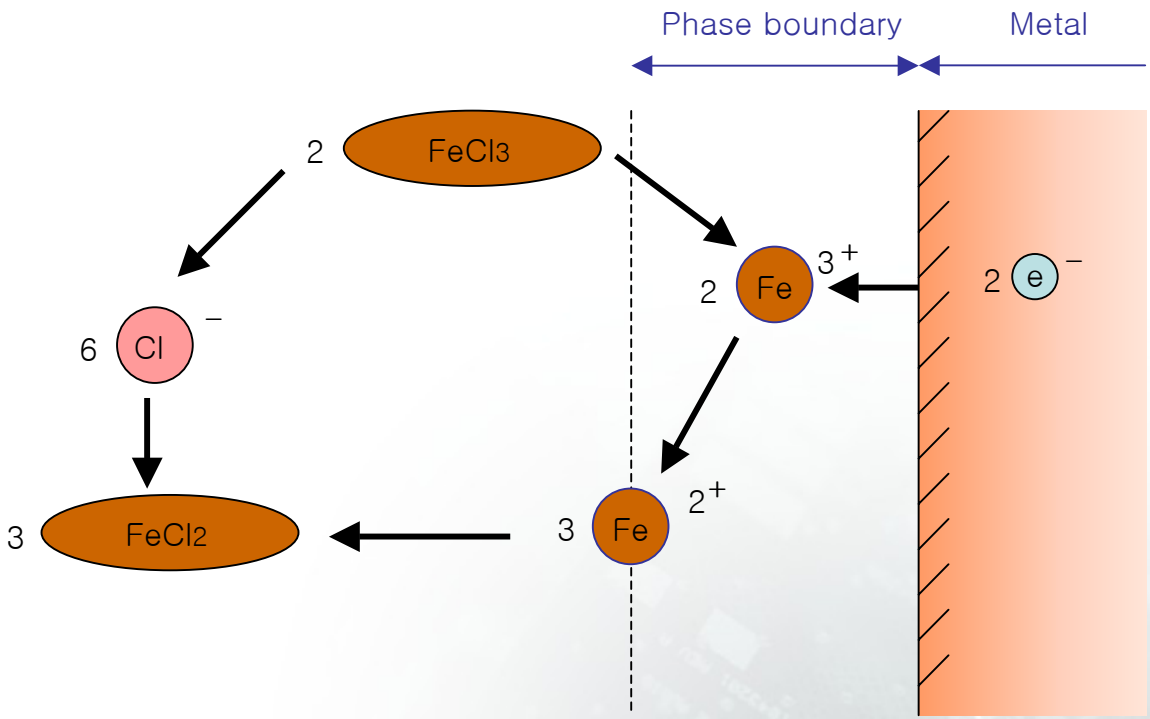
$6FeCl_2 + NaClO_3 + 6HCl \longrightarrow 6FeCl_3 + NaCl + 3H_2O$

Etchant + NH_4Cl → $CuCl_2{*}2NH_4Cl{*}2H_2O$ (Crystallization)

Etchant + Iron plate → Cu Sludge (Displacement)

ETCHING TECHNOLOGY

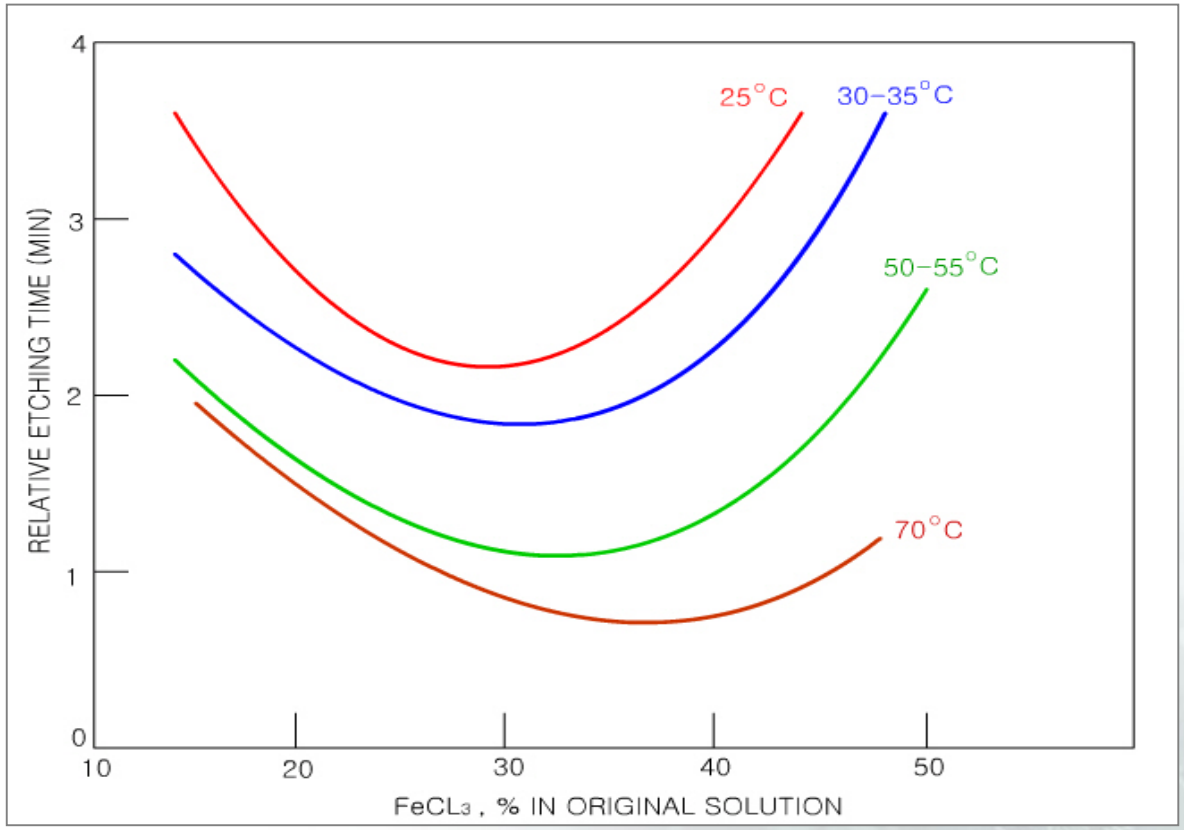
< Boundary Layer Reactions >



$$E_{Fe}\ (ORP) = E^{0}_{Fe} + \frac{RT}{F} \ln \frac{a_{Fe^{3+}}}{a_{Fe^{2+}}}$$

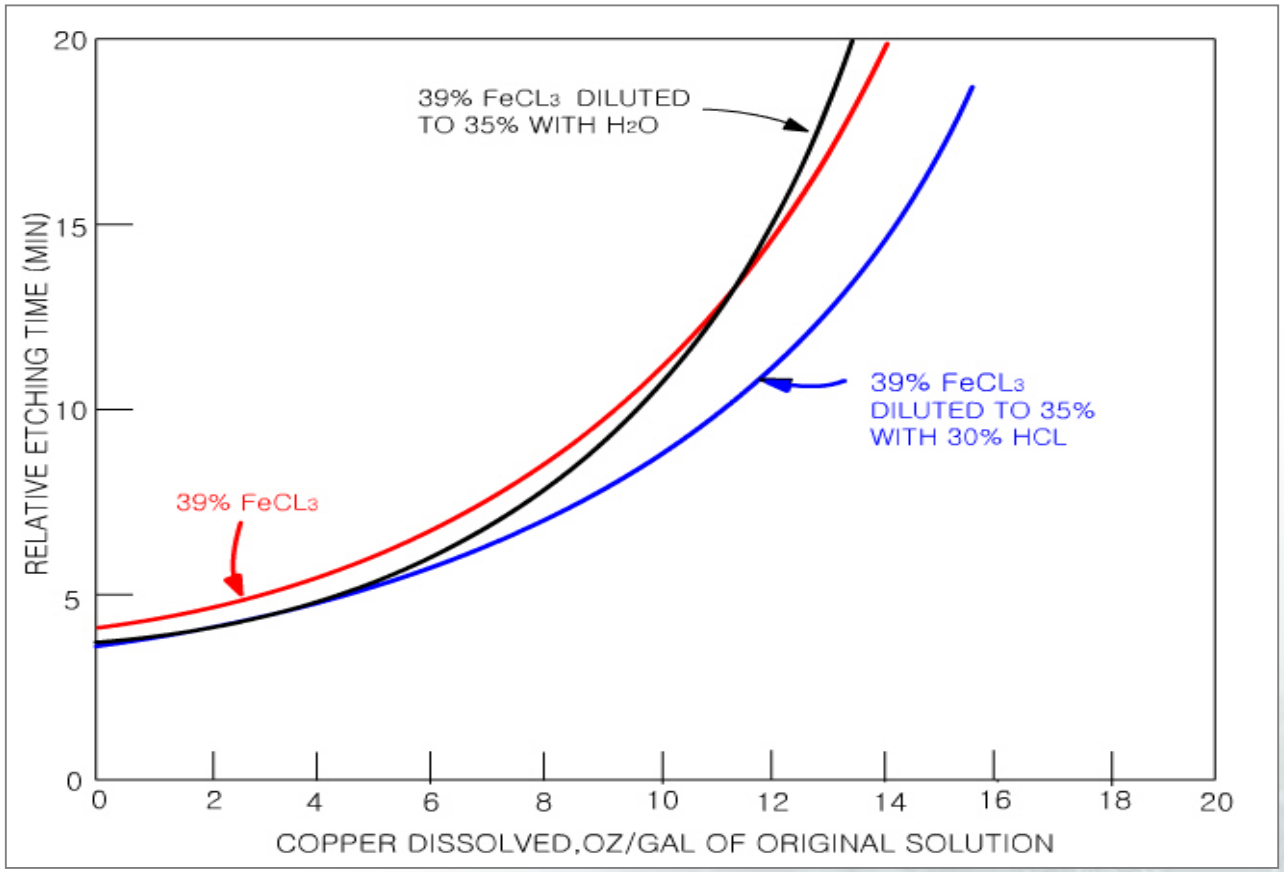
ETCHING TECHNOLOGY

< Relative Etching Time vs. FeCl3 Concentration >



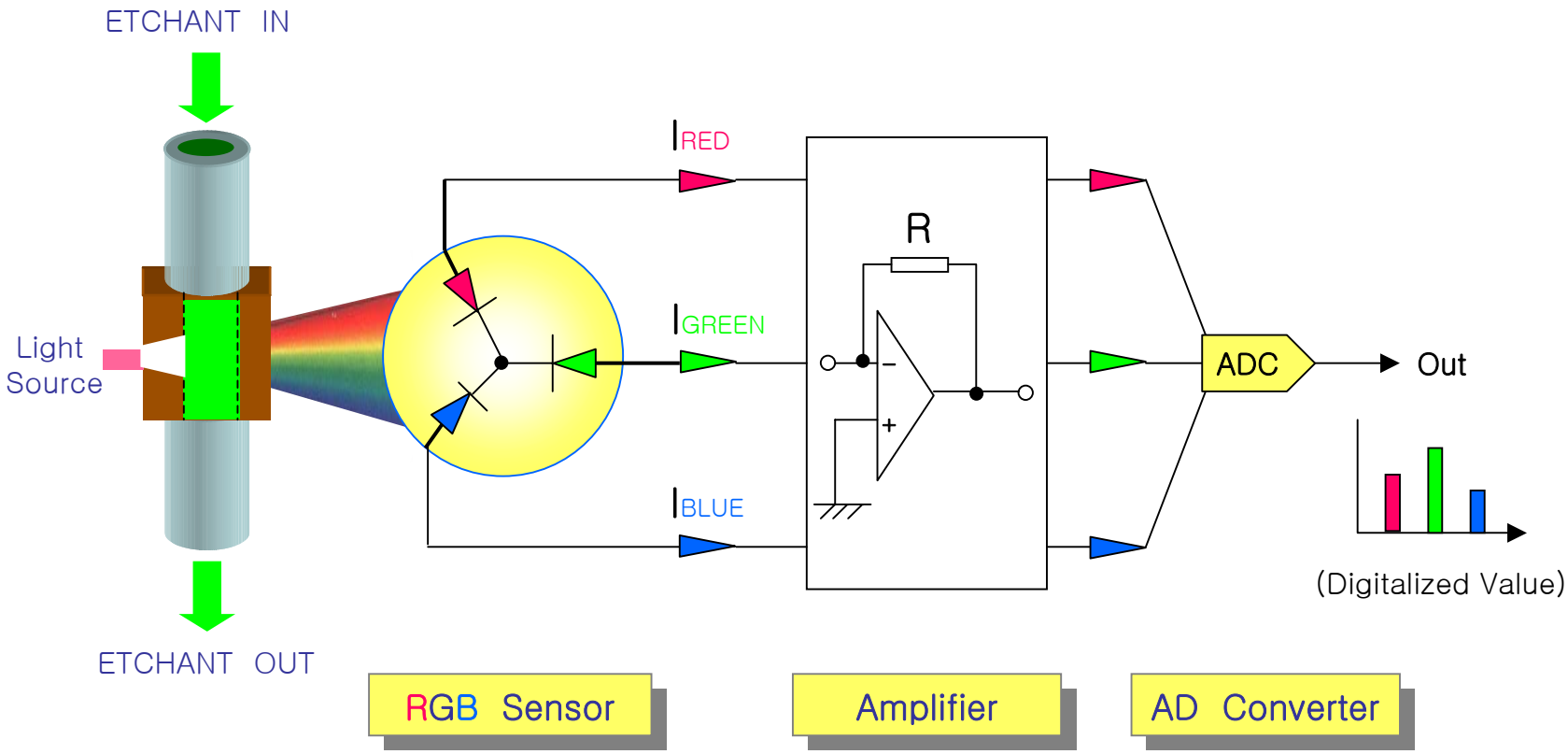
ETCHING TECHNOLOGY

< Relative Etching Time vs. Dissolved Copper >



ETCHING TECHNOLOGY

ETCHANT CONTROLLER (비색 법)



ETCHING TECHNOLOGY

- NEW CONCEPTION OF ETCHANT CONTROLLER
  (US Patented Technology with Color Sensor)
- COMPATIBLE WITH BOTH CuCl2 and FeCl3
- SUITABLE FOR FINE PATTERN DEVICES
  (Zero HCL Normality)
- THE BEST ETCHANT CONDITION SUSTAINABLE
  (Computerized Control & Monitoring System)
- ENVIRONMENTALLY FRIENDLY CONTROL SYSTEM
  (No Toxic Chemical Fume Generate)
- POWERFUL DISPLAY FUNCTION
  (Real-time Data Reading & Recording, Statistical Analysis, ETCHANT Color Monitoring, etc.)

The United States of America

The Director of the United States Patent and Trademark Office

Has received an application for a patent for a new and useful invention. The title and description of the invention are enclosed. The requirements of law have been complied with, and it has been determined that a patent on the invention shall be granted under the law.

Therefore, this

United States Patent

Grants to the person(s) having title to this patent the right to exclude others from making, using, offering for sale, or selling the invention throughout the United States of America or importing the invention into the United States of America for the term set forth below, subject to the payment of maintenance fees as provided by law.

If this application was filed prior to June 8, 1995, the term of this patent is the longer of seventeen years from the date of grant of this patent or twenty years from the earliest effective U.S. filing date of the application, subject to any statutory extension.

If this application was filed on or after June 8, 1995, the term of this patent is twenty years from the U.S. filing date, subject to any statutory extension. If the application contains a specific reference to an earlier filed application or applications under 35 U.S.C. 120, 121 or 365(c), the term of the patent is twenty years from the date on which the earliest application was filed, subject to any statutory extensions.

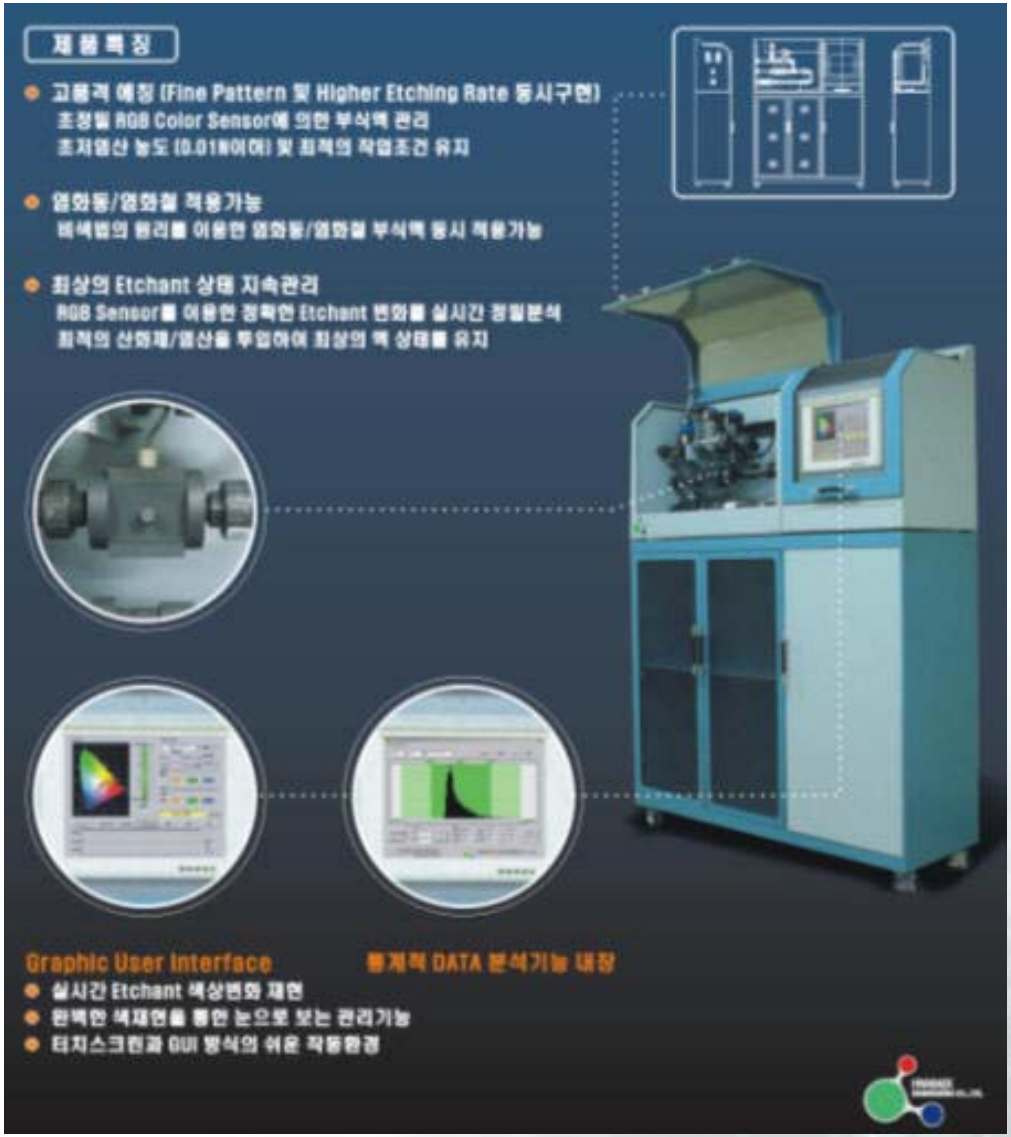
Director of the United States Patent and Trademark Office

Attest Ollie M. Person

ETCHING TECHNOLOGY

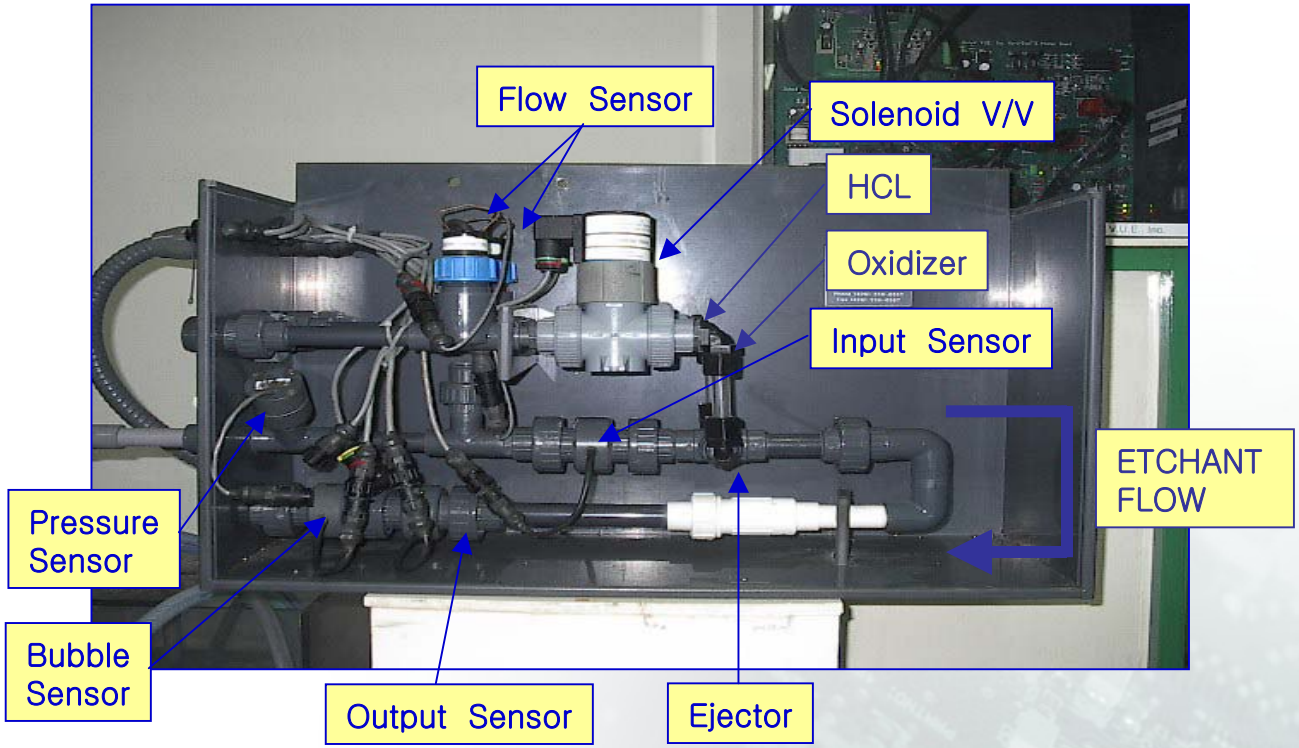
State of ETCHANT	COLOR	ACTION
WELL CONTROLED	CuCl2	
HCL LOW	Cu(OH)2	Add HCL
ORP LOW	CuCl	Add HB-001E
HCL & ORP LOW	Cu(OH)2 + CuCl	Add HCL + HB-001E

ETCHING TECHNOLOGY



ETCHING TECHNOLOGY

< Try and Error Control System >

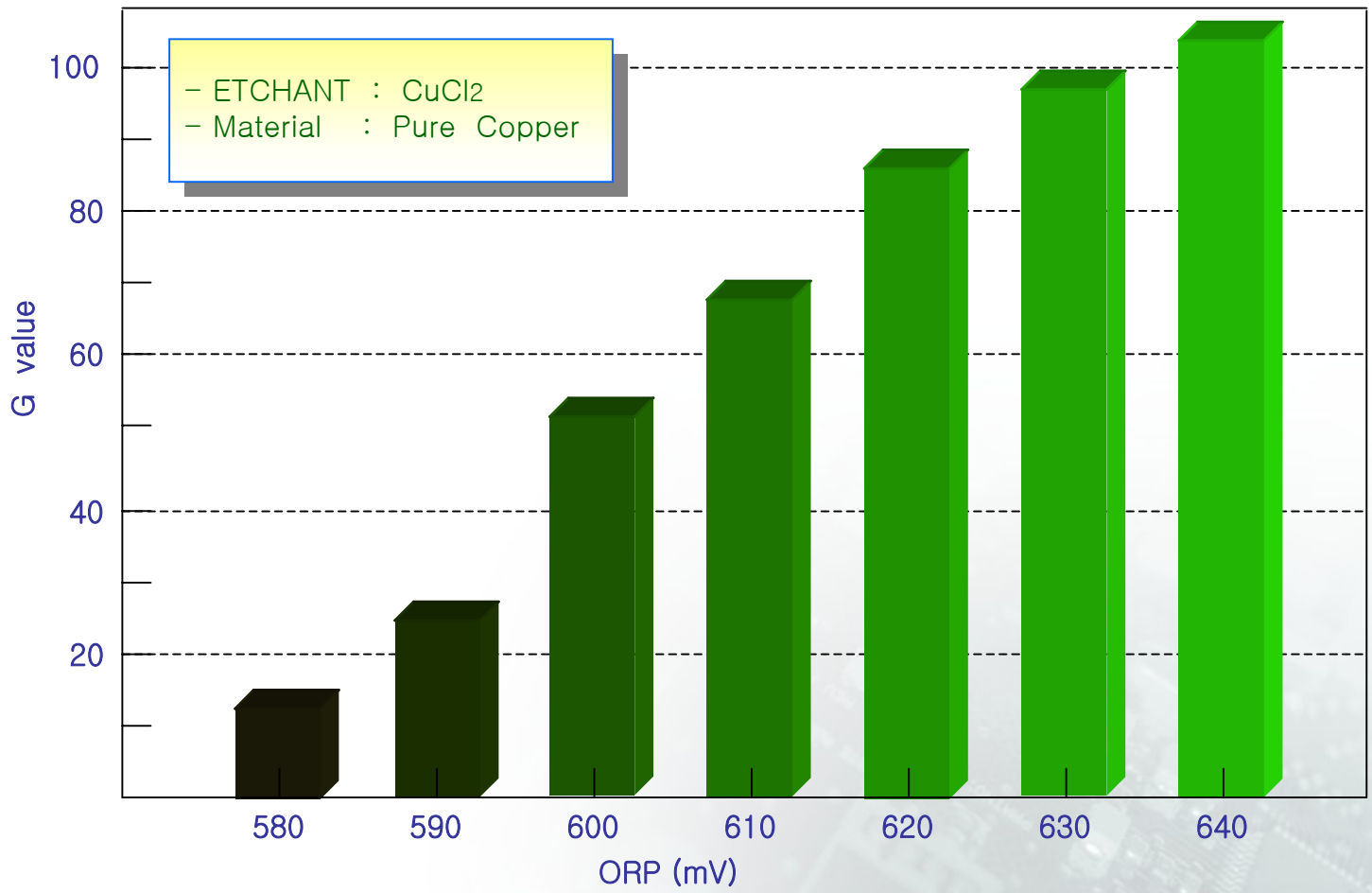


ETCHING TECHNOLOGY

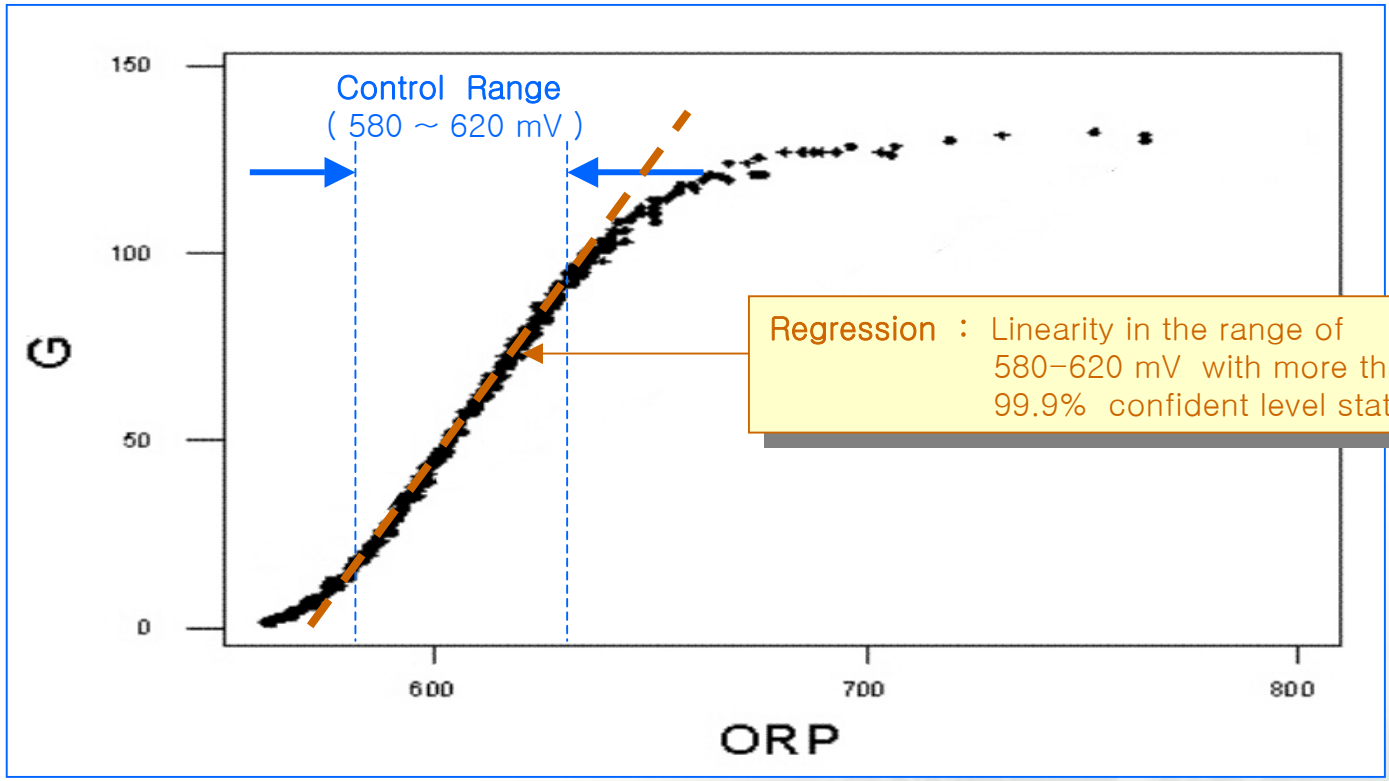
ETCHANT Color	ORP (mV)	R	G	B
	640	21	107	2
	630	20	97	2
	620	19	87	2
	610	18	69	1
	600	17	52	0
	590	16	27	0
	580	16	15	0

< ETCHANT : CuCl2 >

ETCHING TECHNOLOGY

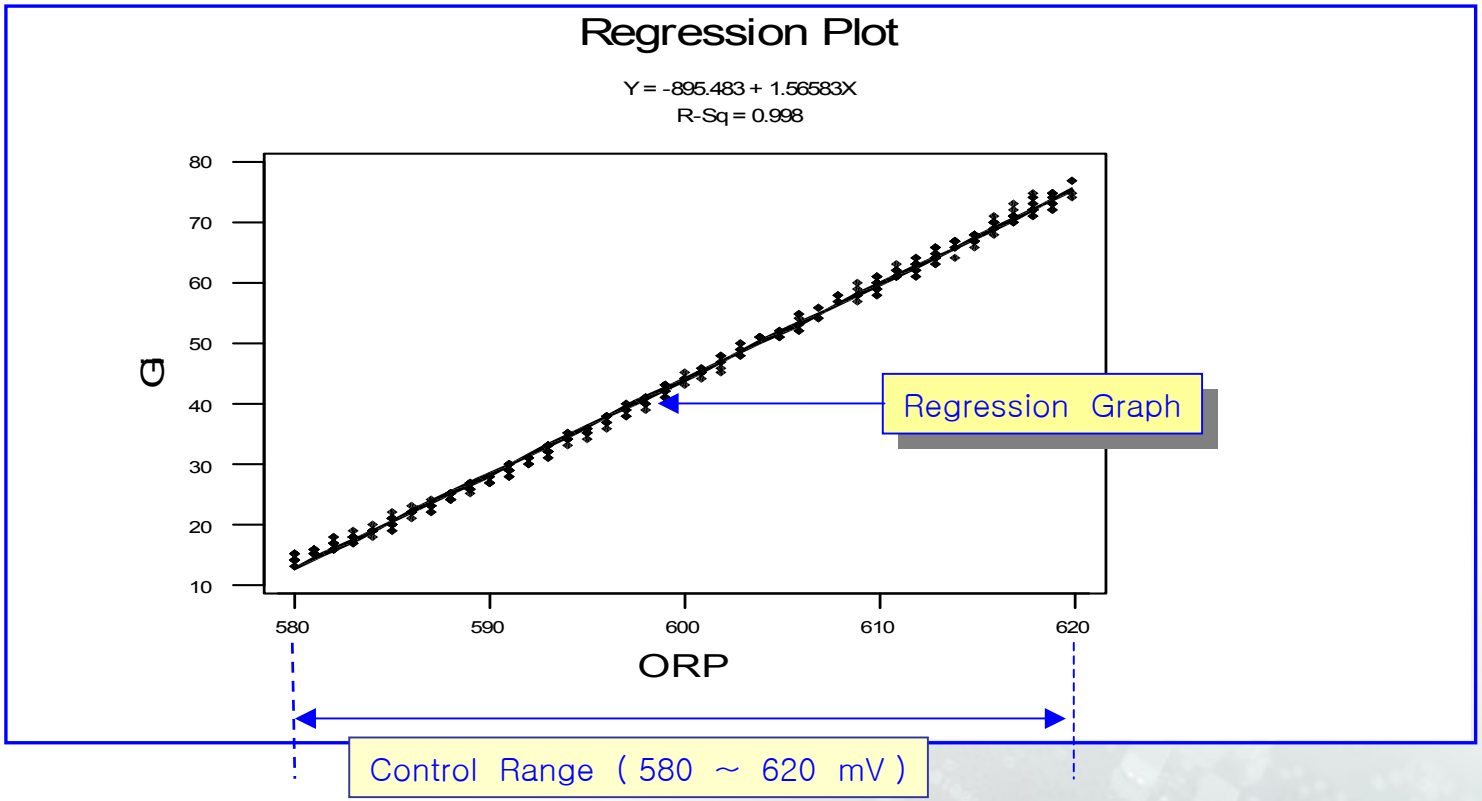


ETCHING TECHNOLOGY



< ETCHANT : $CuCl_2$ >

ETCHING TECHNOLOGY



< ETCHANT : $CuCl_2$ >

ETCHING TECHNOLOGY

Regression Analysis
The regression equation is
G = - 895 + 1.57 ORP
Correlations (Pearson)
Correlation of ORP and Gi = 0.998

Predictor	Coef	StDev	T	P
Constant	-895.483	2.100	-426.32	0.000
ORP	1.56583	0.00351	446.39	0.000

S = 0.9598 R-Sq = 99.8% R-Sq(adj) = 99.8%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	183587	183587	199267.10	0.000
Error	462	426	1		
Total	463	184013			

R denotes an observation with a large standardized residual

Regression Equation

Correlation Coefficient

Verification (F) : The regression is said to be effective in at least 99.9 % confident level.

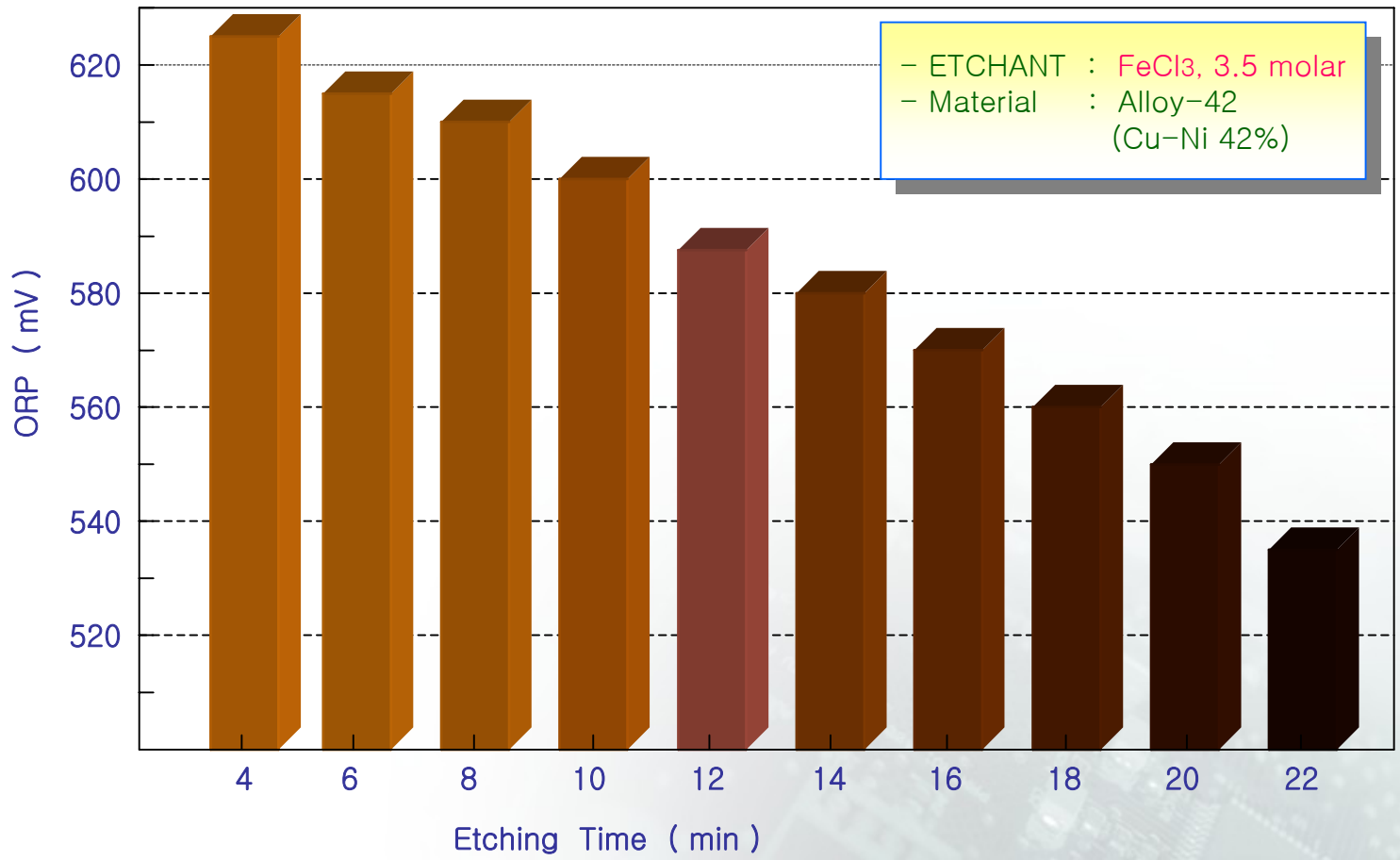
< ETCHANT : $CuCl_2$ >

ETCHING TECHNOLOGY

< FeCl3 + Cu >

State of ETCHANT	SENSOR	ACTION
SG HIGH	Load-cell	Add Water
HCL LOW	Conductivity	Add HCL
ORP LOW	RGB SENSOR	Add HB-001E + FeCl3
Cu CONCENTRATION	RGB SENSOR	Add FeCl3

ETCHING TECHNOLOGY



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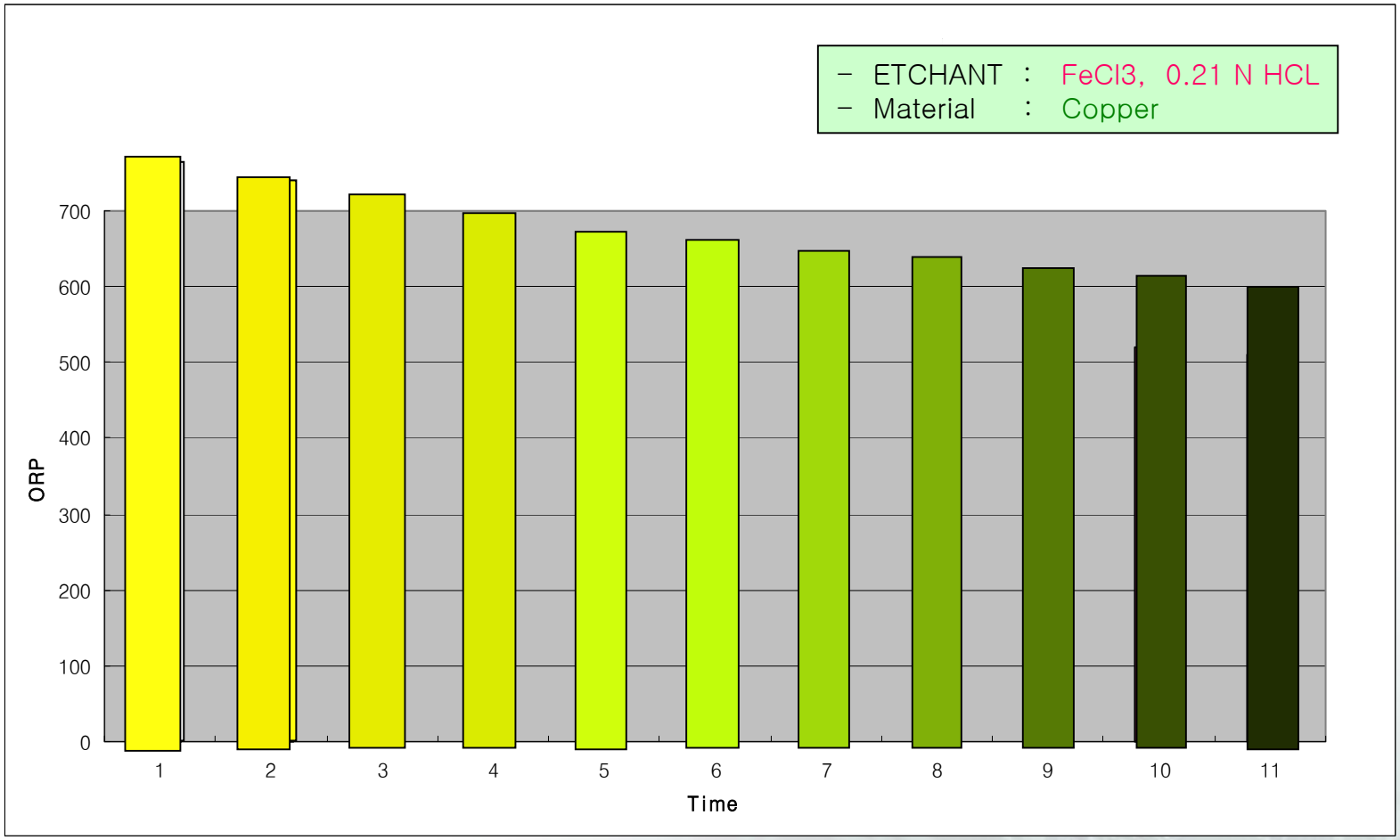
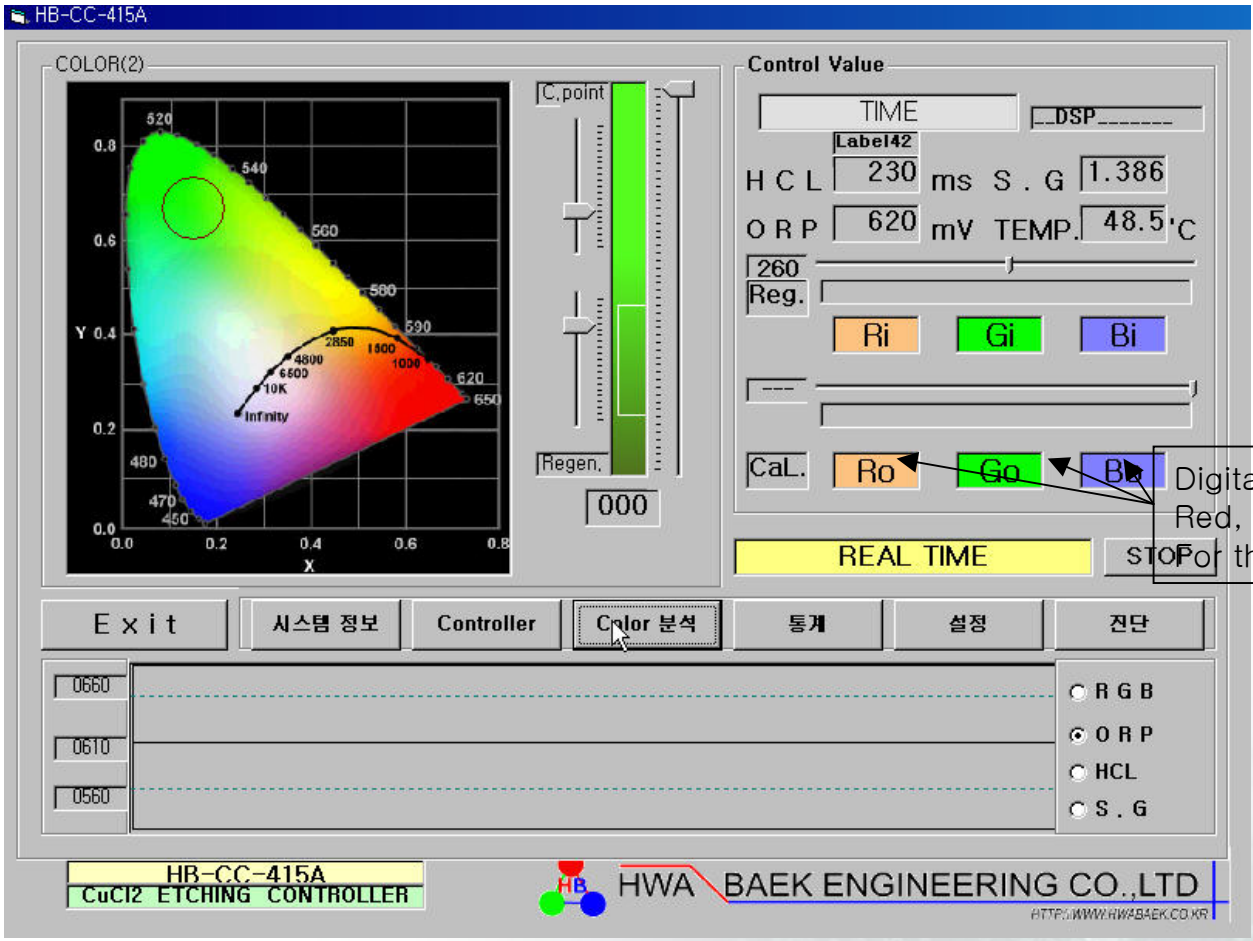
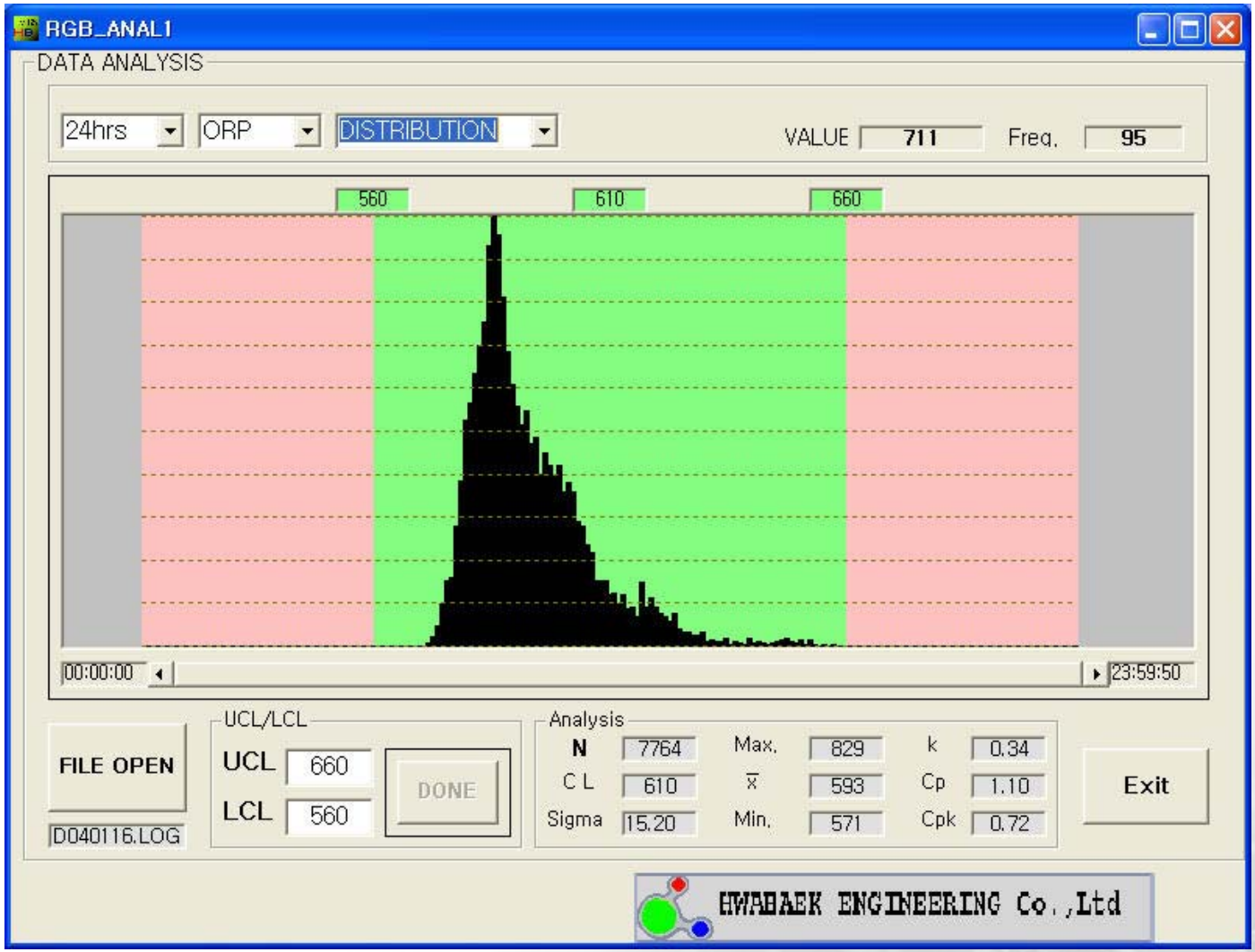


ETCHING TECHNOLOGY



Real-Time ETCHANT Color changes are displayed in the CIE chromaticity on the monitor screen through out the color sensors.

ETCHING TECHNOLOGY



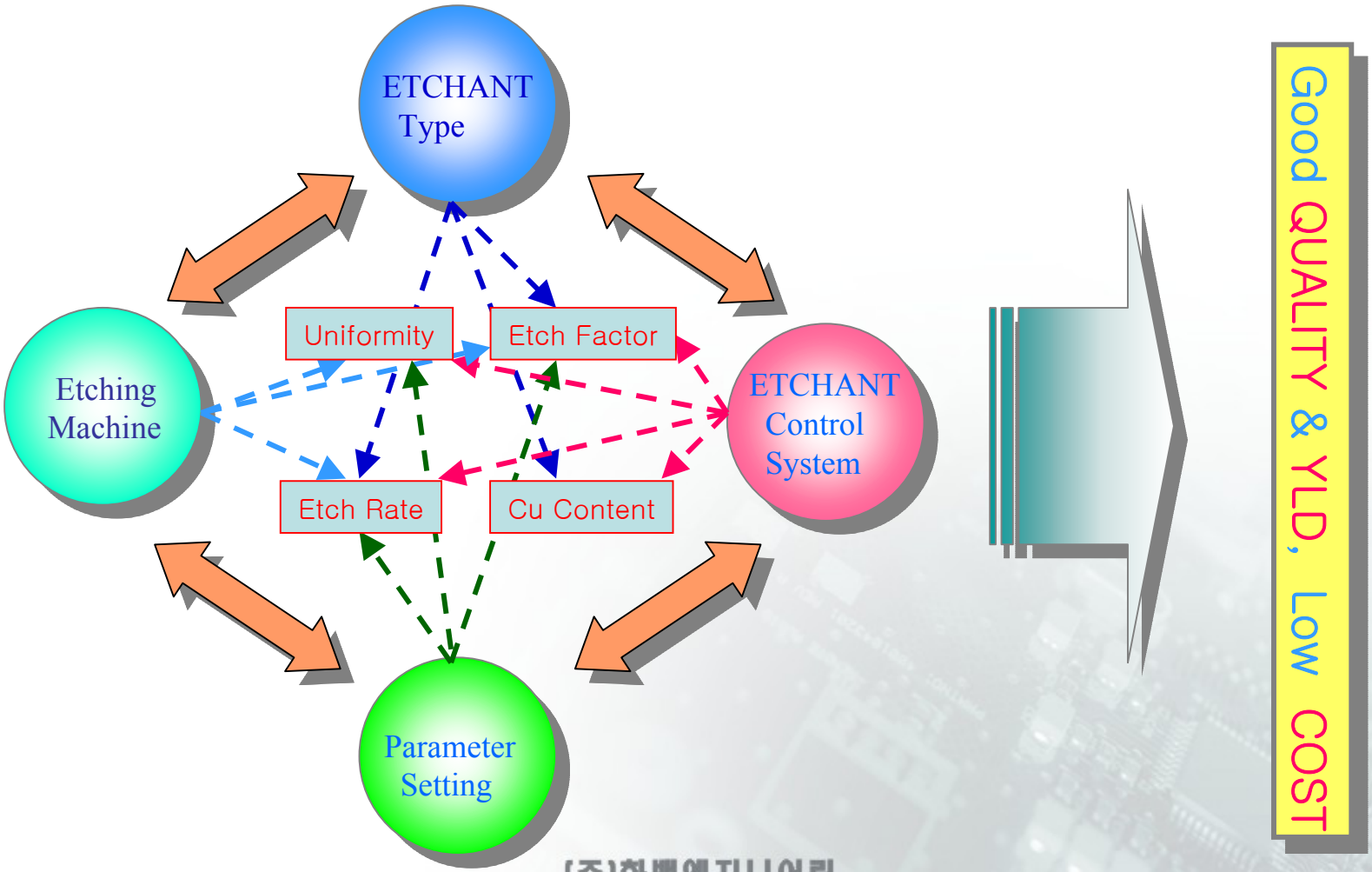
ETCHING TECHNOLOGY

ETCHING 의 핵심 고려 사항

- ETCHING FACTOR (Capability)
- ETCHING UNIFORMITY (Quality)
- ETCH RATE (Productivity)
- COPPER CONTENT (Cost Aspect)

ETCHING TECHNOLOGY

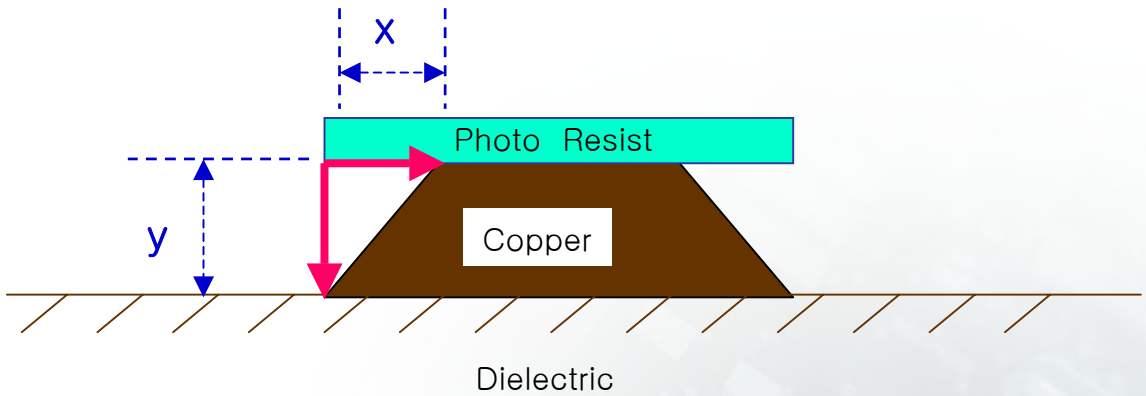
상호 연관성



ETCHING TECHNOLOGY

TERMS & DEFINITION

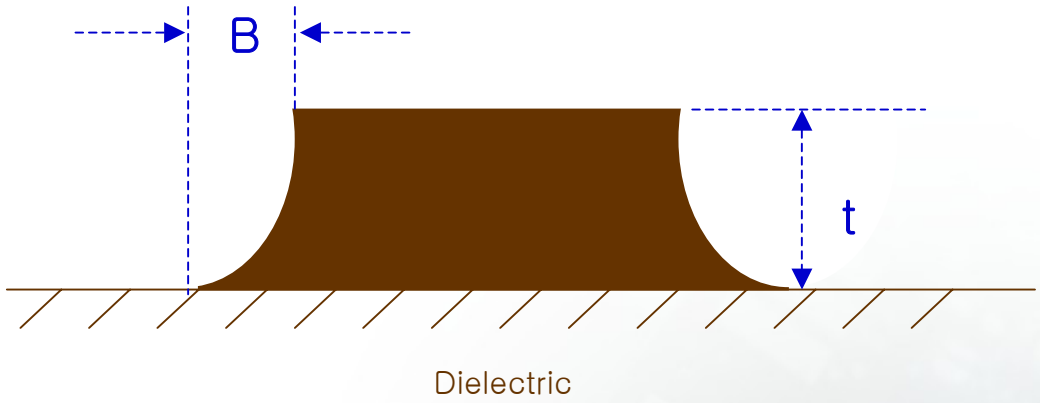
- Etching Factor (f) : the ratio of depth to side attack
  (The greater the better for fine pattern)



$$\text{Etching Factor (f)} = \frac{y}{x}$$

ETCHING TECHNOLOGY

BEVEL (B) : the degree of slope to the wall



BEVEL = Approx. 0.4 * t (one sided)
0.1 * t (double sided)

ETCHING TECHNOLOGY

ETCHING FACTOR

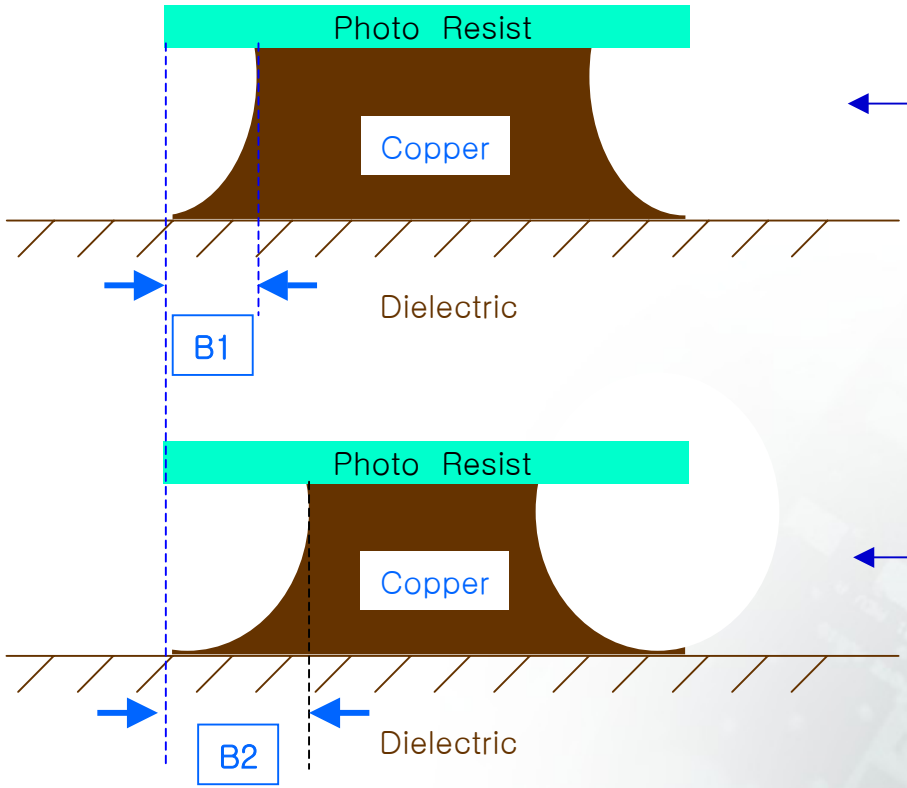
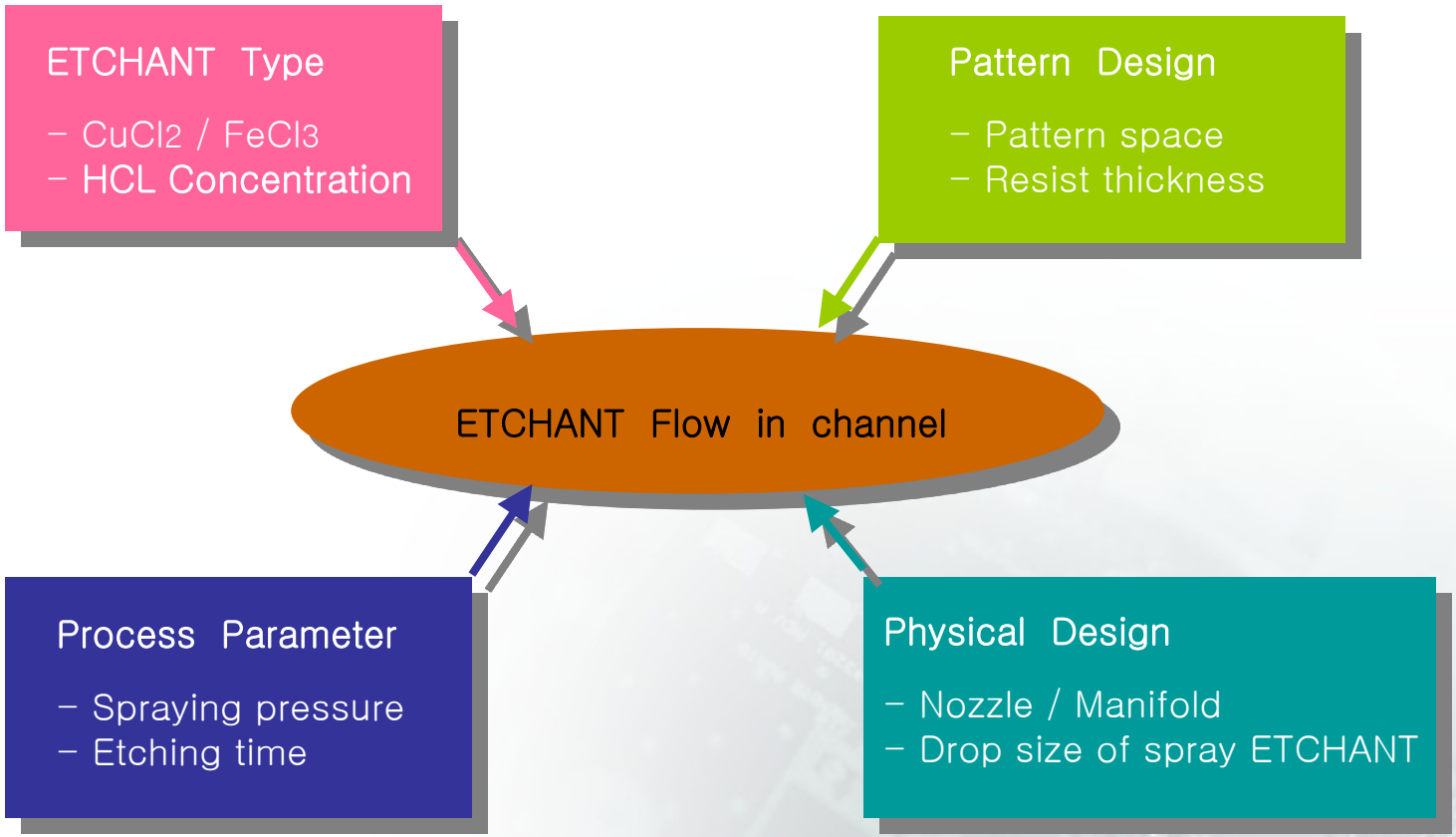


Fig.1) Higher Etch Factor
(Good for Fine Pattern)

Fig.2) Lower Etch Factor
(Bad for Fine Pattern)

ETCHING TECHNOLOGY

KEY FACTORS



ETCHING TECHNOLOGY

< Schematic of anisotropic etching in Etch Channels >

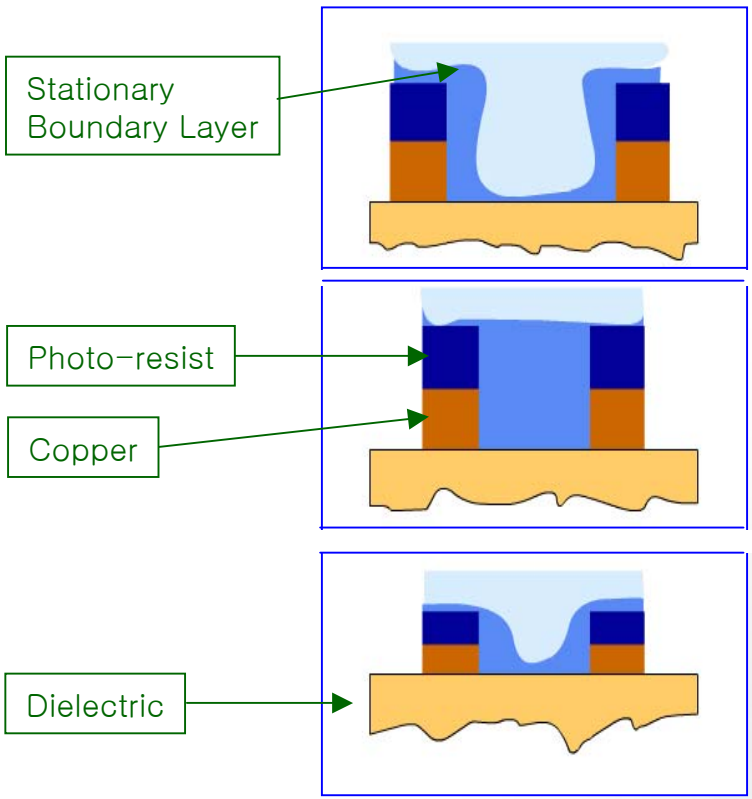


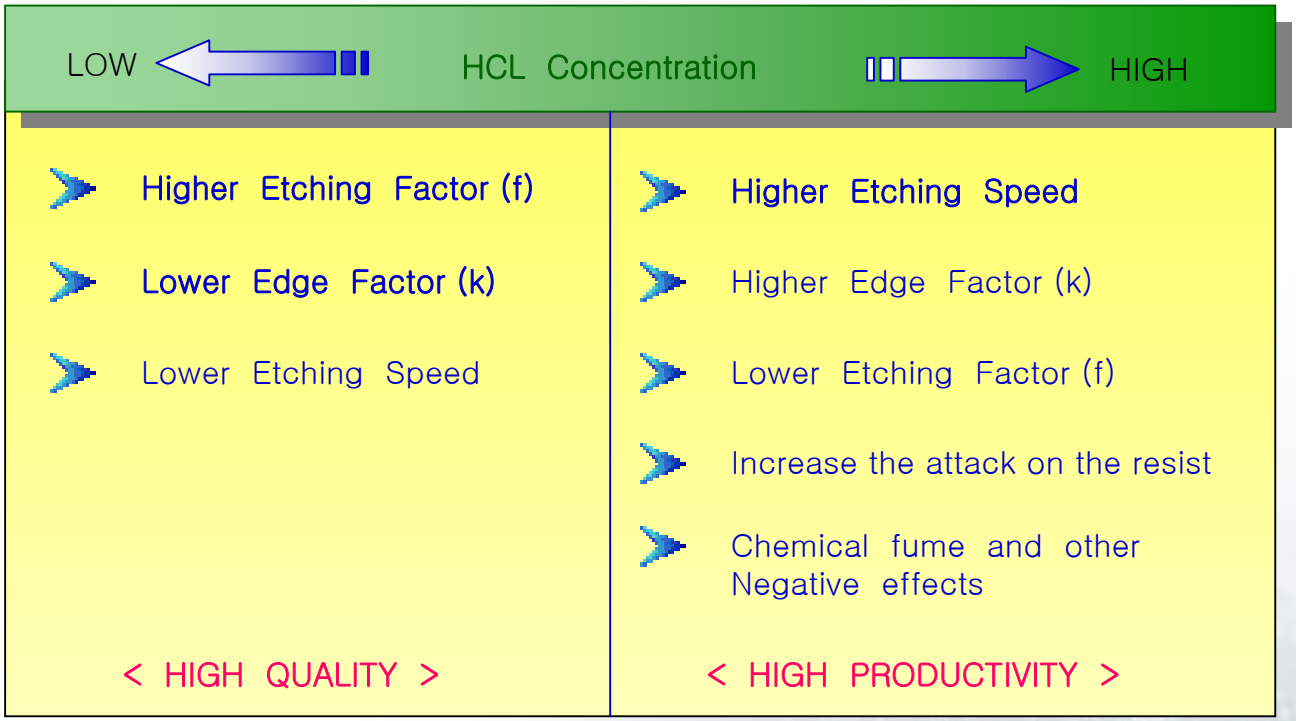
Fig 1) Low Aspect Ratio Etch Channel
(> 3 mils wide) → Higher etch factor

Fig 2) High Aspect Ratio Etch Channel
(< 3 mils wide) → Lower etch factor

Fig 2) Low Aspect Ratio Etch Channel
Higher etch factor

ETCHING TECHNOLOGY

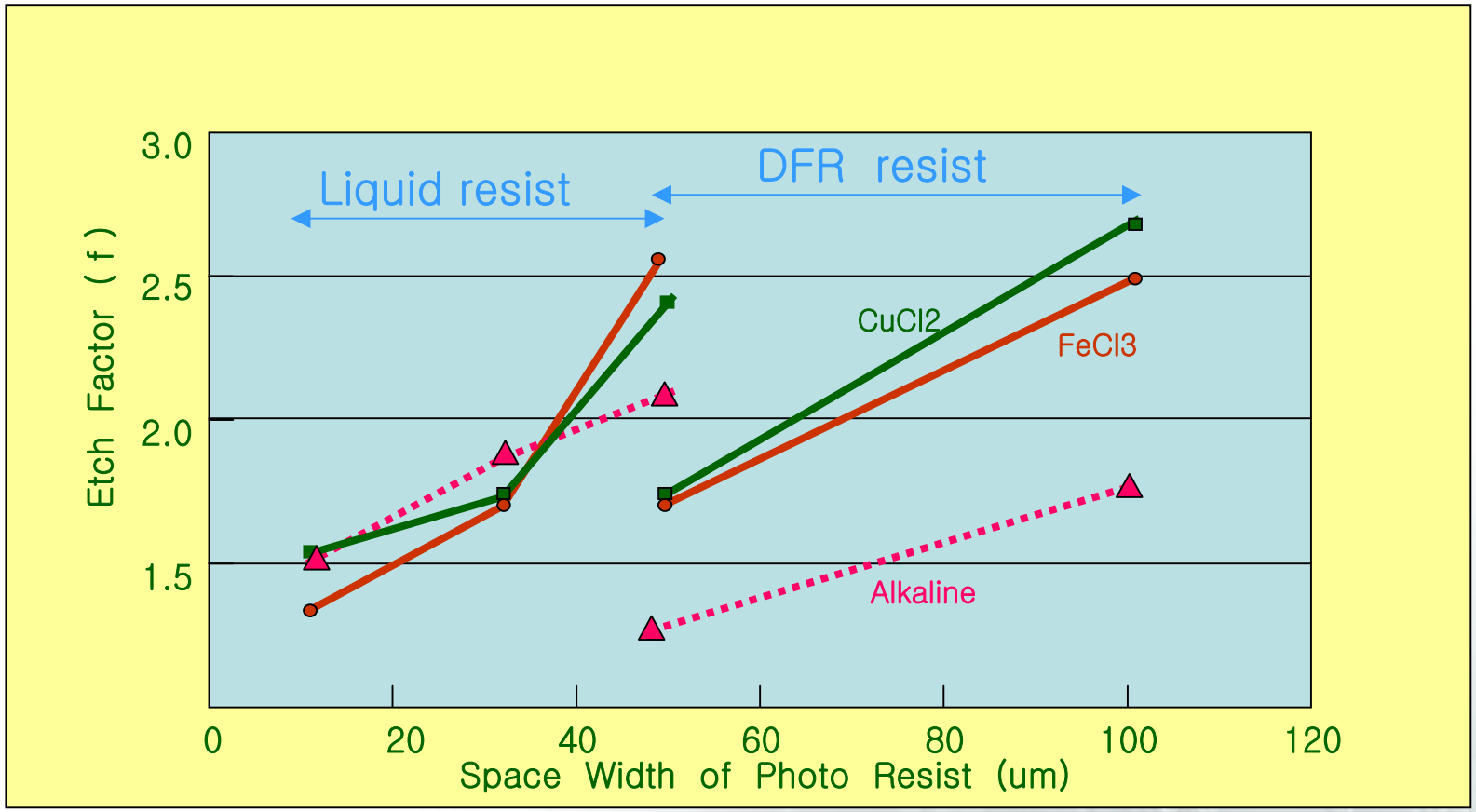
< Effect of HCL on Etching >



HWABAEK ETCHANT CONTROLLER (HBC-100C) is designed for both high and low HCL concentration.

ETCHING TECHNOLOGY

< Key Factors to ETCH-FACTOR >

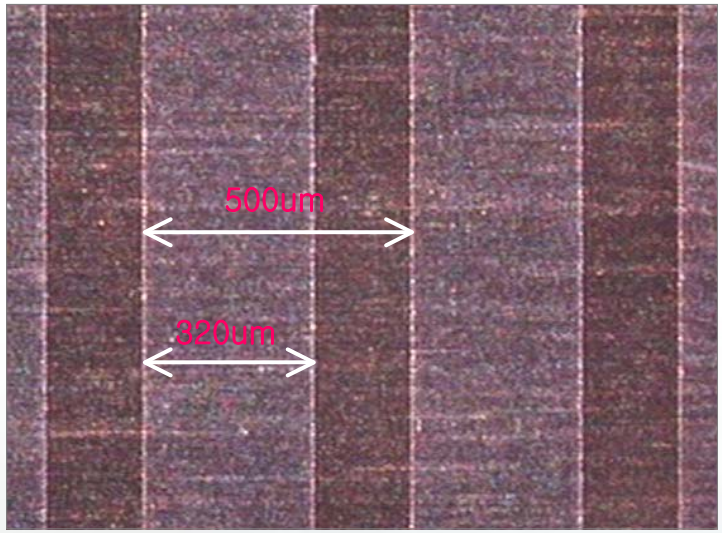


ETCHING TECHNOLOGY

< 실험 DATA (1) >

1. PARAMETER CONDITION

- ETCHANT : CuCL2
- Bath Temp : 50'c
- ORP : 620 mV
- S.G : 1.382
- Pressure : 2.5 Kgf
- Etching Time : 1 min

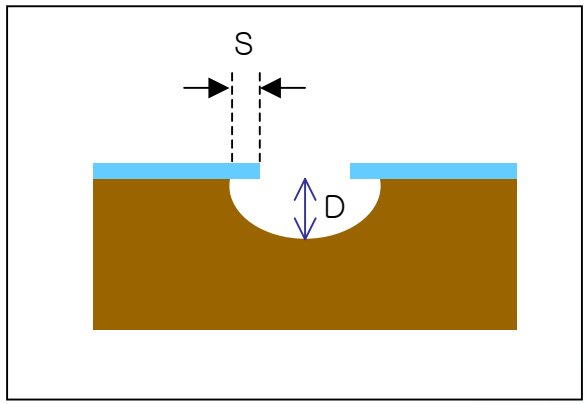


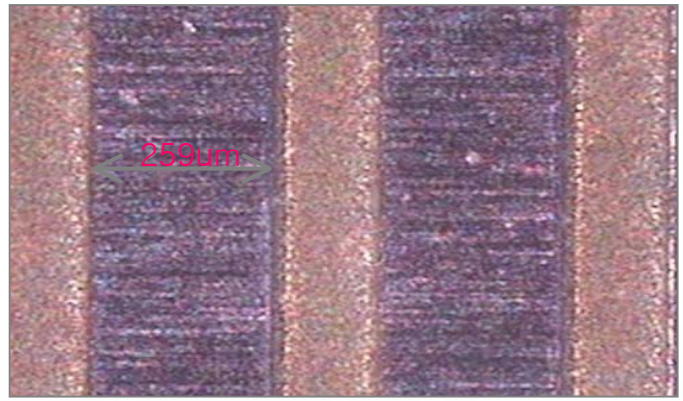
2. SPECIMEN TESTED

- Device : L/F 160 MQFP
- Copper : C-7025 (Copper Alloy)
- Pattern Width / Space : 0.320 / 0.180mm
- Resist : DFR

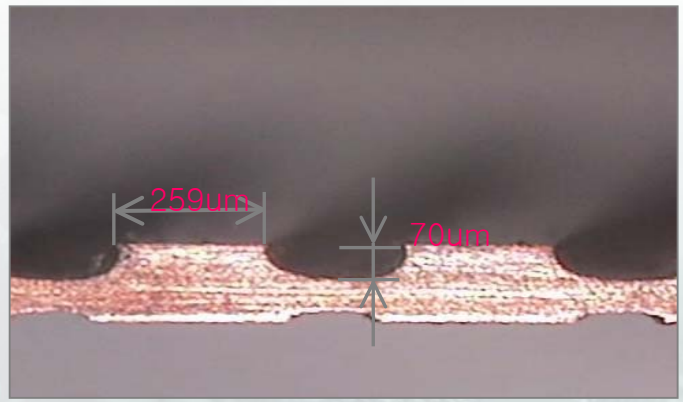
ETCHING TECHNOLOGY

< ETCHING FACTOR @ 1.0 N HCL >



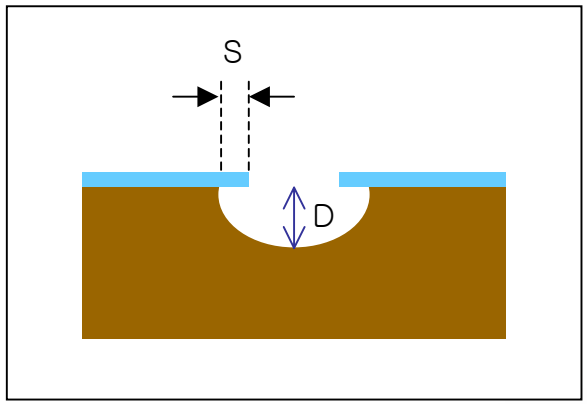


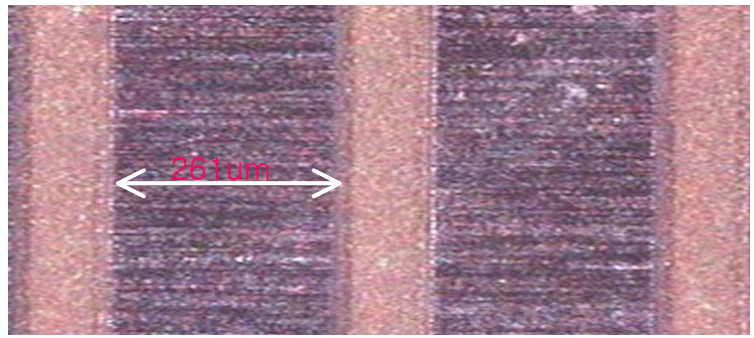
	@ 1.0N HCL
Undercut (S)	31 ㎛
Vertical Etch (D)	70 ㎛
E/T Factor (f)	2.29



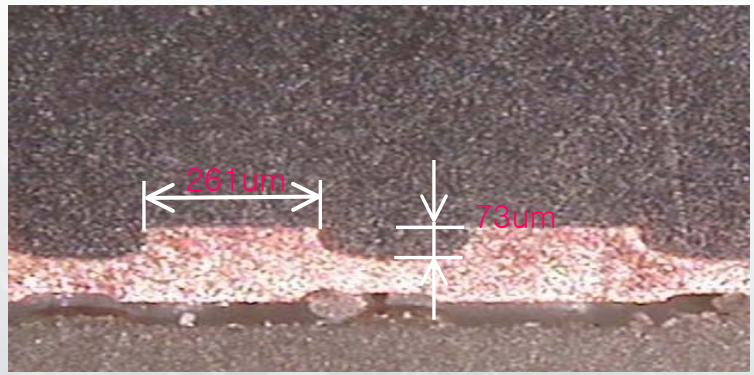
ETCHING TECHNOLOGY

< ETCHING FACTOR @ 0.5 N HCL >



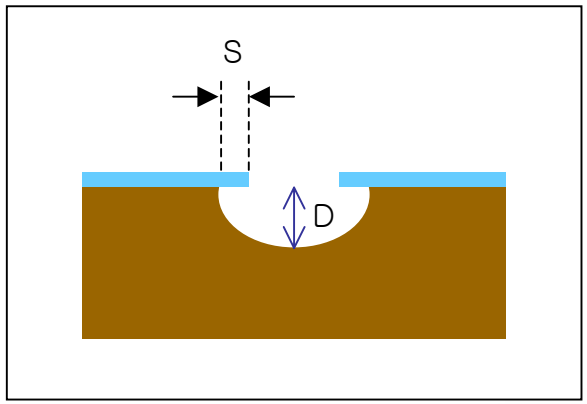


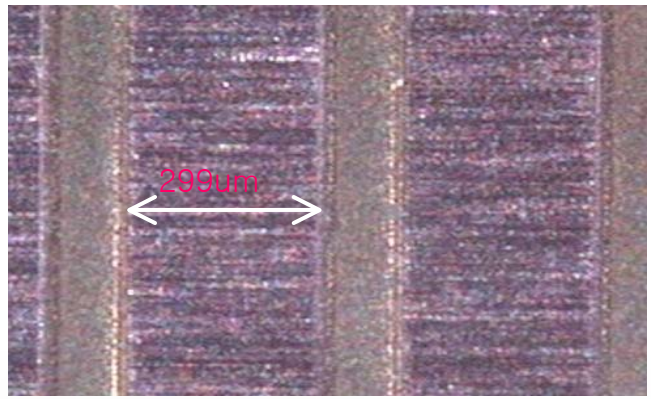
	@ 0.5N HCL
Undercut (S)	30 ㎛
Vertical Etch (D)	73 ㎛
E/T Factor (f)	2.47



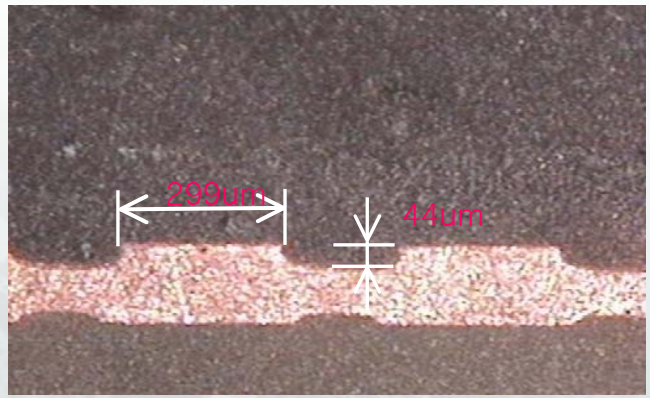
ETCHING TECHNOLOGY

< ETCHING FACTOR @ 0 N HCL >

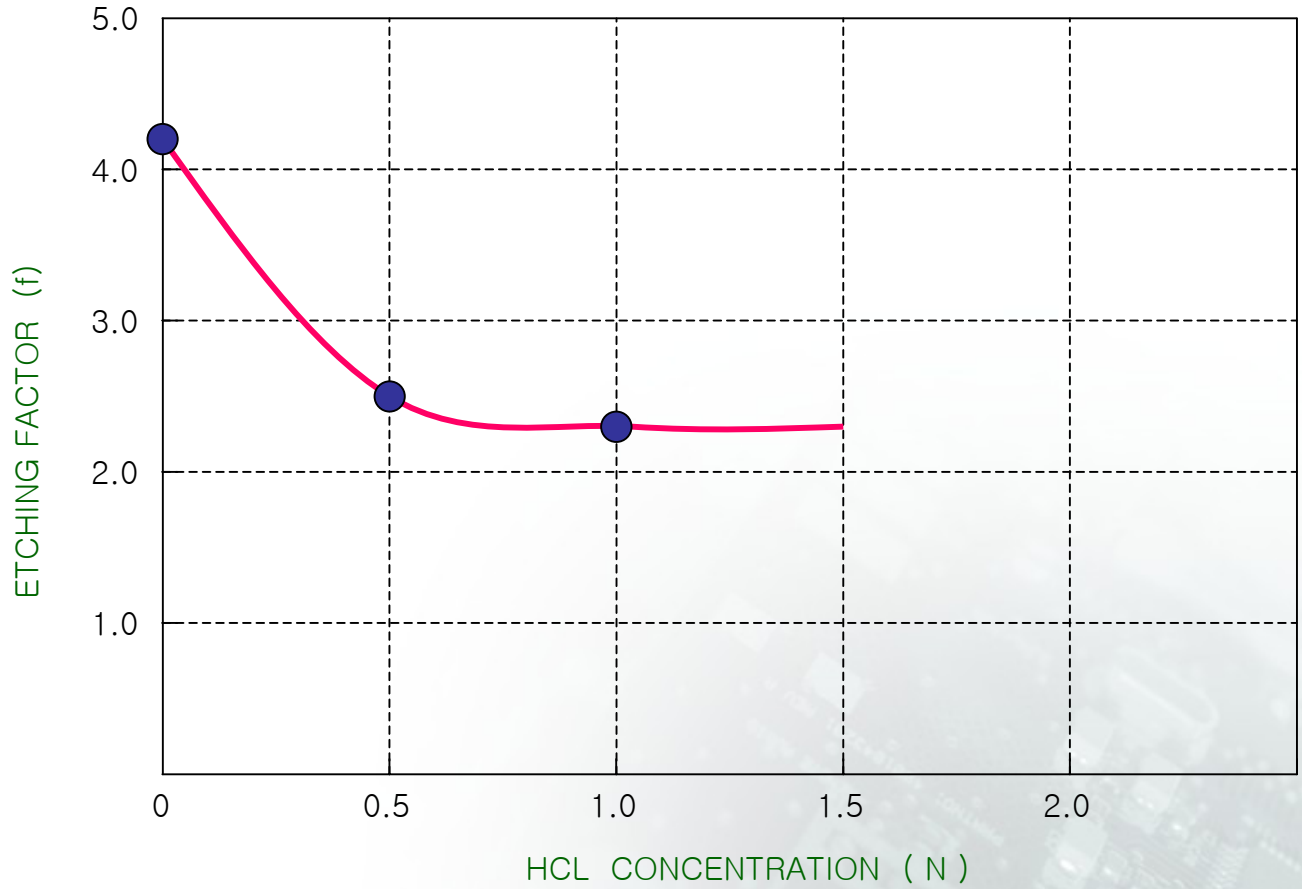




	@ 0N HCL
Undercut (S)	11 ㎛
Vertical Etch (D)	44 ㎛
E/T Factor (f)	4.19



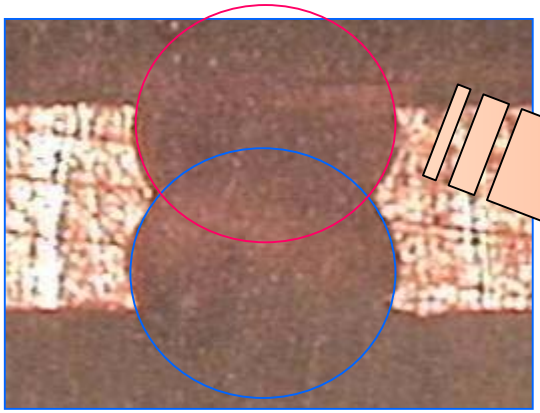
ETCHING TECHNOLOGY



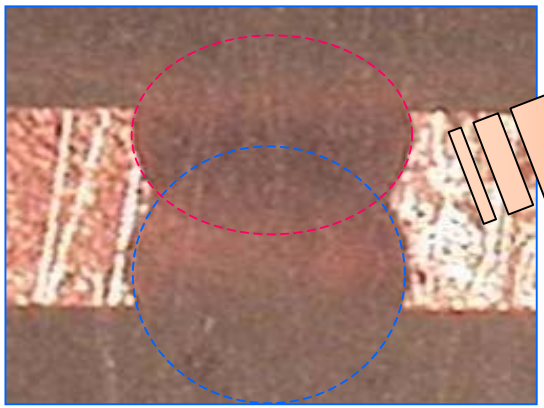
ETCHING TECHNOLOGY

< 실험 DATA (2) >

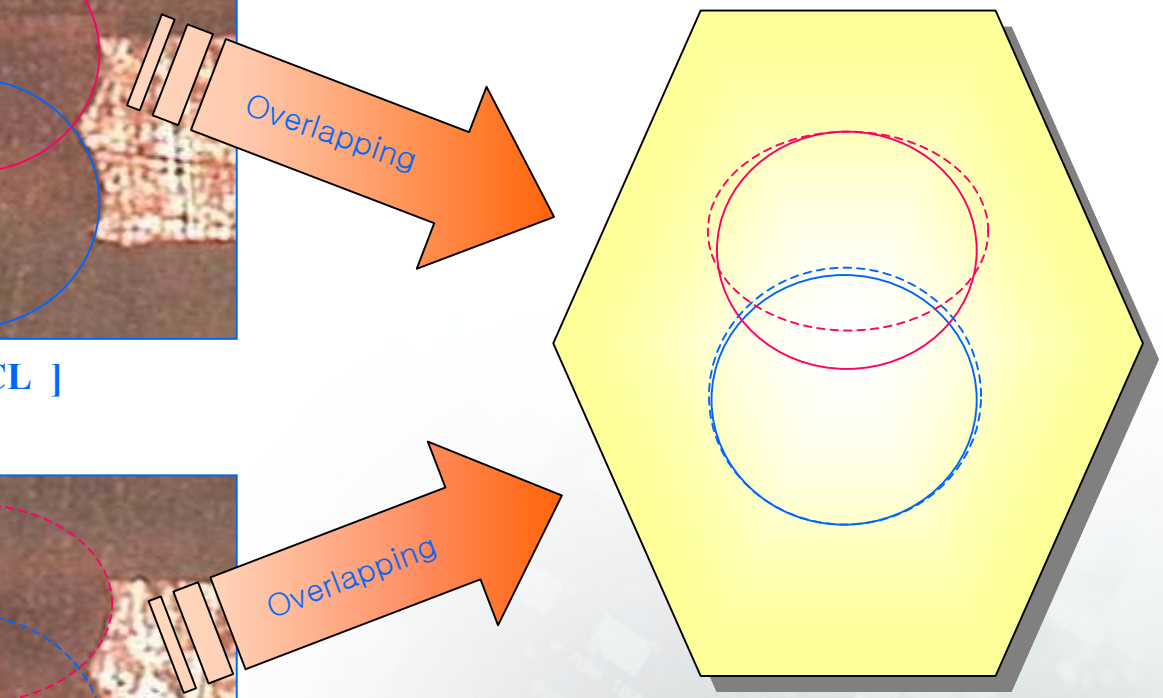
* Sample : L/F MLF 28 LD



[0 N HCL]



[0.5 N HCL]

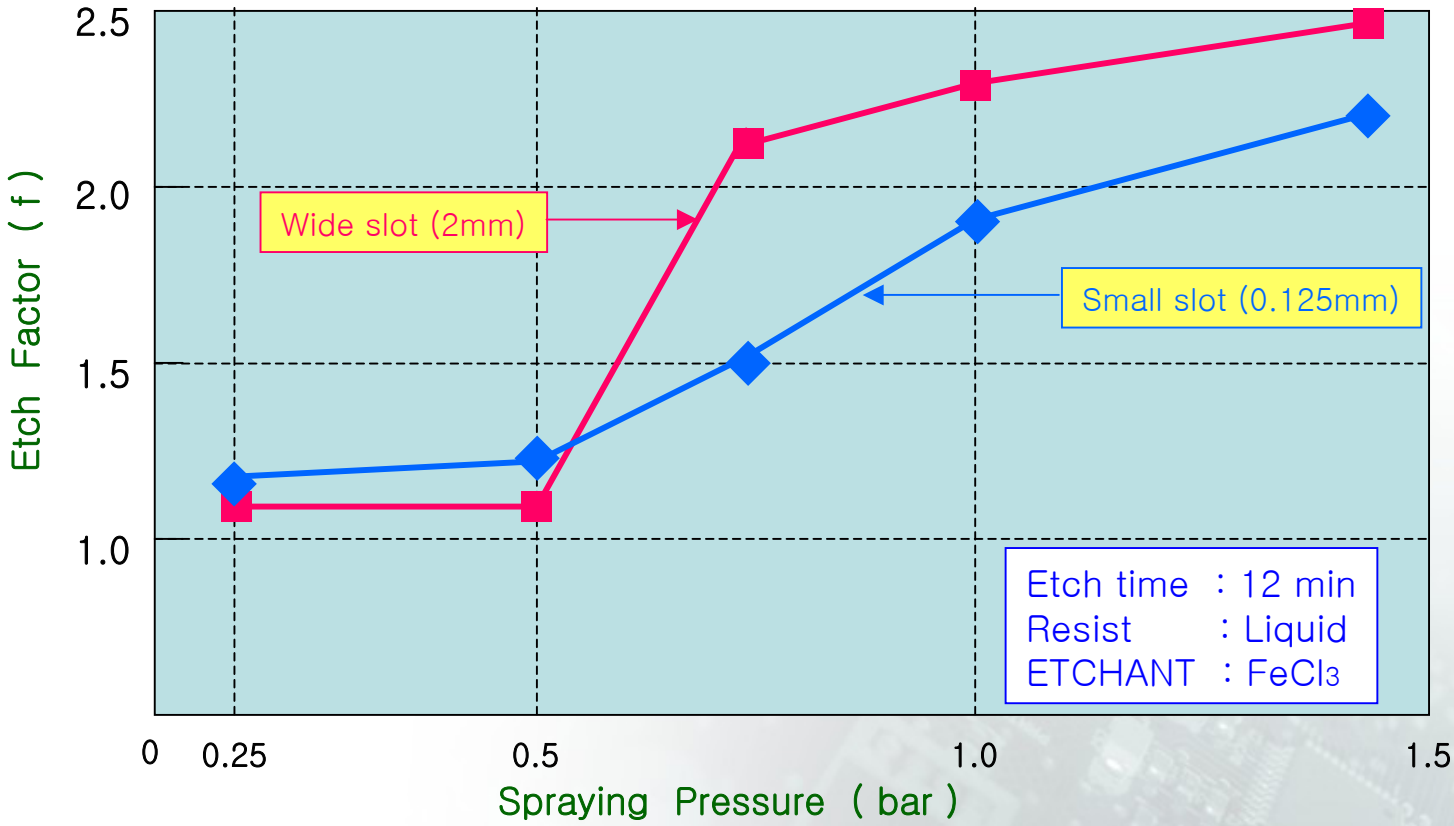


TOP : 0 N HCL is superior

BTM : No difference

ETCHING TECHNOLOGY

< ETCHING FACTOR vs. Spray Pressure >



ETCHING TECHNOLOGY

< Key factors and Effects >

	ETCH Rate	ETCH Factor	Side Effect
HCL Concentration ↑	▲	▼	Safety issue (CL_2 gas)
Temperature ↑	▲	●	Limitation on material
Spray Pressure ↑ (Flow rate)	▲	▲	Limitation on Flexible circuit
Spray Pattern Change (Flat Fan → Full Cone)	▲	▼	
Nozzle Density ↑	▲	▼	
Oscillation (Swing → Horizontal)	●	▲	
ORP ↑	▲	●	

▲ Positive effect
▼ Negative effect
▲ Conditionally Positive
● Negligible

ETCHING TECHNOLOGY

Poor etch-factor

The loss of turbulent flow and impingement at etch channel when the stationary layer begins to fill the entire etch space !!!

Recommendation

1. Free HCL concentration to be maintained as low as possible.
2. Geometry of the equipment to be designed properly to enhance the exchange of ETCHANT in tunnel.
3. The dropping size of spraying ETCHANT shall be minimized, especially for narrower pattern space product.

ETCHING TECHNOLOGY

4 If the situation is permitted, the design of pattern space is recommended to be as wide as possible.

5 Likewise, the thickness of photo-resist is recommended to be as small as possible.

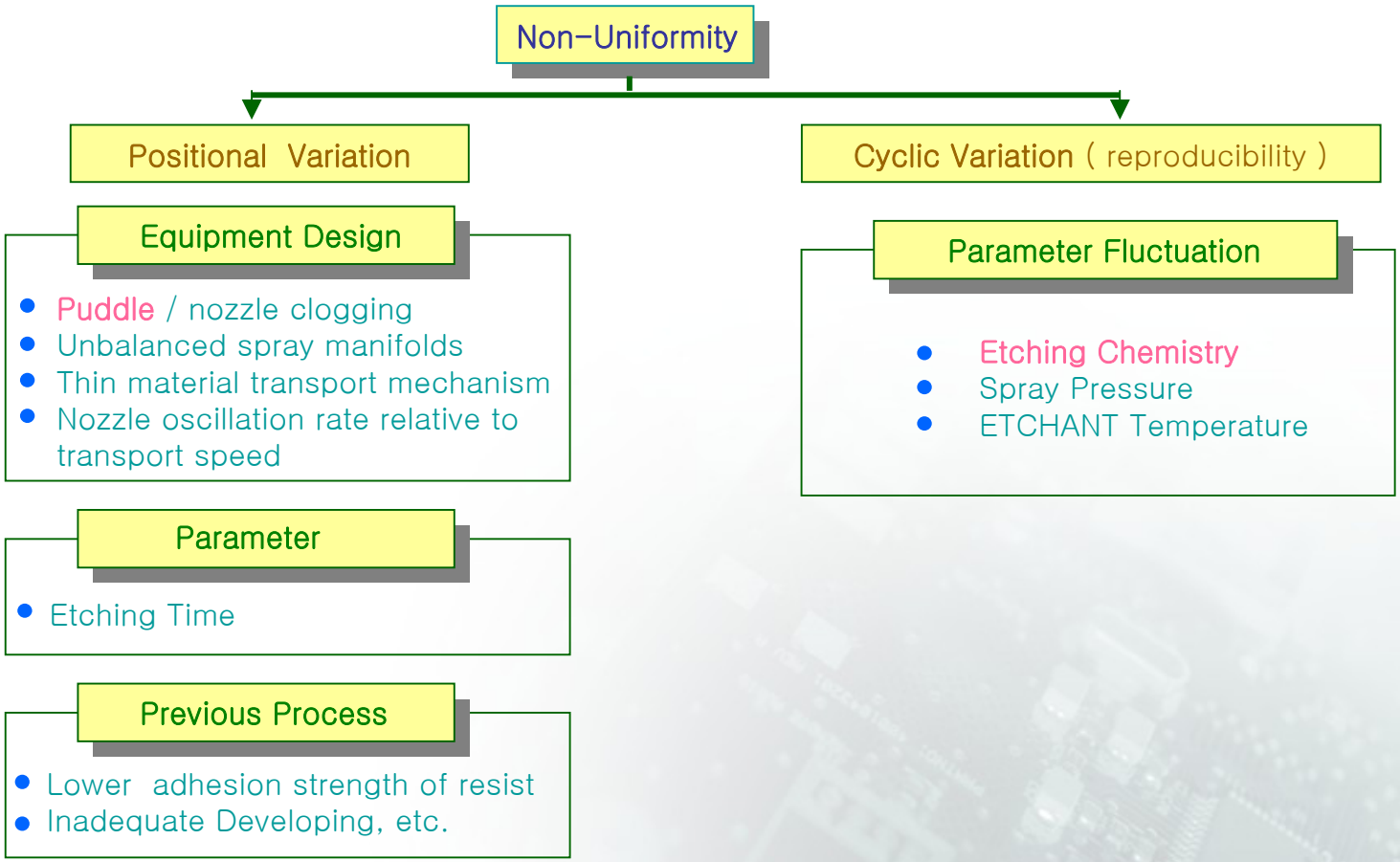
6 The type of ETCHANT might not be a crucial for etching factor.

7 With increasing spraying pressure, etching factor is getting higher, but stable at more than 1.5 bar.

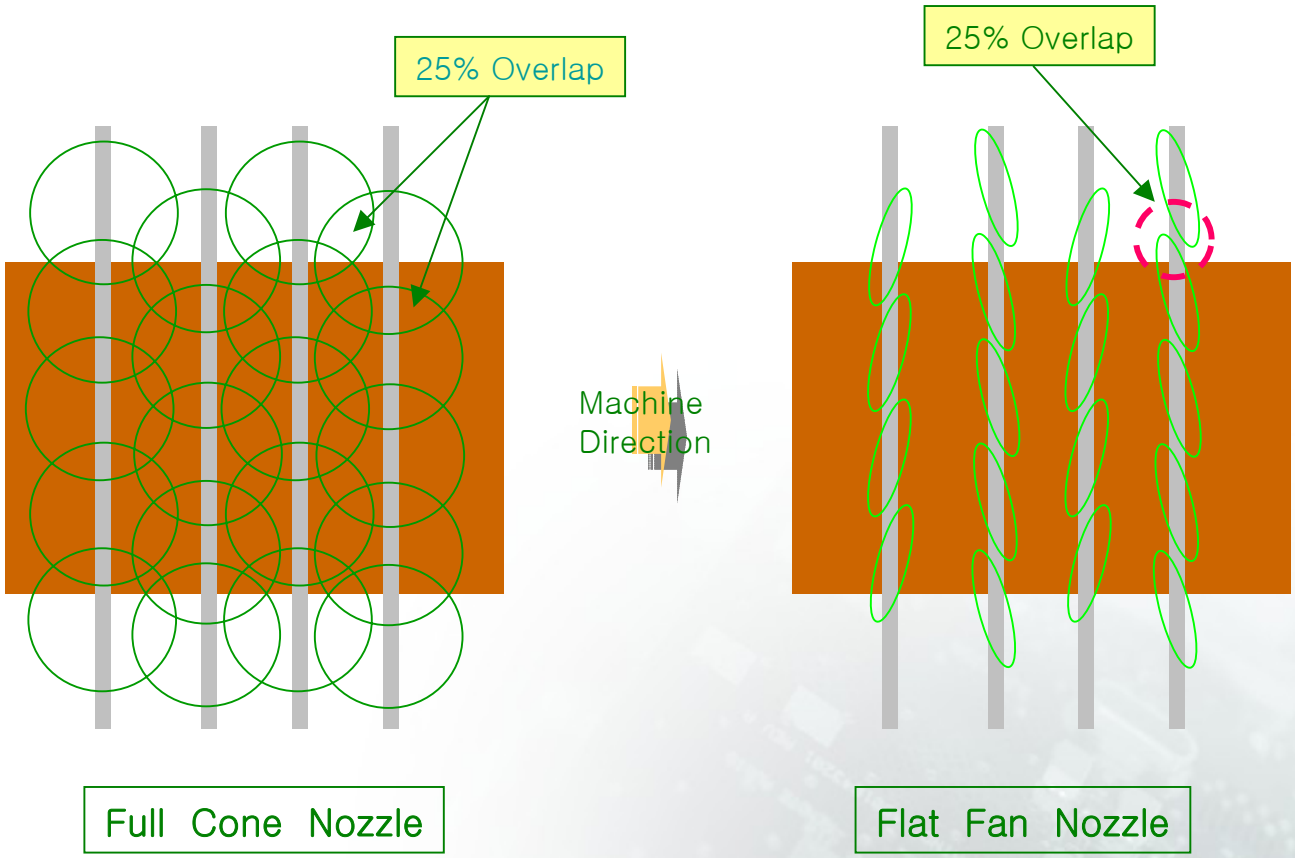
8 With the elapse of etching time, etching factor is dropping exponentially.

ETCHING TECHNOLOGY

UNIFORMITY

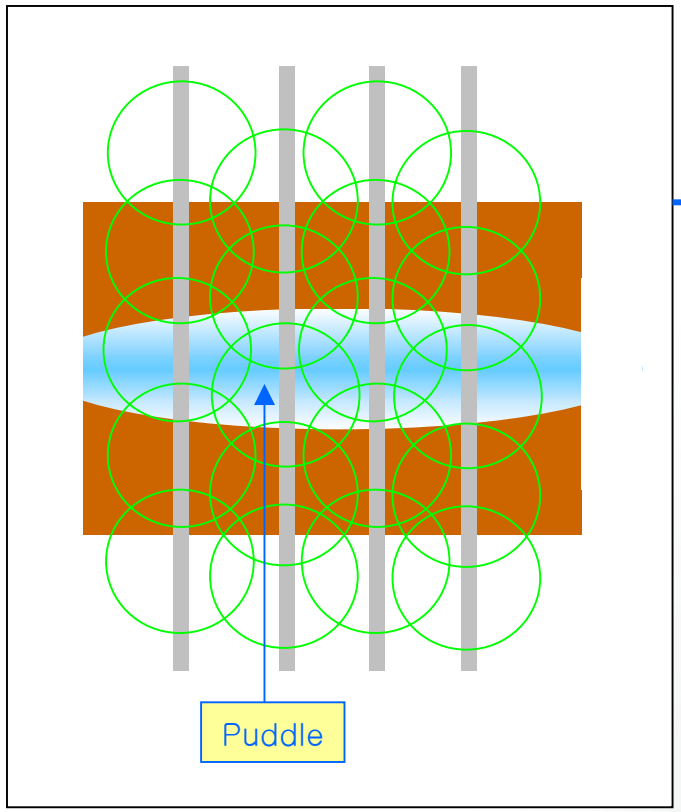


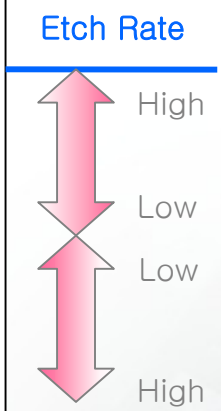
ETCHING TECHNOLOGY



ETCHING TECHNOLOGY

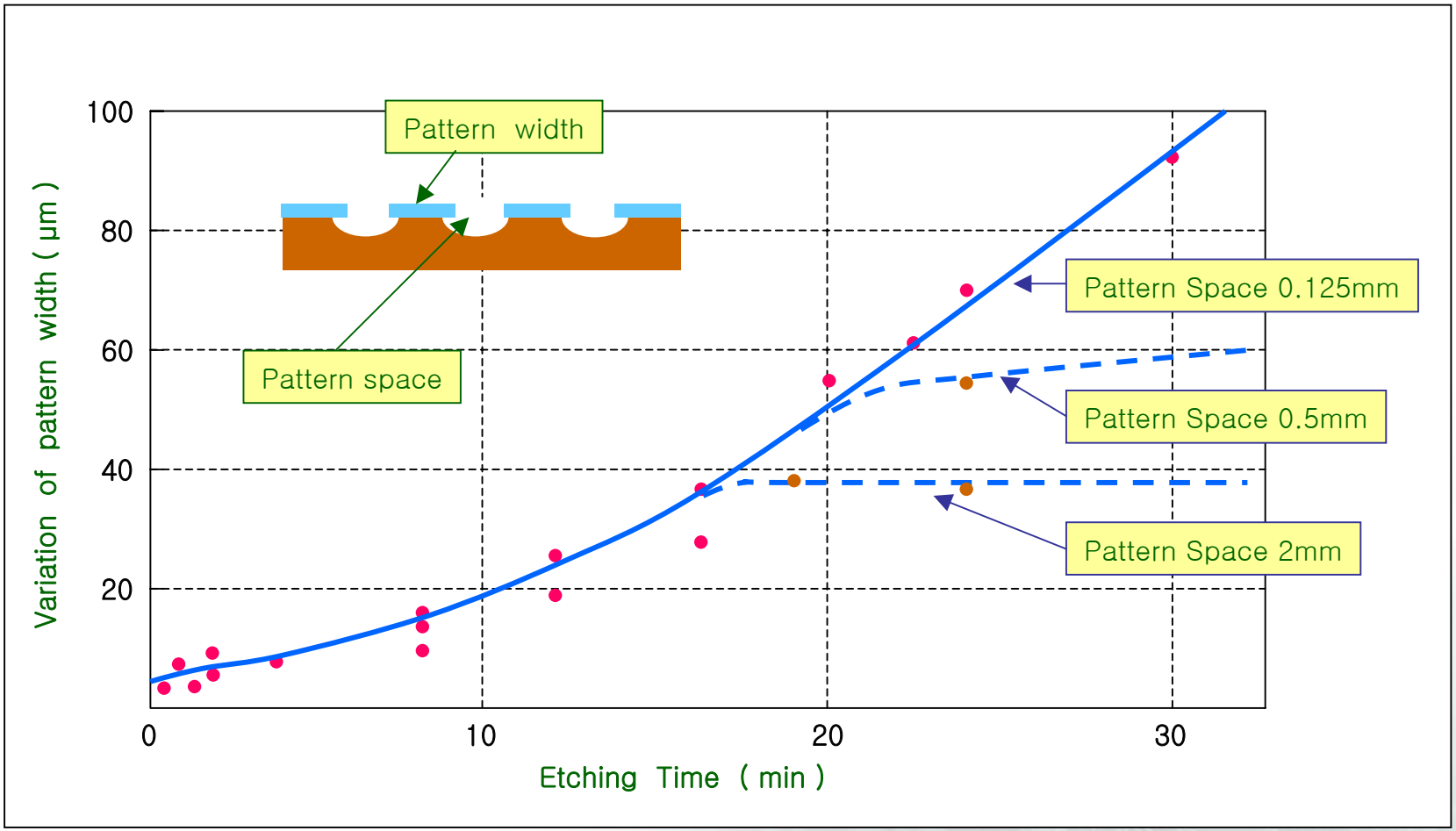
< Schematic of Puddle Phenomenon >





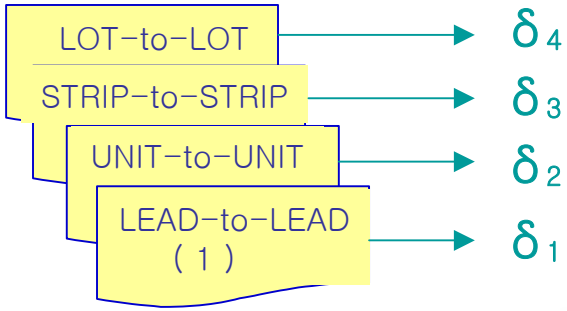
- The wider the panel is, the more Puddle
- The higher Flow rate, the more Puddle
- The higher Puddle, the higher Non-uniformity

ETCHING TECHNOLOGY



ETCHING TECHNOLOGY

< Capability Analysis >



$$\delta_T^2 = \delta_1^2 + \delta_2^2 + \delta_3^2 + \delta_4^2$$

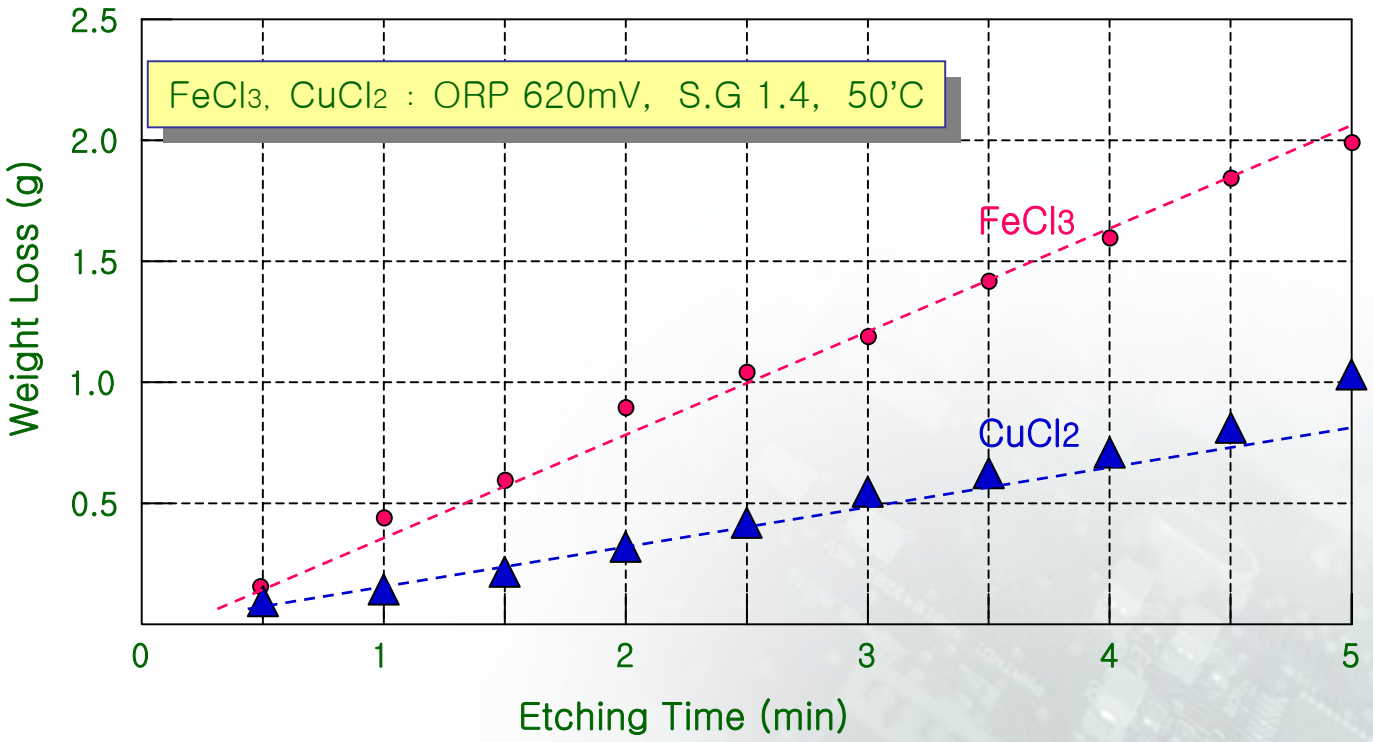
$$\delta_T = \sqrt{\delta_1^2 + \delta_2^2 + \delta_3^2 + \delta_4^2}$$

$$\text{Overall Capability} = 3 * \delta_T = 3 * \sqrt{\delta_1^2 + \delta_2^2 + \delta_3^2 + \delta_4^2}$$

ETCHING TECHNOLOGY

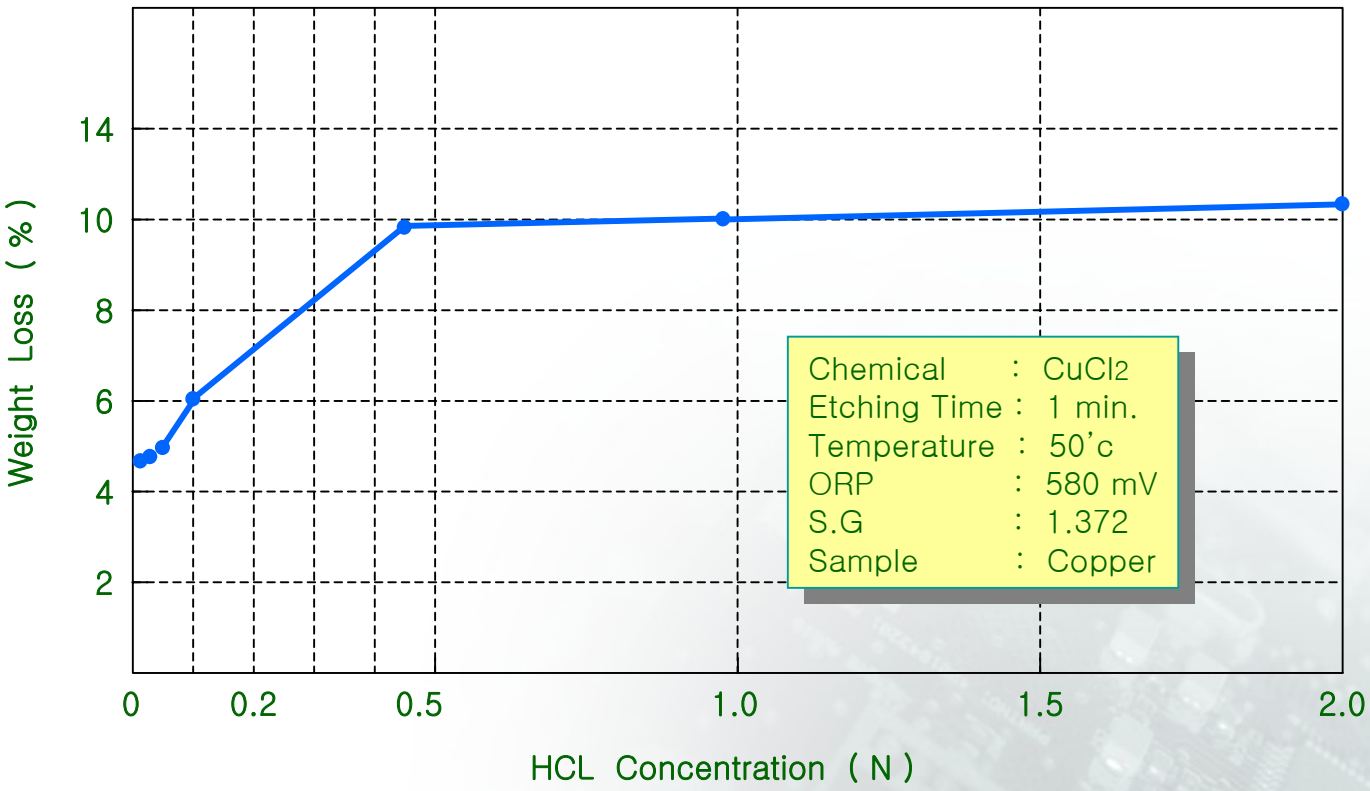
ETCHING SPEED

< Comparison of Etching Rate - FeCl3 vs. CuCl2 >



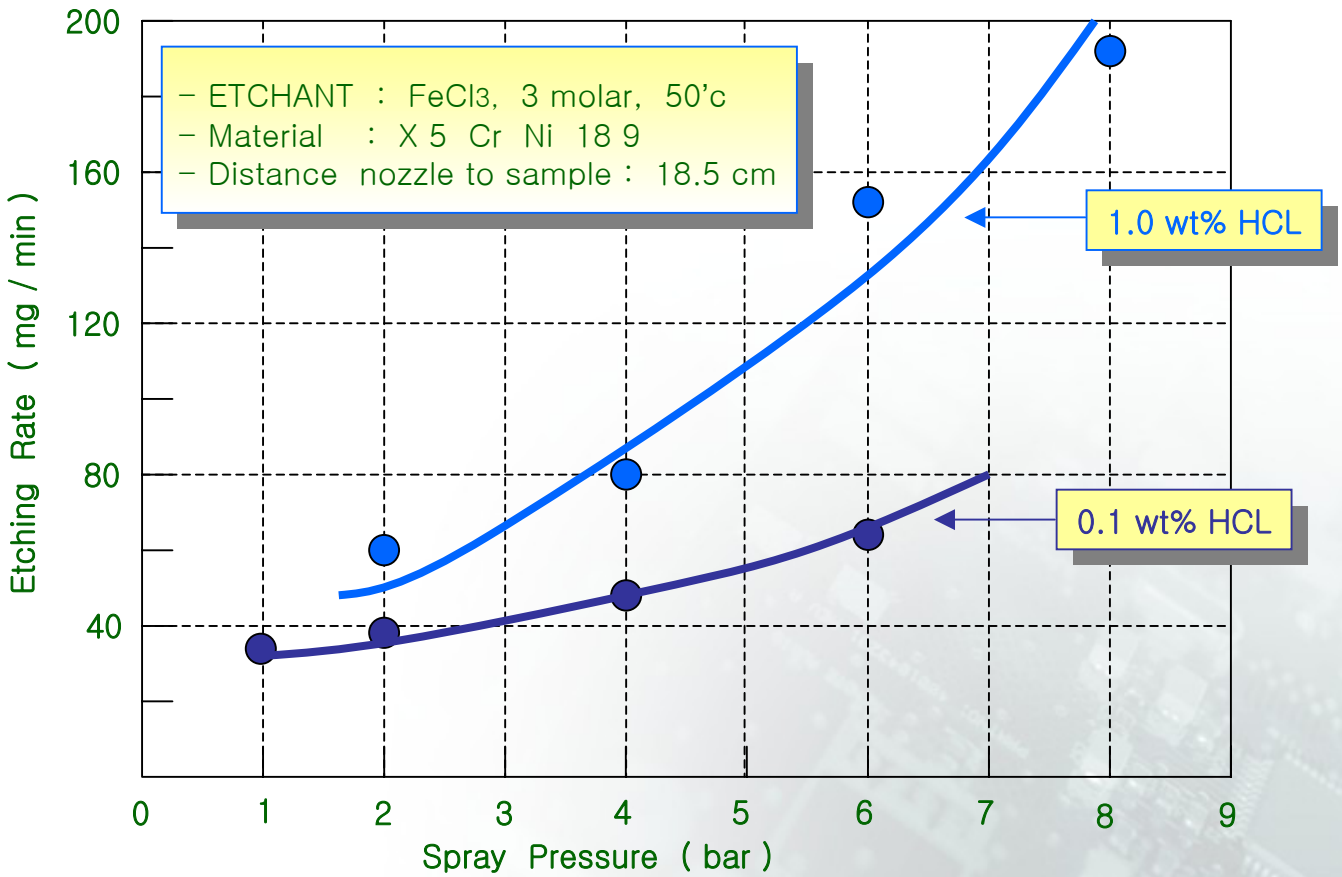
ETCHING TECHNOLOGY

< Dependence of Etch Rate on HCL >



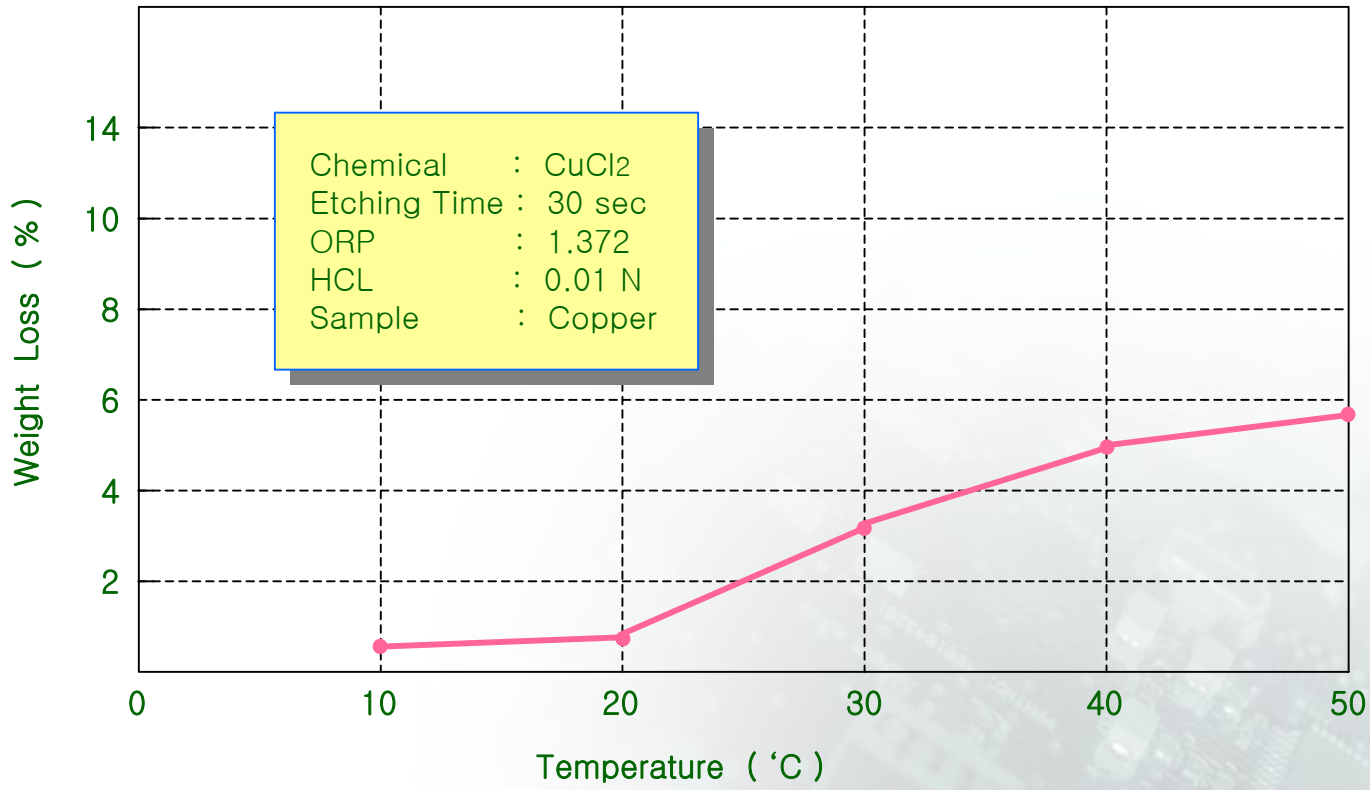
ETCHING TECHNOLOGY

< Effect of HCL and spray pressure on etch rate >



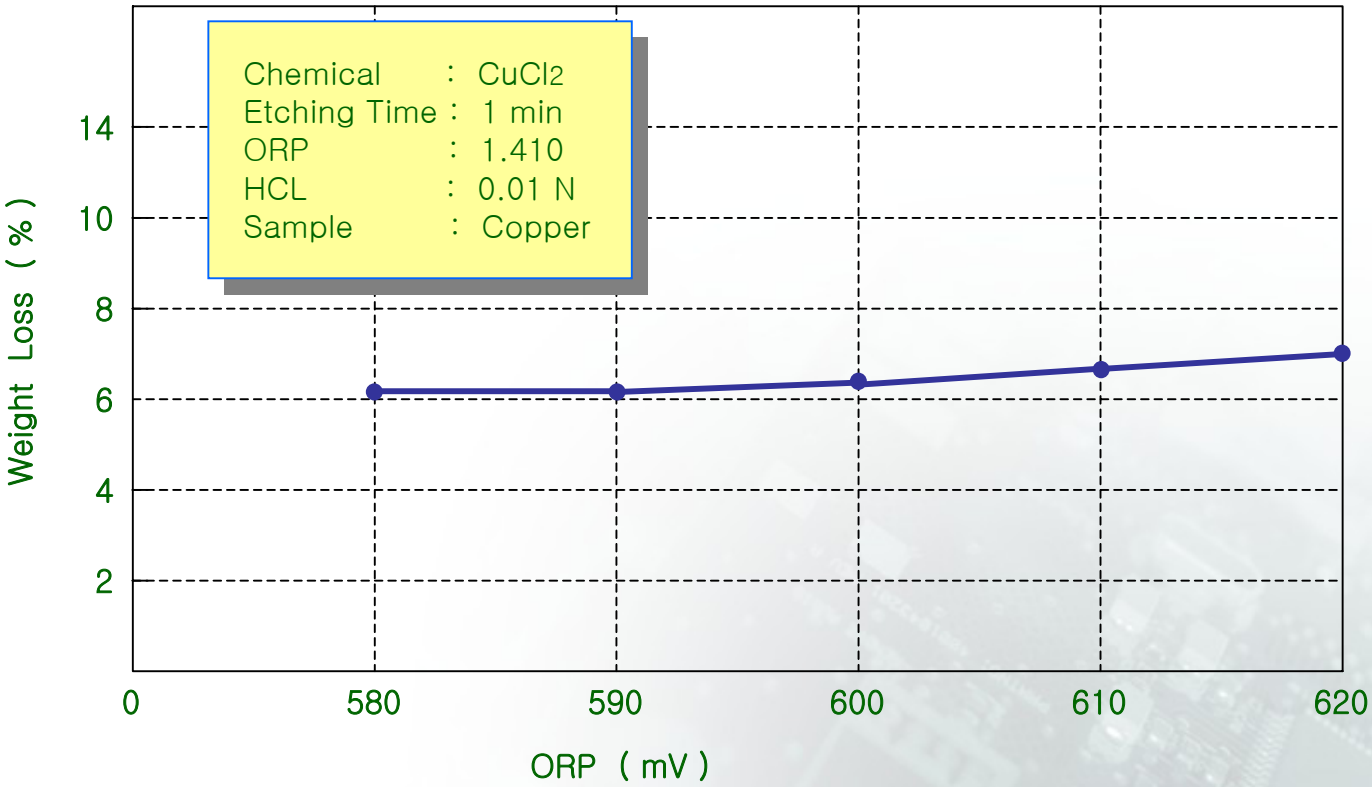
ETCHING TECHNOLOGY

< Dependence of Etch Rate on Temperature >

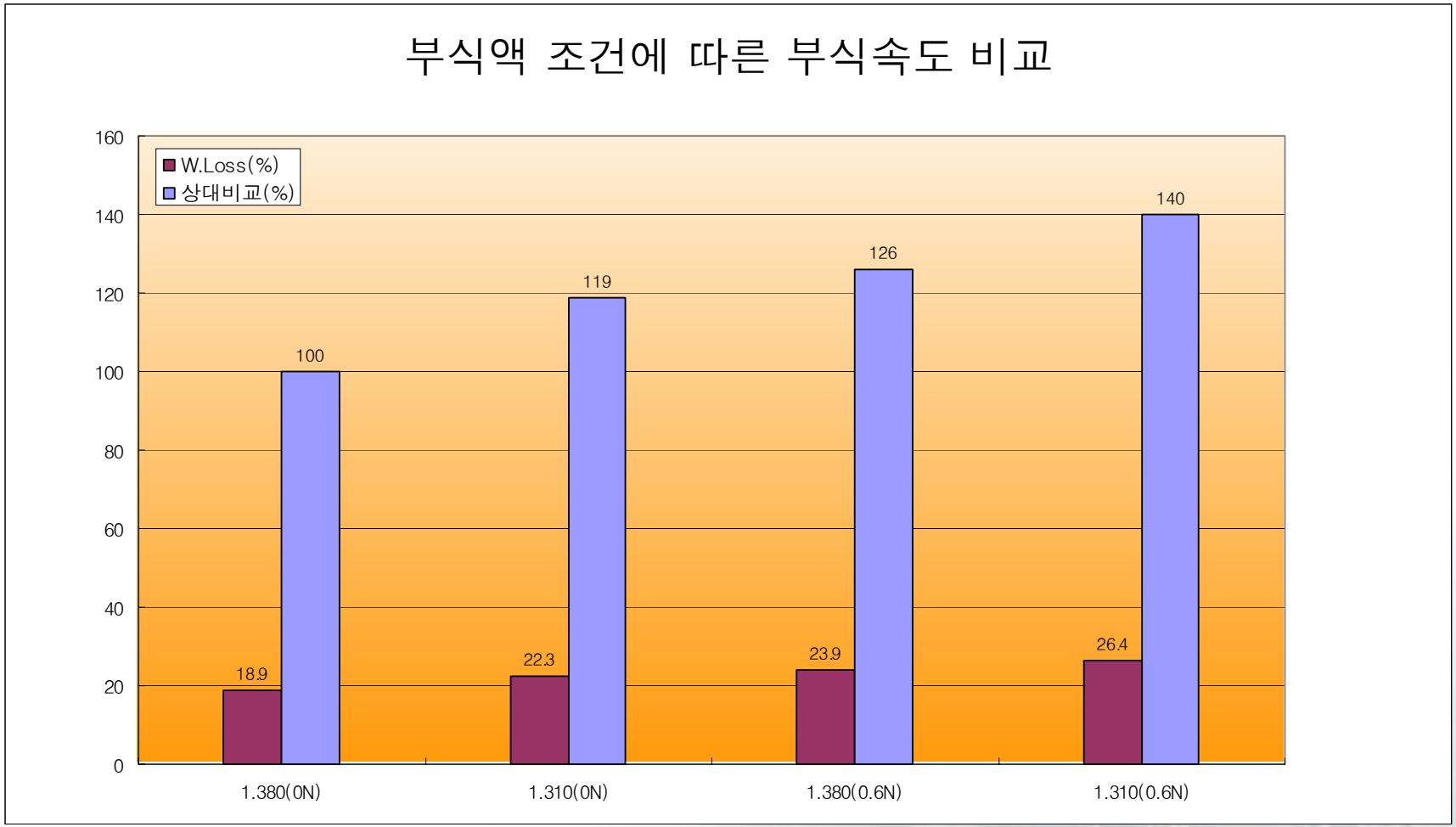


ETCHING TECHNOLOGY

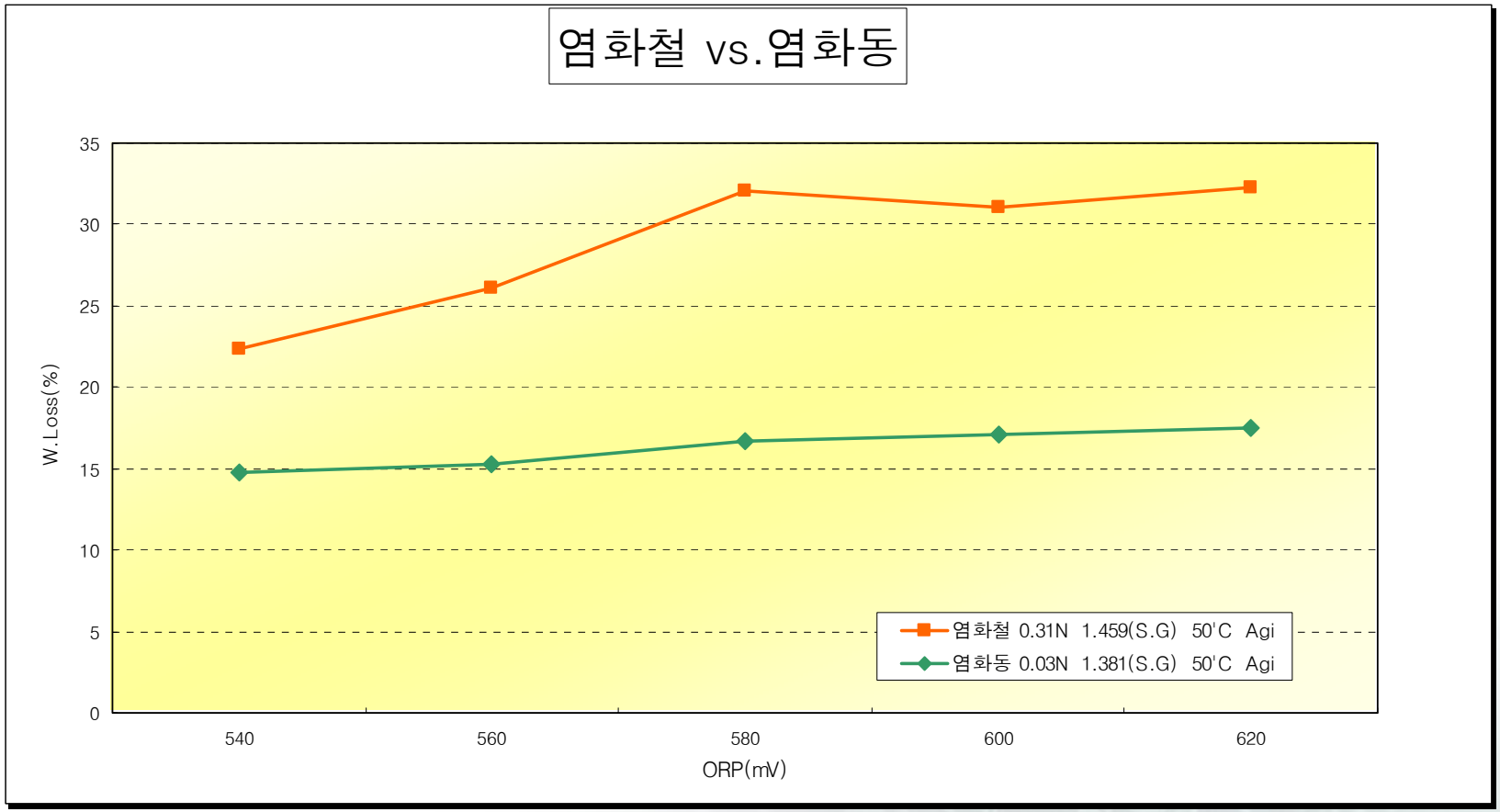
< Dependence of Etch Rate on ORP >



ETCHING TECHNOLOGY

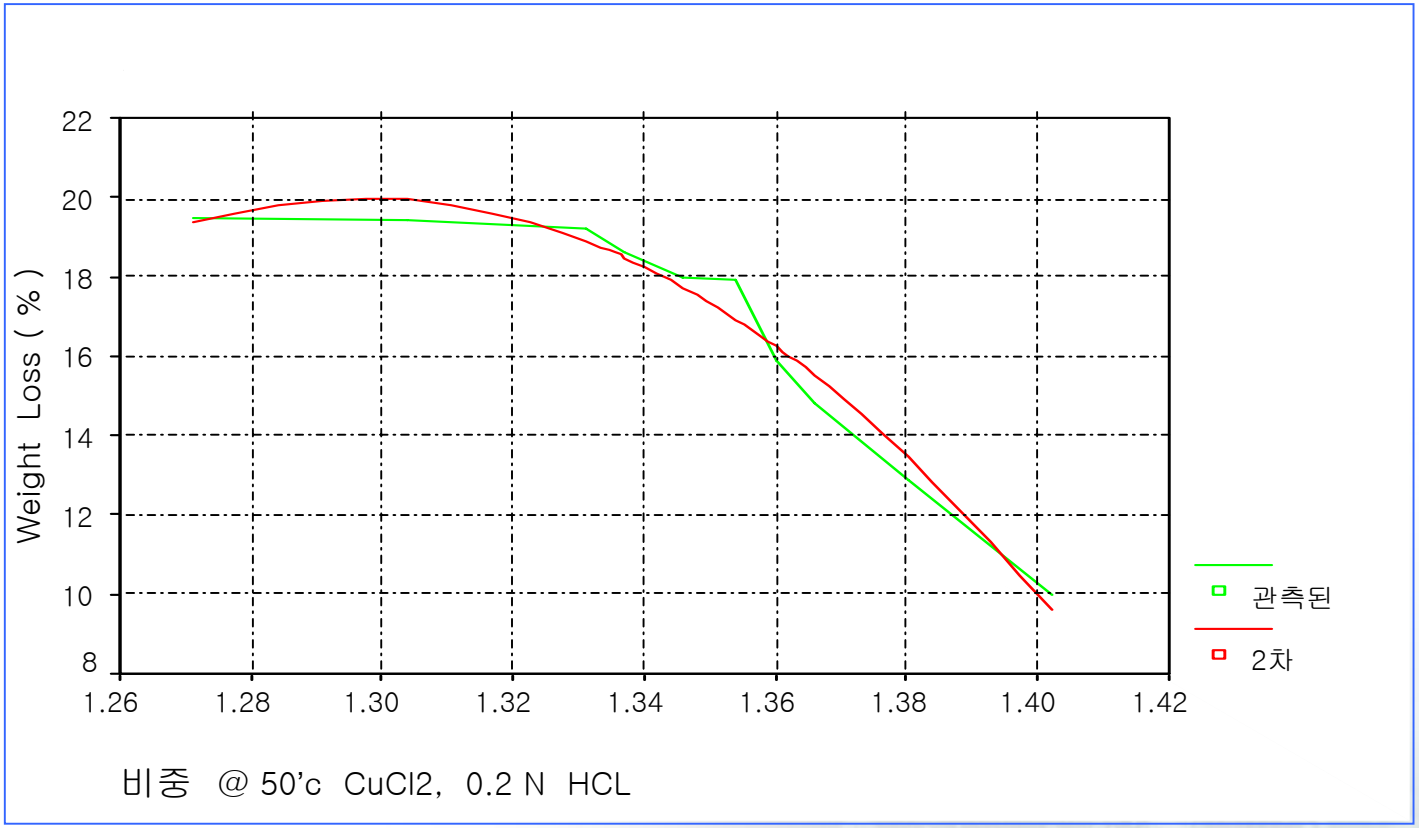


ETCHING TECHNOLOGY

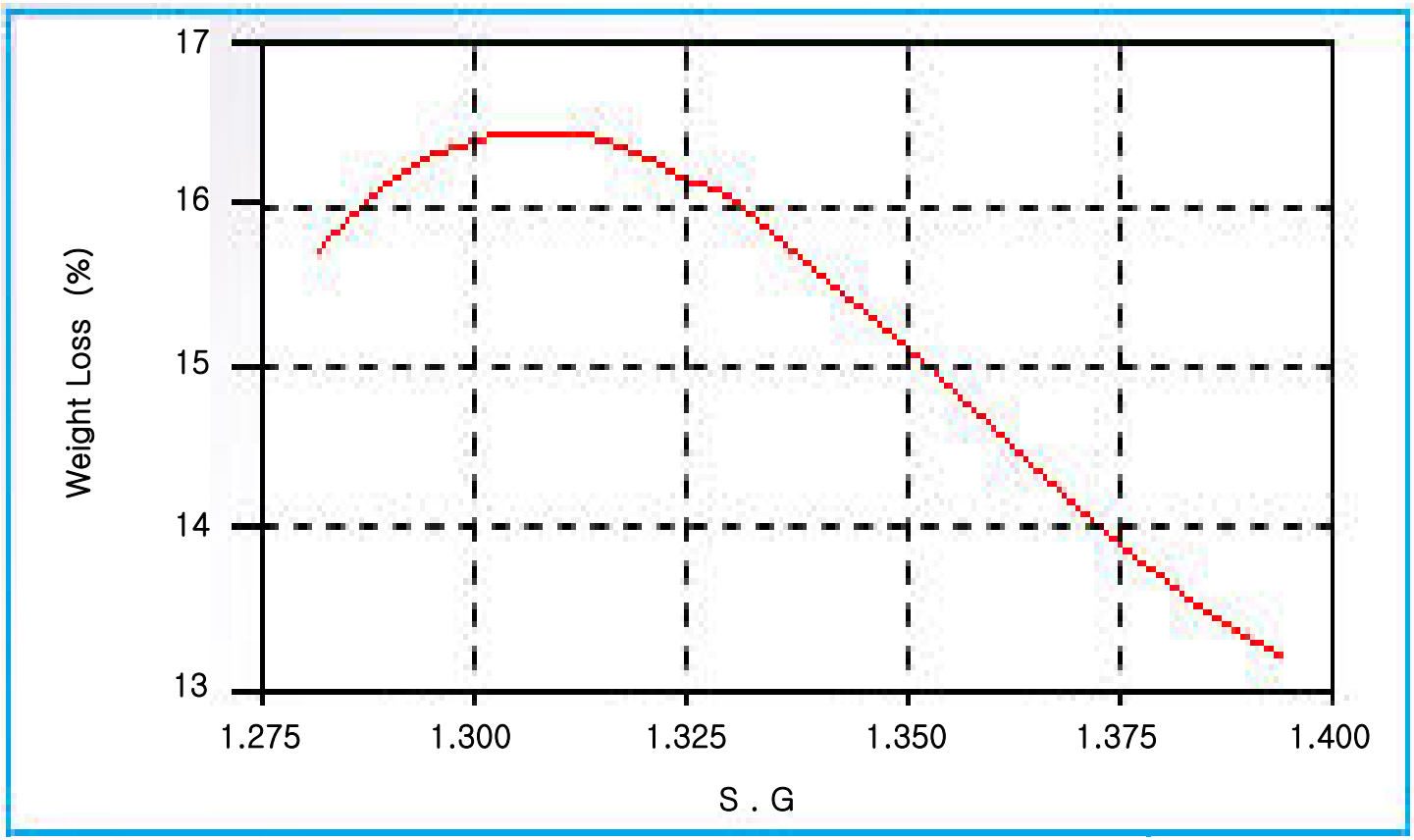


1) 염화철의 ORP에 의한 영향이 상대적으로 민감함. (Narrow Process Window)

ETCHING TECHNOLOGY



ETCHING TECHNOLOGY



5 min dipping in CuCl2 with NaClO3 @ 50'c, 0 N HCL

ADD-100 부식속도 첨가제

ADD –100 은 CuCl2 부식 액의 부식속도를 증가시킬 목적으로 개발된 첨가제로서, 다음과 같은 장점이 있음.

- 부식속도 증가 (기존대비 약 50%)
- 생산성 향상 및 원가절감
- ETCHING FACTOR 증가

ETCHING TECHNOLOGY

ADD -100	S.G (비중)	초기무게(g)	나중무게(g)	W.Loss (%)	AVG (%)	Etching 증가율(%)
0 %	1.360	1.9341	1.6053	17.3	19.1	0
		1.9623	1.5818	19.4		
		1.9515	1.5475	20.7		
1 %	1.375	1.9233	1.5232	20.8	20.6	7.8
		1.9086	1.5287	19.9		
		1.9416	1.5516	20.1		
2 %	1.383	1.9367	1.5280	21.1	21.3	11.5
		1.9280	1.5272	20.8		
		1.9339	1.5069	22.0		
3 %	1.393	1.9066	1.4604	23.4	23.9	25.1
		1.9484	1.4827	23.9		
		1.9403	1.4649	24.5		
4 %	1.402	1.9104	1.3984	26.8	26.9	40.8
		1.9086	1.3875	27.2		
		1.9139	1.4044	26.6		
5 %	1.409	1.9446	1.3320	31.5	31.0	62.3
		1.9680	1.3539	31.2		
		1.9265	1.3469	30.2		
6 %	1.413	1.9362	1.3006	33.0	32.8	71.7
		1.9305	1.3262	32.0		
		1.9713	1.3115	33.5		

ETCHING TECHNOLOGY