

# New Technology to Improve Etching Performance using Shiny Side Surface Treatment for HDI

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## Abstract

This paper discusses a new technology to improve etching performance using shiny side surface treatment on copper foil. Until now, a lot of electro-deposited copper foils (ED foil) with very low profile on matte side have been introduced to the market to obtain fine line products such as HDI. In addition to copper foil thickness, roughness of matte side is thought to be a key factor to improve etching performance. However, our new technology is quite unique and different from other methods to obtain narrow traces. Using new technology, 30 micron pitch circuits could be obtained using 9 micron copper foil.

## Experimental

### (1) Sample preparation flow and test condition

Copper foil was laminated onto coverlay to make FCCL(flexible copper clad laminate). The flow of the sample preparation was shown below.

Copper foil → Coverlay press → resist spin coating → UV exposure → Development → resist baking → Etching

\*Mask pattern : 30 micron pitch (Line/space=25/5)  
40 micron pitch (Line/space=25/15)  
50 micron pitch (Line/space=33/17)

\*Etching solution condition  
FeCl<sub>3</sub> 37wt%  
Temp. 50C  
Baume scale 40 Be  
Spray 0.15Mpa

### (2) Copper foil samples

In order to verify the effect of surface roughness of copper foil, different type foils were chosen for the test shown in Table 1. Two foils were chosen from RA (rolled copper foil) and two foils from ED.

**Table 1 Type of copper foil used for etching test.**

Copper foil sample	Type of copper foil	Surface treatment
BHYA	RA (Rolled foil)	Smooth type
BHY	RA (Rolled foil)	Regular treatment for RA
Special ED	ED (Flat type)	Regular treatment on Flat type ED
Standard ED	ED (Standard)	Regular treatment on Regular ED

### (3) Etching performance evaluation

Surface morphology was investigated by SEM on the matte side of the samples shown in Figure 1. It is clear that roughness of ED was quit bigger than that of RA. The difference between BHY and BHYA was relatively small compared to ED. After etching, line width and the length only for the tail along the circuit was measured to obtain etching factor. Etching factor was defined as shown in Figure 3.

From the etching test results, etching factor improved when matte side surface roughness decreased. Flatter foil seemed to be better to create narrower traces. So, flatter and thinner copper foil has been used to make narrower traces for such as COF application and packaging materials. Recently it was found that 30 micron pitch seemed to be the limitation for the subtractive method, especially for COF industry. Thus, new technology should be investigated soon to overcome the limitation.

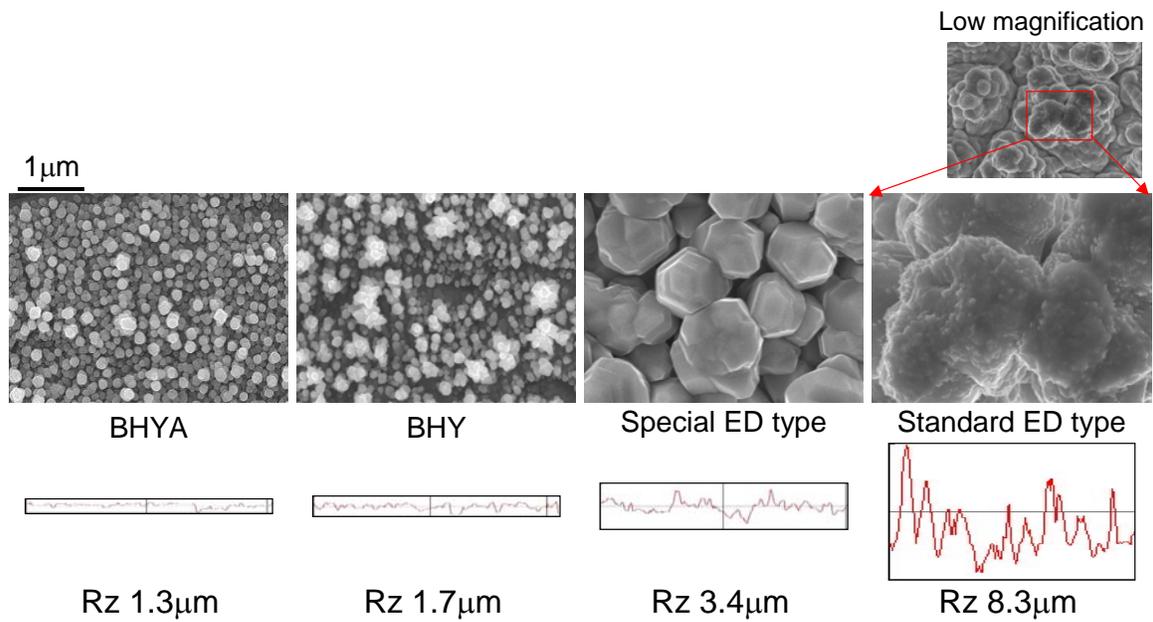


Figure 1 Comparison among various copper foils with regards to different surface roughness.

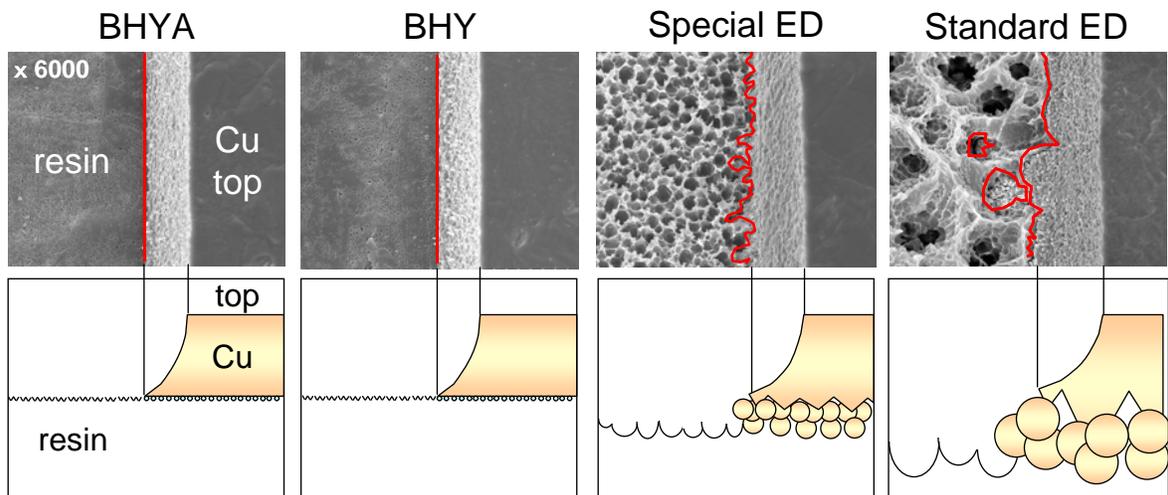


Figure 2 The effect of surface roughness on matte side of the copper foil on etching performance. (60 micron pitch pattern)

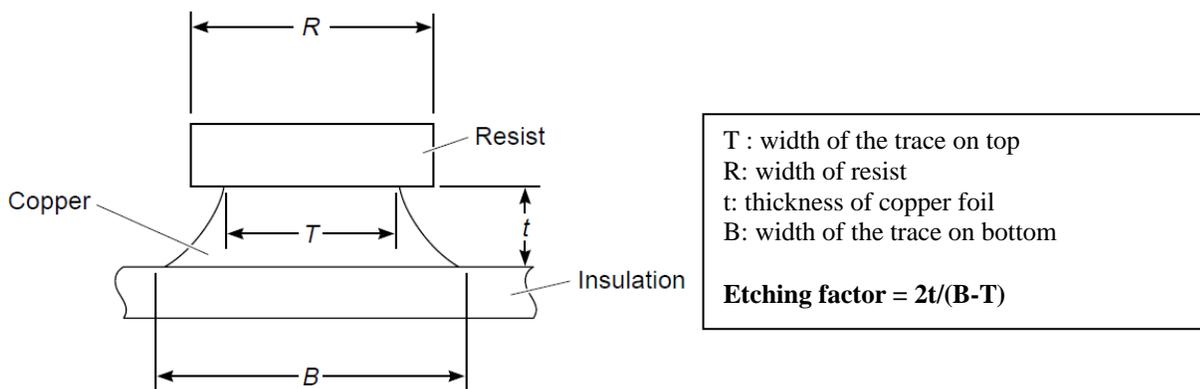
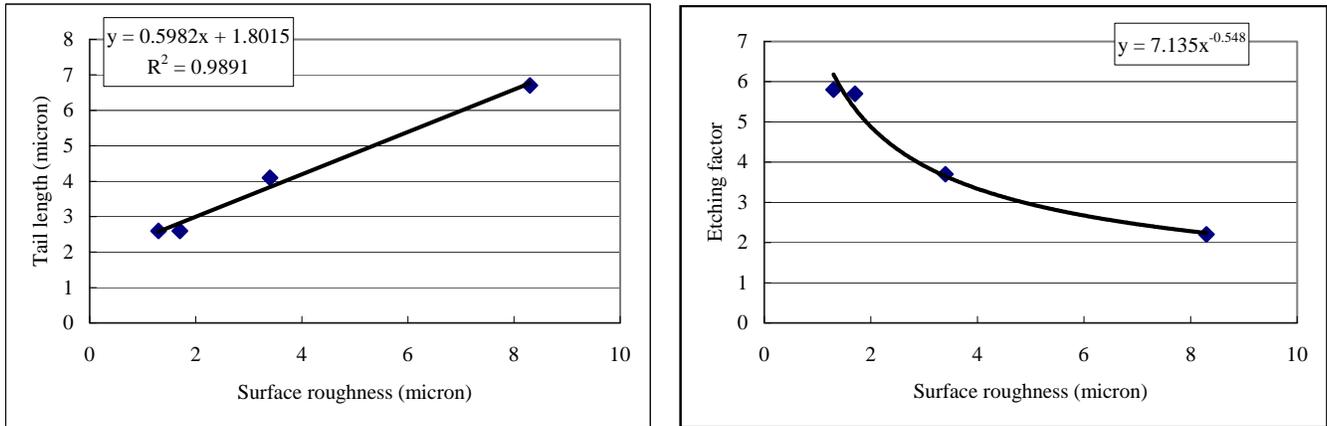


Figure 3 The definition of etching factor.

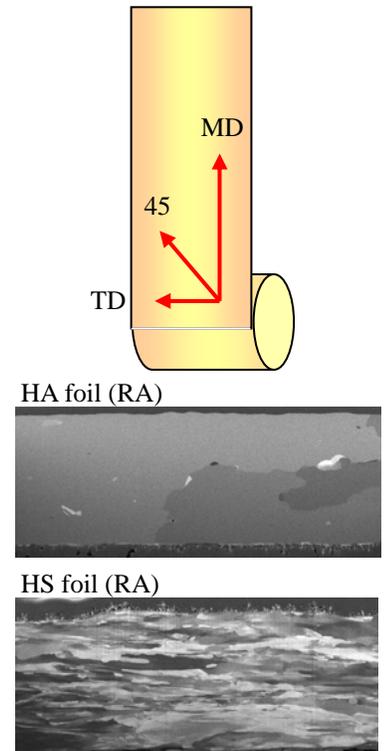
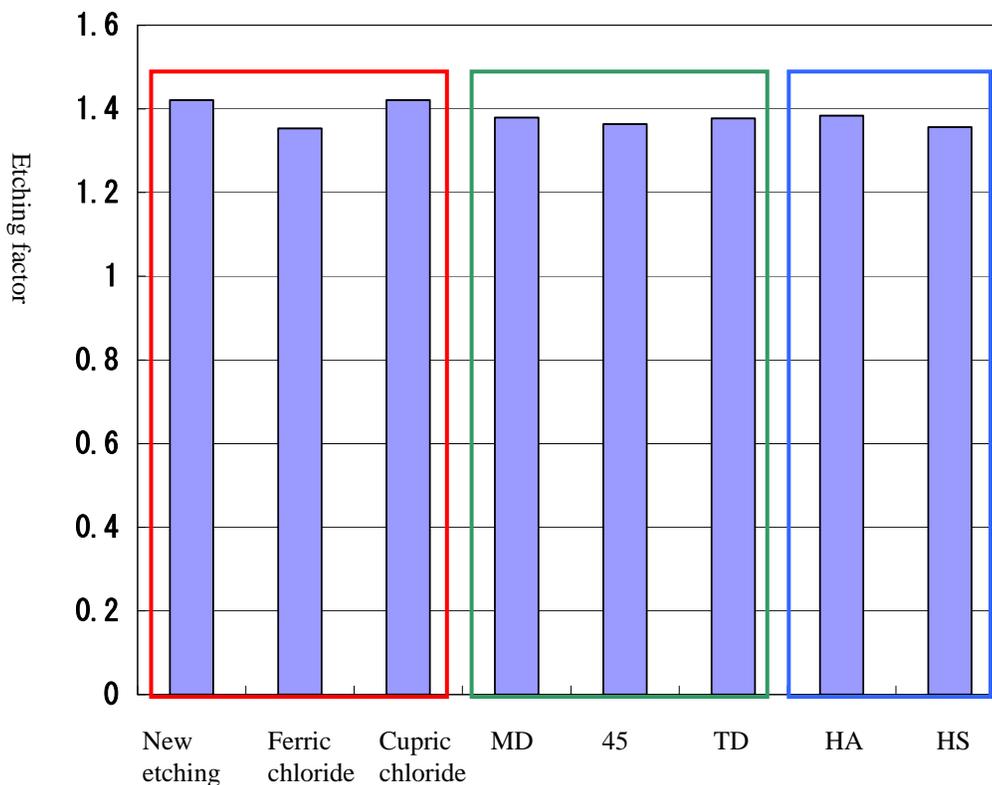


	BHYA (RA)	BHY(RA)	Special ED	Standard ED
Etching factor	5.8	5.7	3.7	2.2
Etching tail length (micron)	2.6	2.6	4.1	6.7
Surface roughness (micron)	1.3	1.7	3.4	8.7

**Figure 4** The results of etching factor using different foils.

(5) Effect of etching solution, direction of copper foil, and grain structure on etching performance

In order to develop etching performance, three factors were investigated to affect on etching factor. Type of etching solution, circuit direction, and grain structure of copper foil were determined. 30 micron patter mask and 9 micron RA copper foil were used for the test. Generally, new etching which was told to have anisotropic etching property was the best, second was ferric chloride, the last was cupric chloride. However, we could not see any difference on etching performance. In the same way, the effect of circuit direction was determined. It was not found any difference on the etching performance with regards to direction of the circuit. The last one was effect of grain structure. There were two copper foil chosen for the test. One was HA foil which had very large re-crystallized grains, the other was HS foil which had layered structure related to rolling process. Even though the grain structure was so different, the etching factor for each did not have any difference.



**Figure 5** The effect of various factors on etching factor.

(4) Idea of the new etching technology

From our results, the assumed major factors (etching solution, direction of circuit, and grain structure) for etching did not affect on the actual etching performance. Thus new approach should be considered to overcome this situation. The followings are the idea of our new technology to improve etching performance.

Usually, etching proceeds evenly to side wall and to the bottom. In the case of narrow traces, side etching creates a big problem. The width of top circuit cannot be kept due to the side etching. In order to refrain this side etching behavior, special coating on shiny side was thought. If this special coating was not easy to dissolve in the etchant compared to copper, this layer may be able to protect side etching or somehow reduce side etching speed. From now, this special coating is called "EF treatment" which enhances etching performance.

9micron RA foil, 30 micron pitch pattern were used for the etching test to determine the effect of the EF treatment. Surprisingly, the etching factor of EF treatment improved twice compared to that without EF treatment shown in Figure 6. The width of top circuit was almost the same as 10 micron, but the width of the bottom was different. If this sample was etched longer, the top width should be much shorter. This is the reason why the subtractive method has fine line limitation.

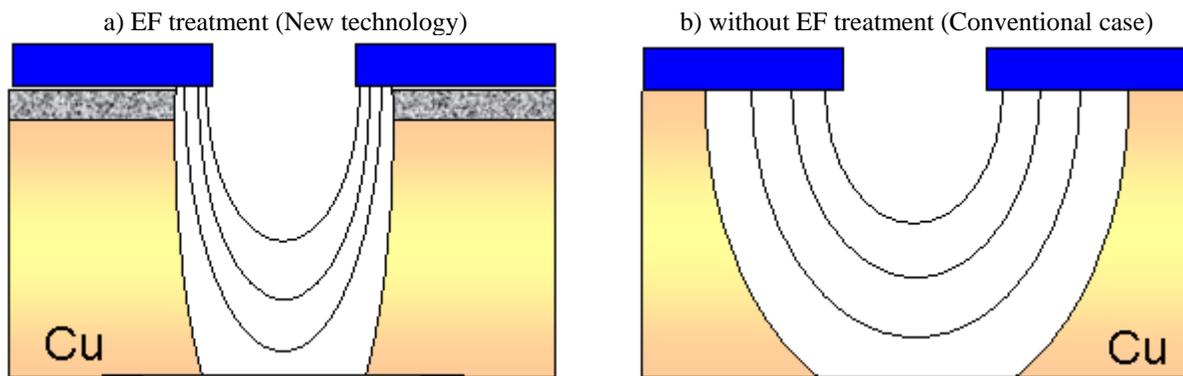
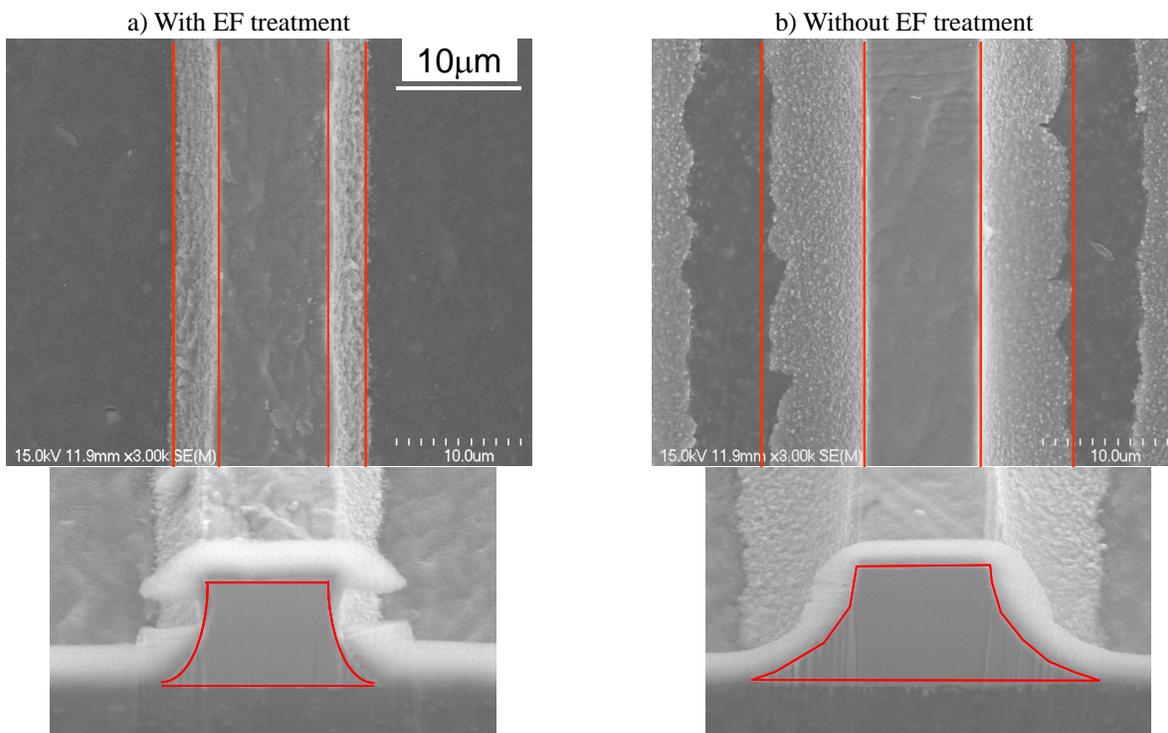


Figure 5 Image of the cross section during etching process.



Etching factor : 2.7

Etching tail length : 3.3 micron

Etching factor : 1.2

Etching tail length : 7.8 micron

Figure 6 The cross sectional observation on the etching test using EF treatment.

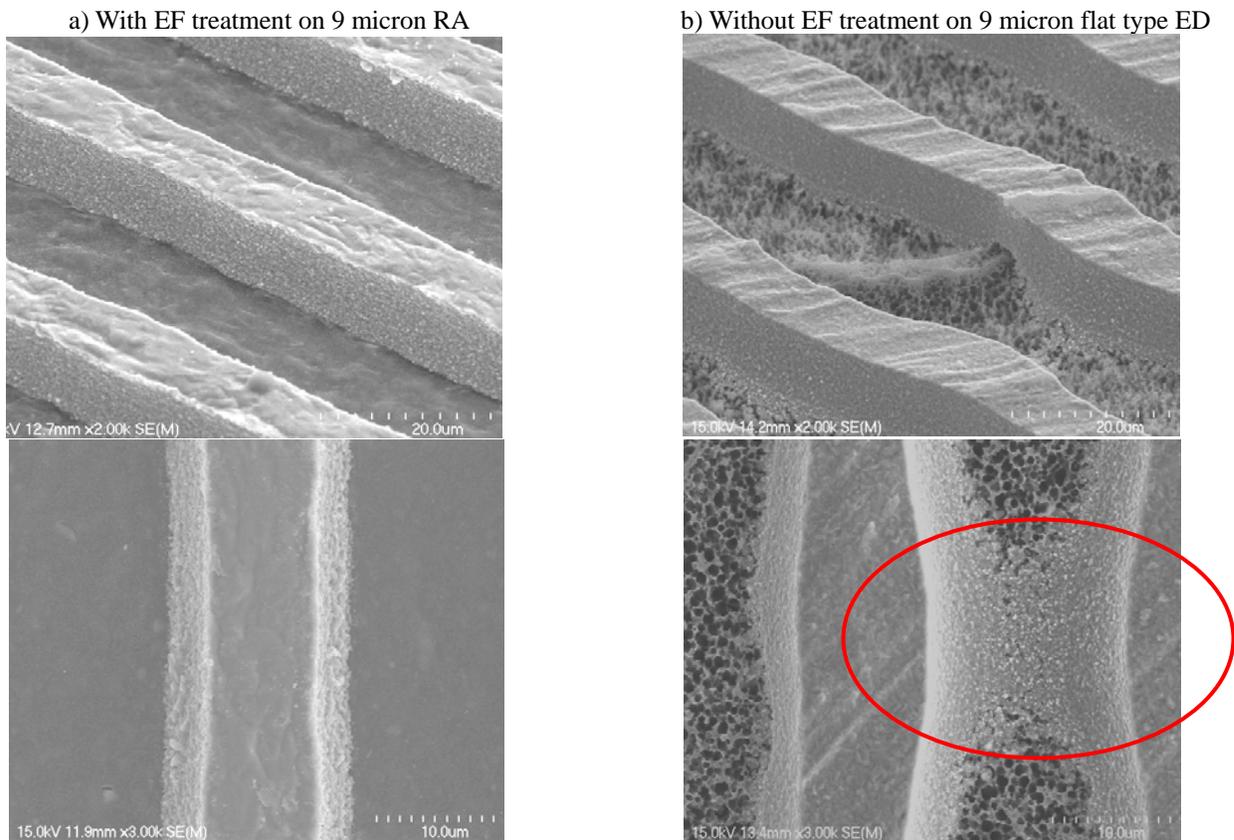
(30 micron pitch pattern, 9 micron RA foil were used.)

In Figure 7, comparison was made between 9 micron RA with EF treatment and 9 micron flat type ED. Due to the rougher surface on matte side, some circuit shorted area was found on ED foil, while no irregular was found on RA with EF treatment.

In Figure 8, cross sectional analysis was done to verify the difference between EF treatment and without EF treatment. At the beginning of the etching, the width of the opening did not change at all. However, the difference of the opening width became larger when the etching continued. When etching stopped at almost the middle of the copper foil thickness, there was 6 micron difference between EF and without EF. In addition, overhang at the top edge attached to resist could be found in the case of EF, while there was not overhang on without EF. Thus it was found that EF treatment actually could refrain side etching.

Figure 9 showed the potential of the EF treatment making very narrow traces. Using 18 micron RA, 40 micron pitch trace could be produced by EF treatment, while top width disappeared in the case of ED foil. Even for the thicker foil, still narrower traces can be made using EF treatment.

In addition, Figure 10 showed the result of EF using COF material, which was 2 layer sputtering type FCCL. EF treatment could improve etching factor almost triple compared to that without EF. Using EF treatment, it could be assumed that it may be able to make narrower trace less than 30 micron pitch using regular subtractive method.



**Figure 7 the comparison between RA with EF treatment and flat type ED without EF treatment. (30 micron pitch pattern, 9 micron copper foils were used. Red circle marked circuit shorted area.)**

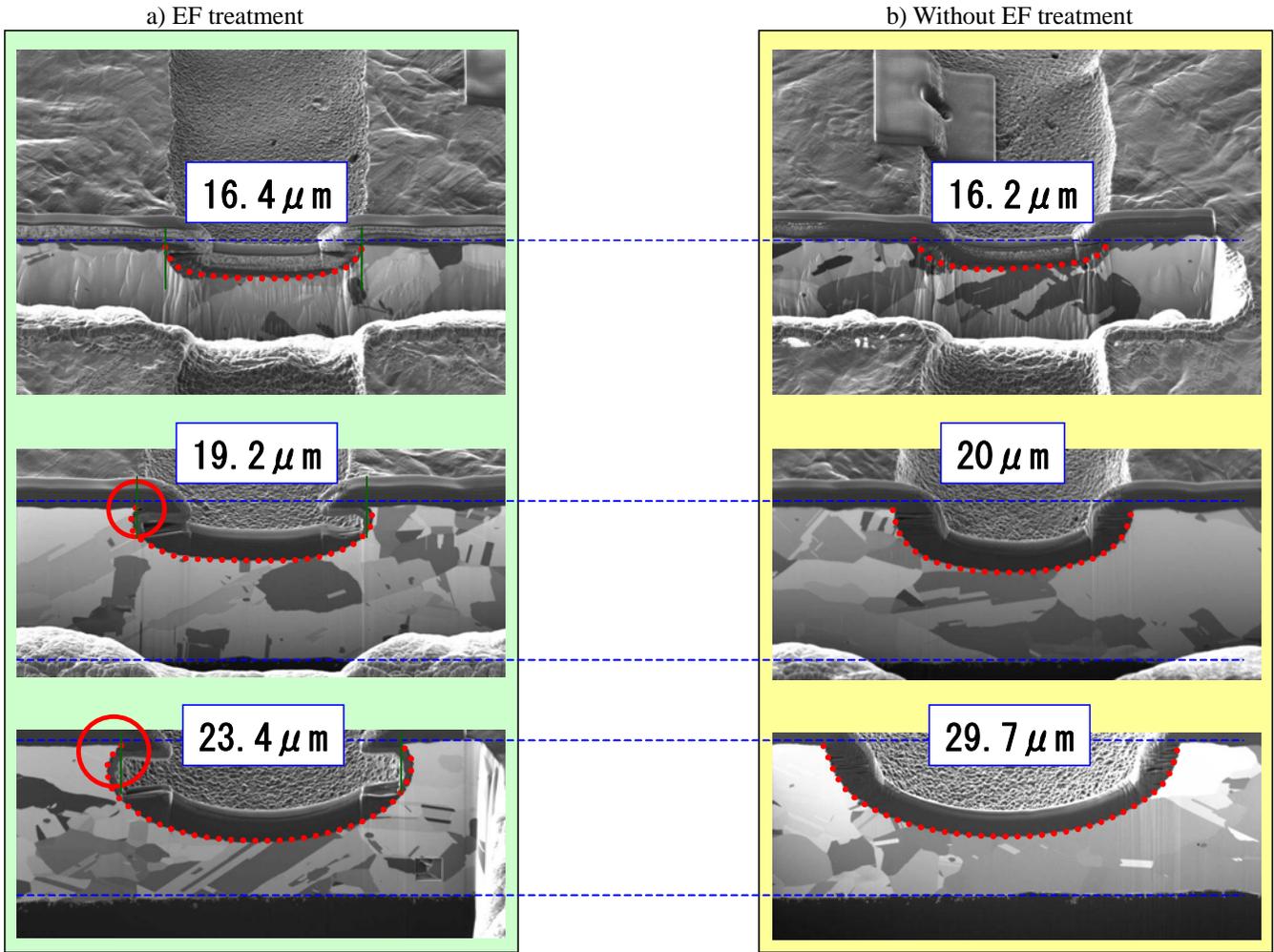
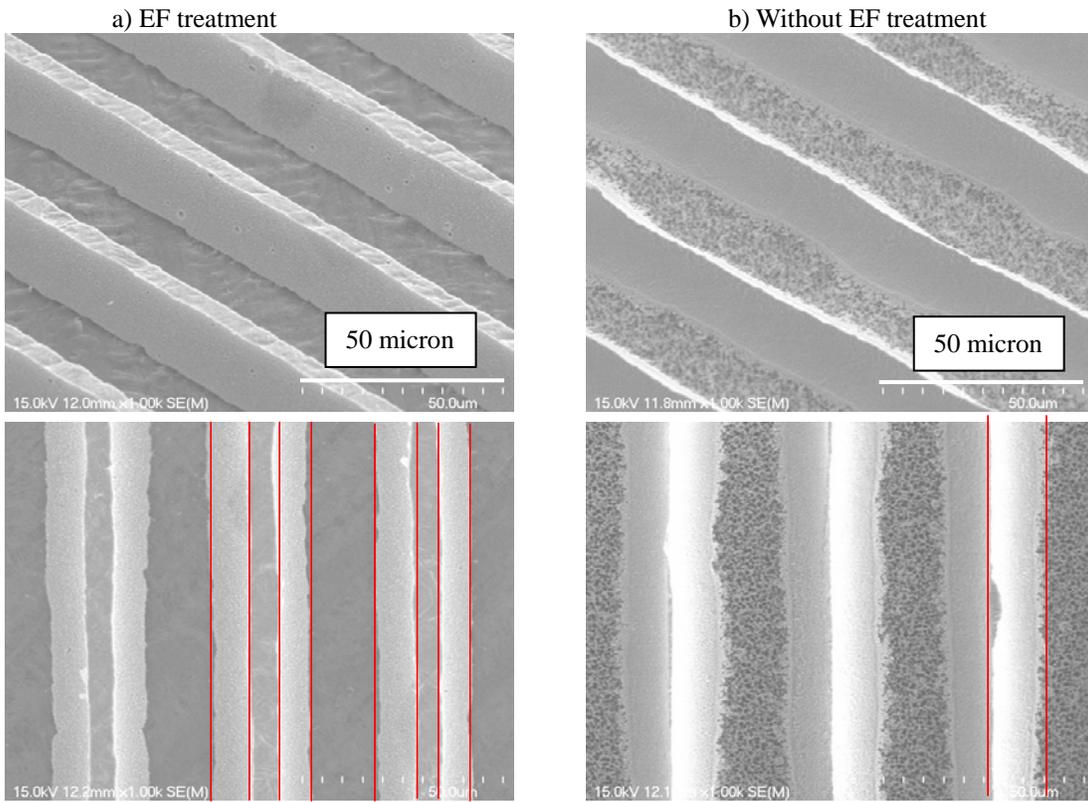
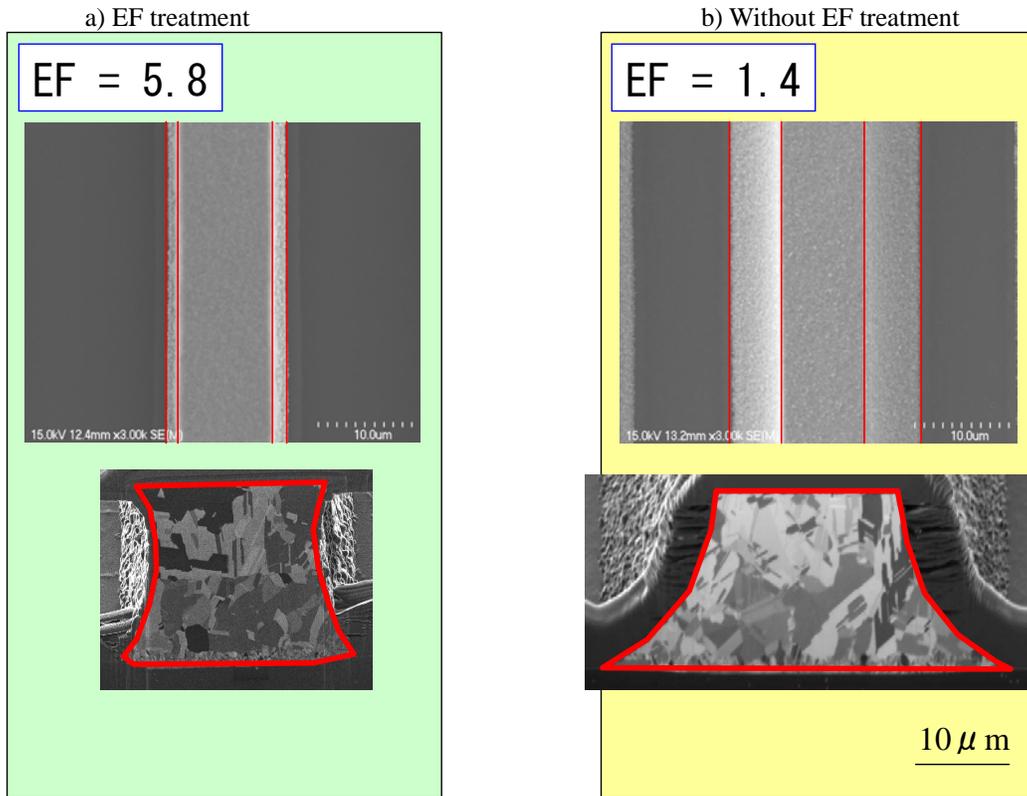


Figure 8 The cross section analysis to compare between EF treatment and without EF treatment on RA during etching process. (50 micron pitch pattern, 18 micron copper foil were used.)



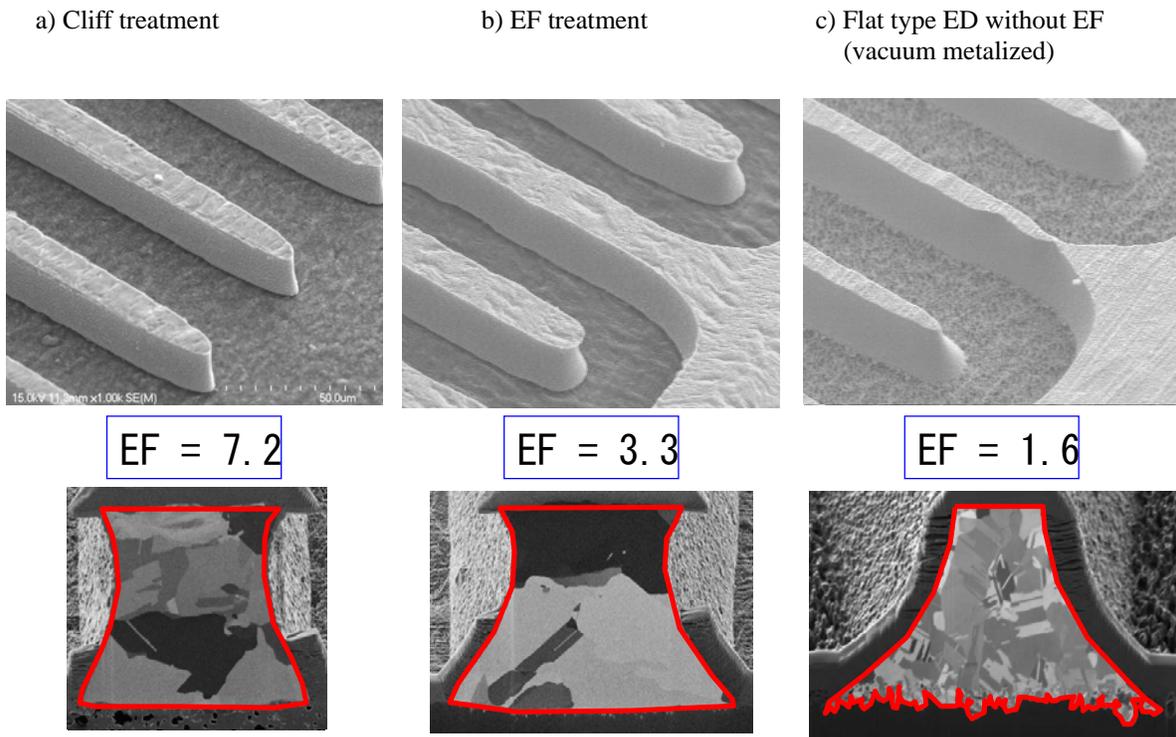
**Figure 9** The comparison between RA with EF treatment and flat type ED without EF treatment. (40 micron pitch pattern, 18 micron copper foil were used)



**Figure 10** The comparison between EF and without EF treatment on 2 layer sputtering type FCCL. (30 micron pitch pattern, 8 micron copper thickness)

In Figure 11, our latest surface treatment for shiny side was “Cliff treatment”. The Cliff treatment was laboratory base made using vacuum metallization process. The element used for the treatment was different from the EF treatment. Both elements were not easy to dissolve in etchant compared to copper. It was very interesting that the Cliff treatment could improve etching factor much more compared to that of EF. Without EF treatment, etching factor was 1.6 for EF foil. In the case of EF treatment on RA foil, etching factor was 3.3 similar to the previous results. On the other hand, surprisingly, etching factor of the Cliff treatment was 7.2.

Thus, it was found the possibility to improve etching performance by shiny side surface treatment.



**Figure 11** The comparison among Cliff treatment, EF treatment on RA foil and flat type ED without EF treatment. (30 micron pitch pattern, 9 micron copper foil were used)

### Conclusion

Recent high-end electronic products need the printed circuit board with HDI. For instance, cellular phone is going to have multi-function in the same size. Flat panel display is going to become much more high density type which needs more circuit traces in the same space. Thus circuits seem to be much more narrower than before. Now we are facing the limitation using conventional subtractive etching method. In this paper, new etching technology, EF treatment was introduced and showed its possibility to overcome the limitation. EF treatment is ready to supply samples to customer, and more trials is to be completed for the Cliff treatment.

# New Technology to Improve Etching performance Using Shiny Side Surface Treatment

April 1, 2009

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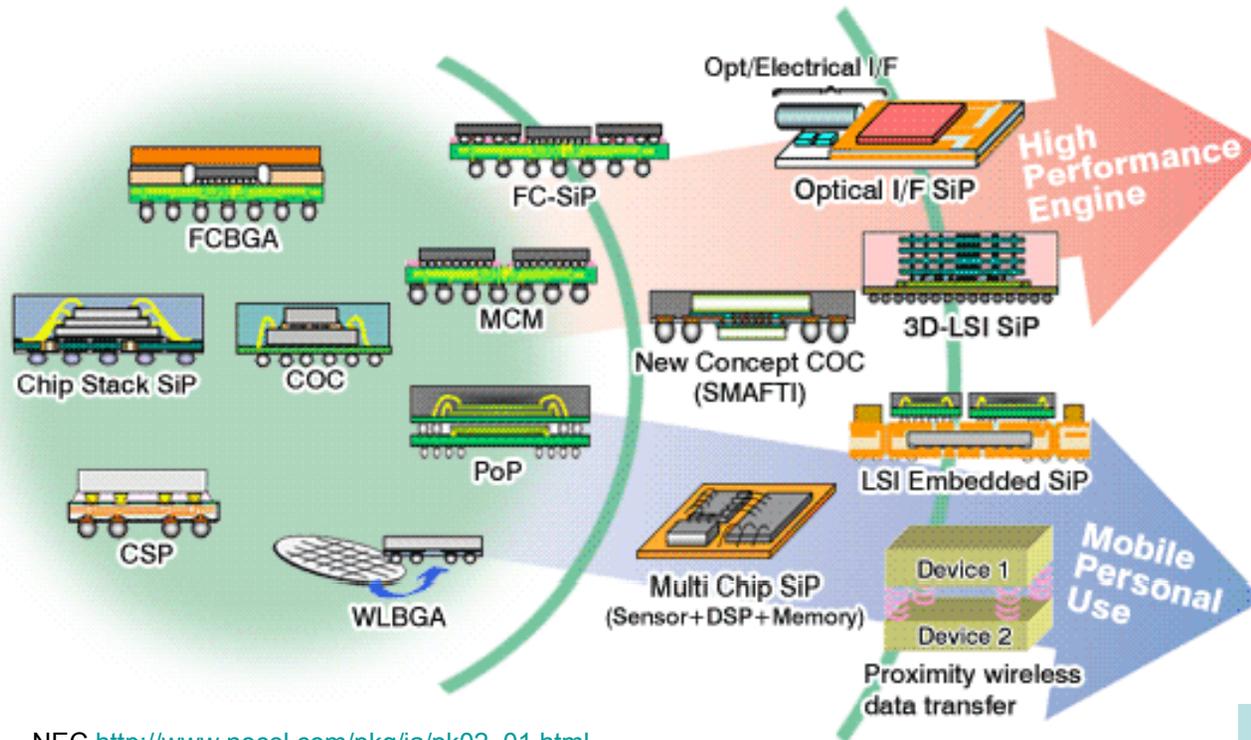
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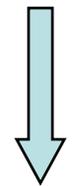
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  - Study of effect of etchant, circuit angle(TD,MD), and grain structure
3. New technology
  - Etching factor promoter (EF treatment) on shiny side
  - Potential of EF treatment

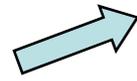
# Technical trends for HDI



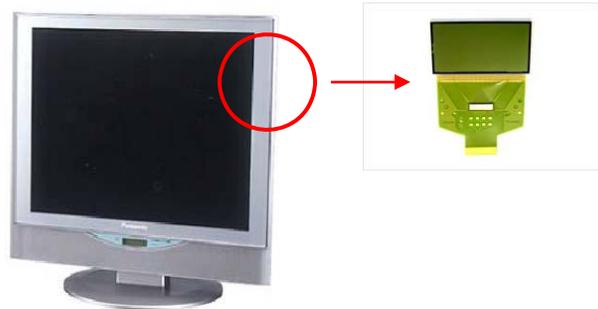
**\* IC package  
High density circuit  
in small space**



**Circuits much be  
narrower and narrower**



NEC [http://www.necel.com/pkg/ja/pk02\\_01.html](http://www.necel.com/pkg/ja/pk02_01.html)

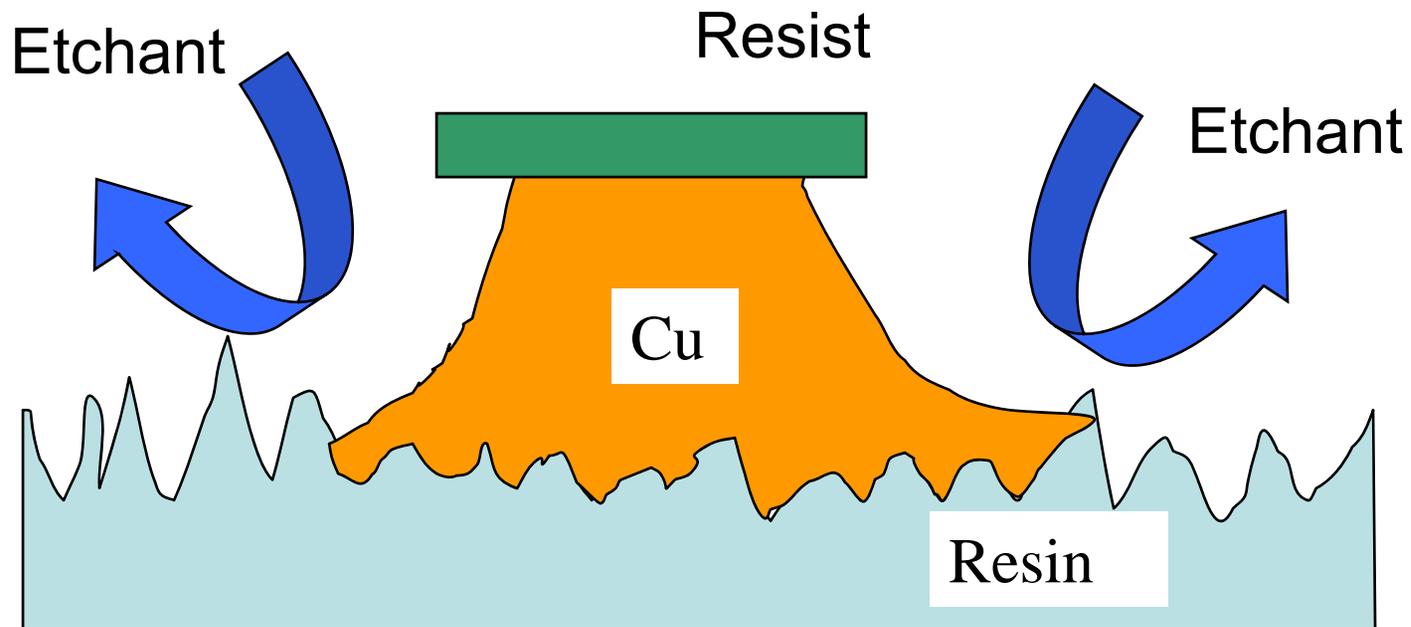


**\*COF  
High density in  
small space**

# Approaches for fine line manufacturing from Copper foil side

- (1) Low profile on matte side
  - Low profile
  - Small nodule treatment
- (2) Thin copper foil

# Basic idea of etching



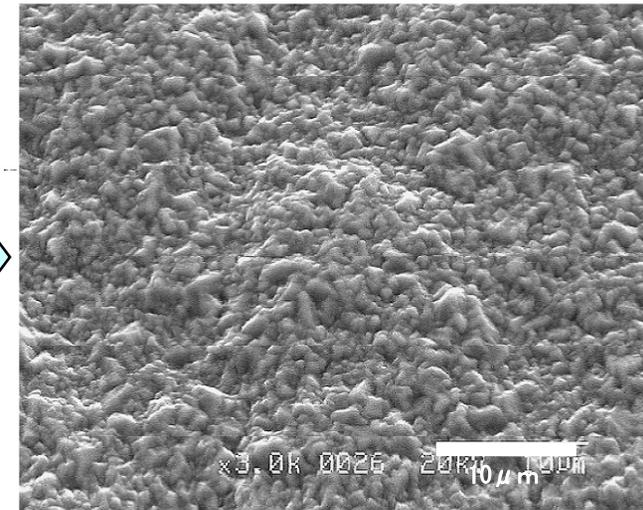
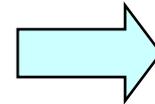
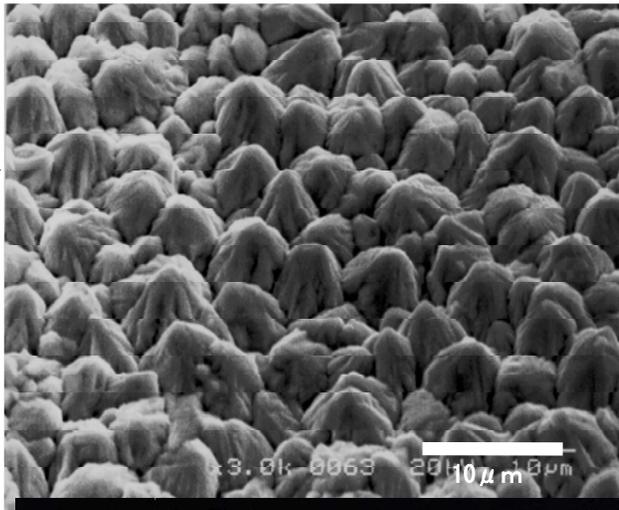
- \* Circuits width become finer and narrower, top width of circuits become much narrower due to side etching using subtractive method.

# Lower base foil profile (Example)

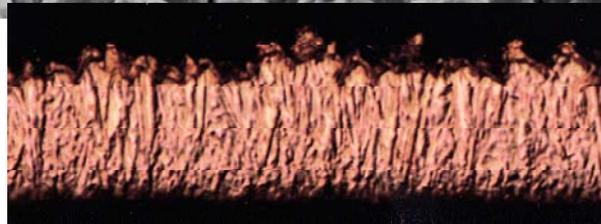
Standard ED

Low profile ED

Matte  
side

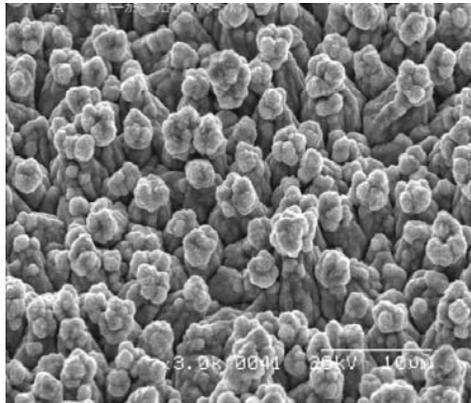


Cross  
section



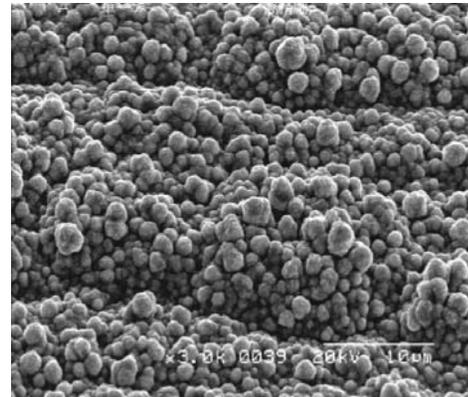
# Lower surface roughness

Standard  
ED



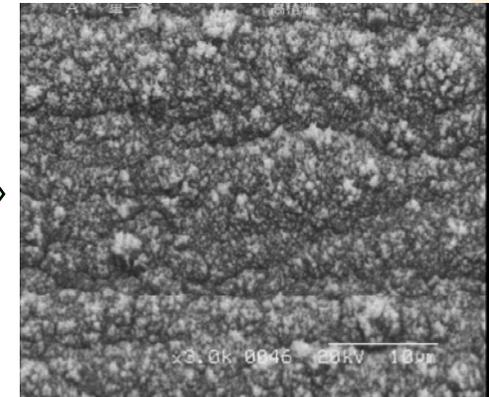
Rz 4.5 micron

Low profile  
ED



Rz 3.3 micron

Low profile +small  
nodule ED

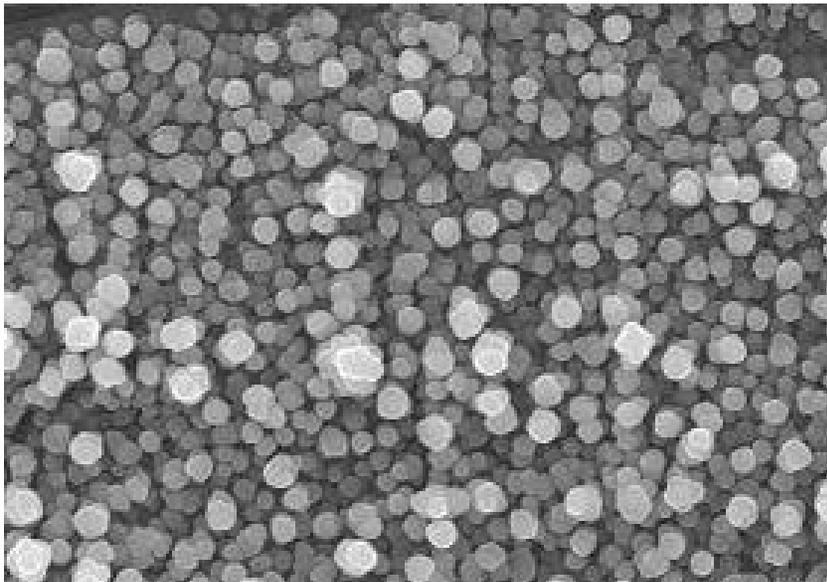


Rz 1.8 micron

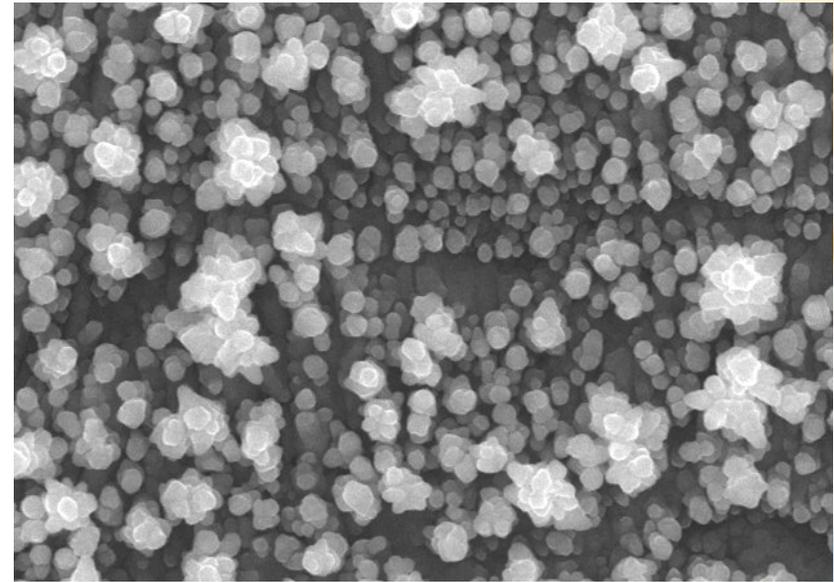
Lower surface roughness on matte side could be achieved by lower base foil profile and smaller nodule treatment.

## Lower profile in case of RA foil

BHYA



BHY

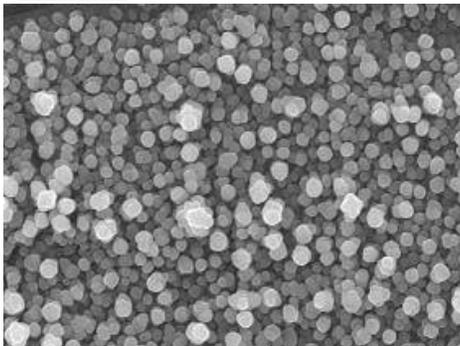


1  $\mu$ m

RA copper foil is used for flexible circuit board.  
Rz 0.8 micron (contact stylus measurement)

# Surface roughness comparison

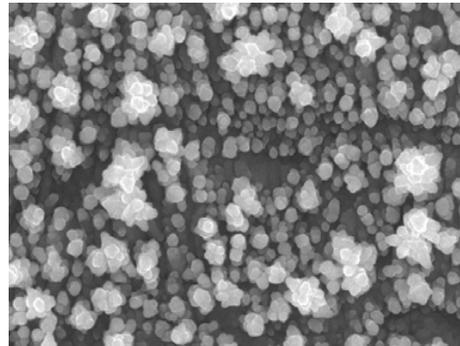
1  $\mu\text{m}$



BHYA



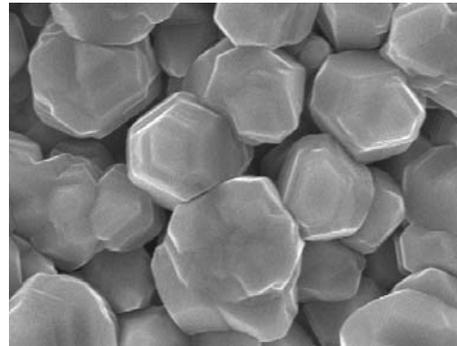
Rz 1.3  $\mu\text{m}$



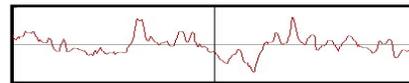
BHY



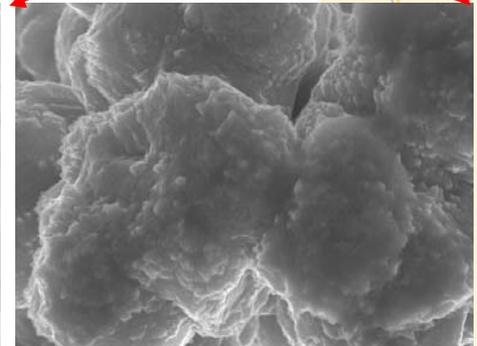
Rz 1.7  $\mu\text{m}$



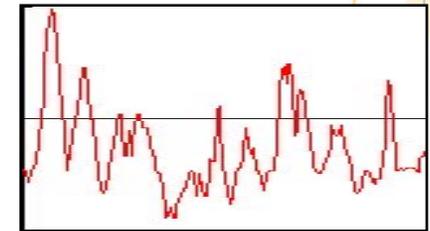
Special ED type



Rz 3.4  $\mu\text{m}$



Standard ED type



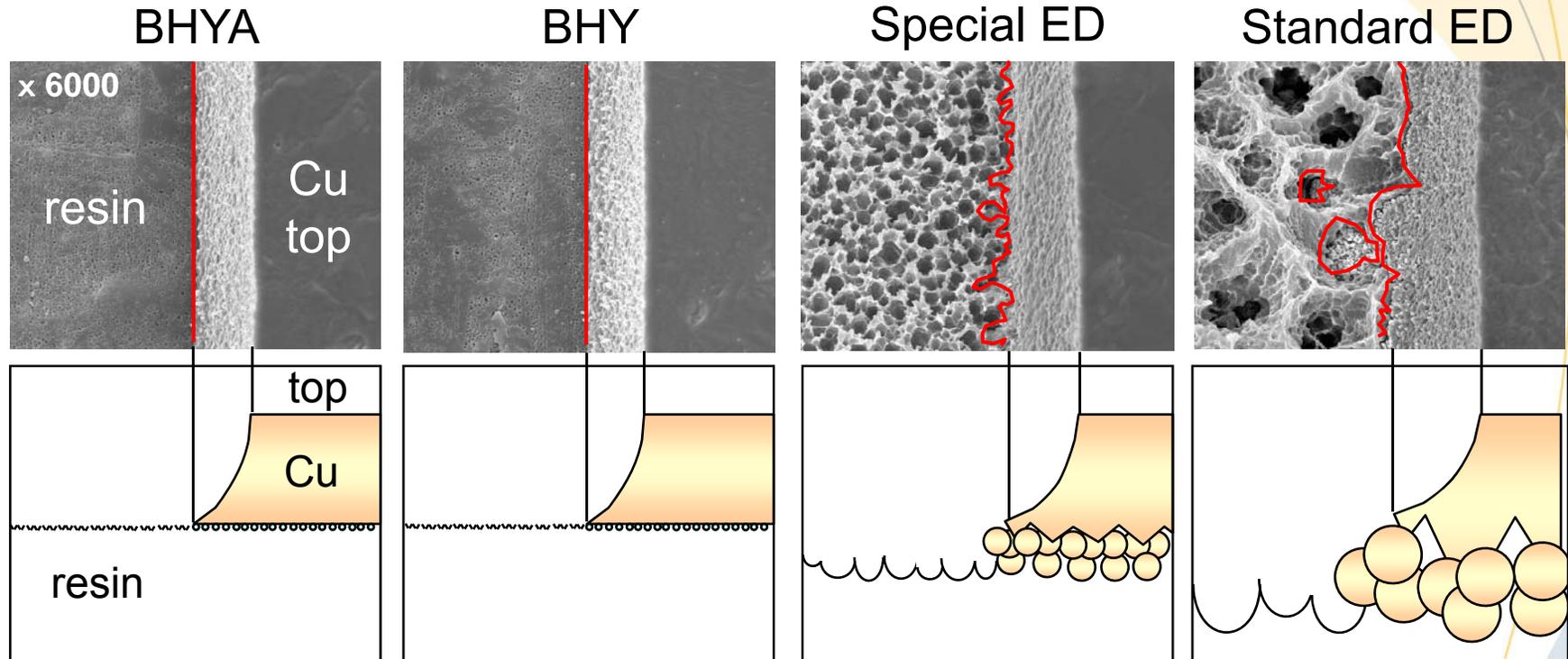
Rz 8.3  $\mu\text{m}$

Low magnification

Roughness : Measured by Laser microscope

RA copper foils are smoother than ED.

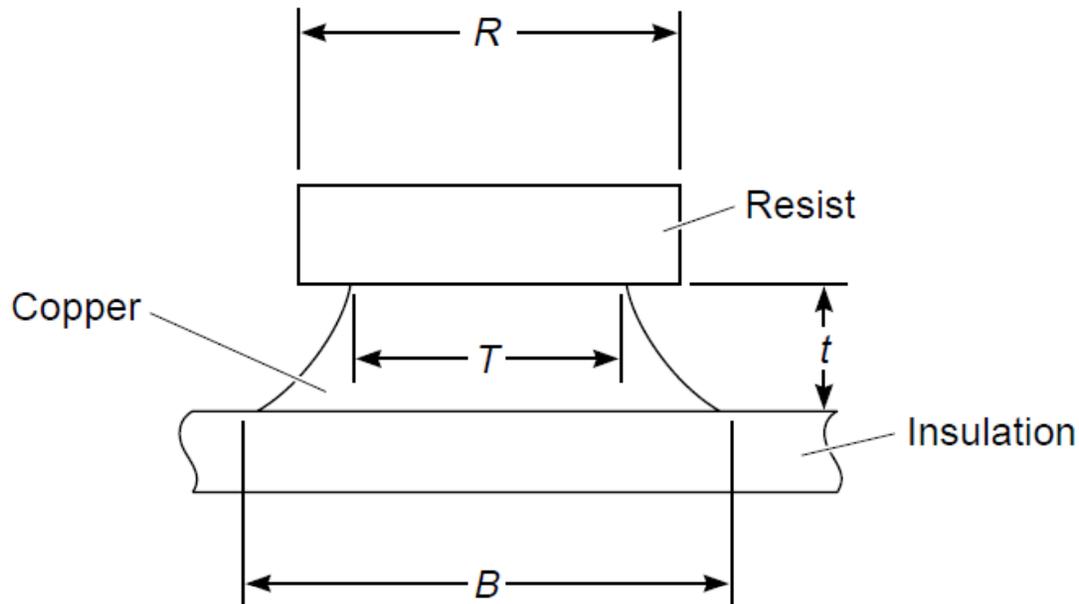
# Effect of surface roughness on etching factor



60µm pitch	BHYA	BHY	Special ED	Standard ED
Etching factor	5.8	5.7	3.7	2.2
Etching tail length	2.58	2.64	4.07	6.86

Both RA foils performed the best

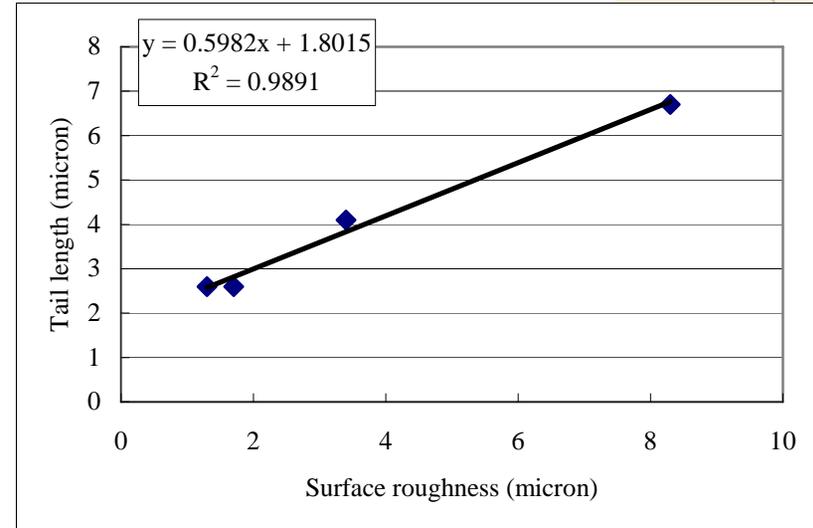
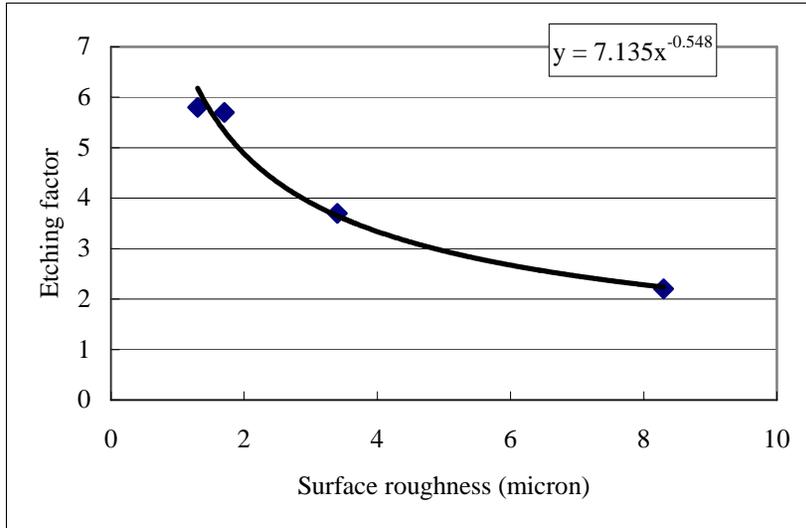
# Definition of etching factor



T : width of the trace on top  
R: width of resist  
t: thickness of copper foil  
B: width of the trace on bottom

$$\text{Etching factor} = 2t/(B-T)$$

# Surface roughness effect on etching factor



	BHYA	BHY	Special ED	Standard ED
Etching factor	5.8	5.8	5.8	5.8
Etching tail length (micron)	5.7	5.7	5.7	5.7
Surface roughness (micron)	3.7	3.7	3.7	3.7

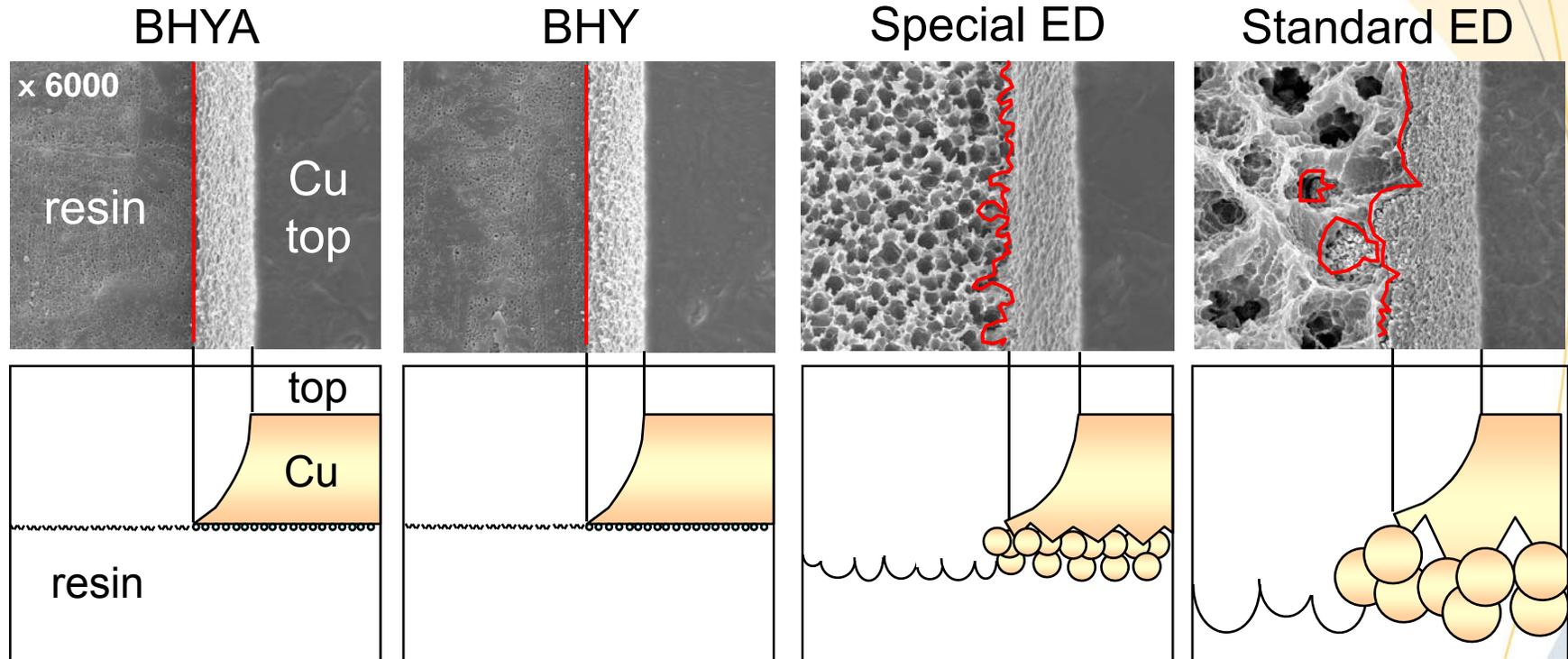
Tail length is related to surface roughness.

Etching factor is inverse proportion to surface roughness.



Lower profile is better for etching.

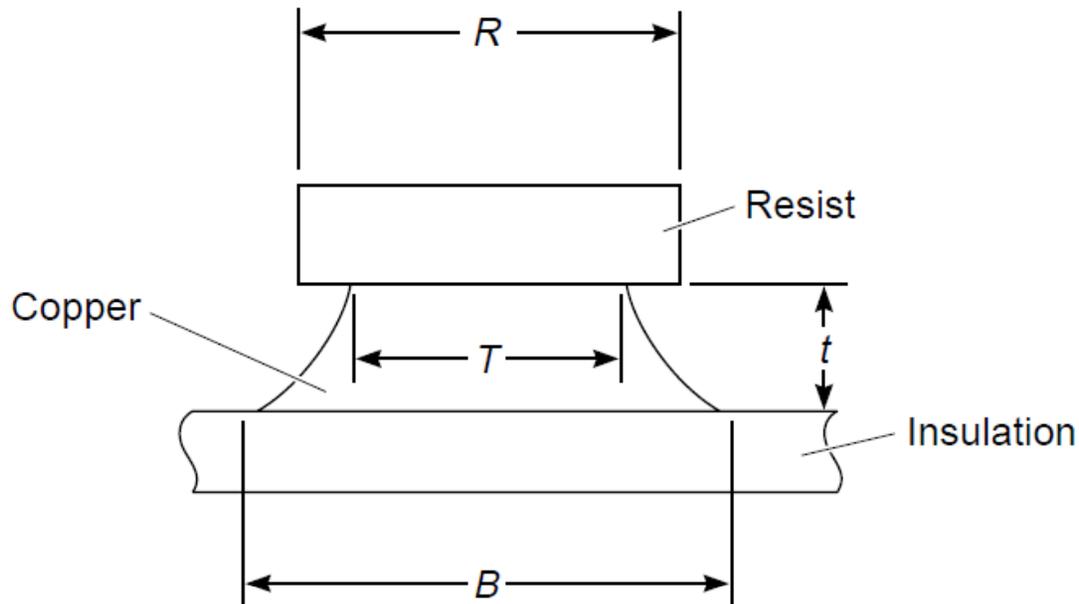
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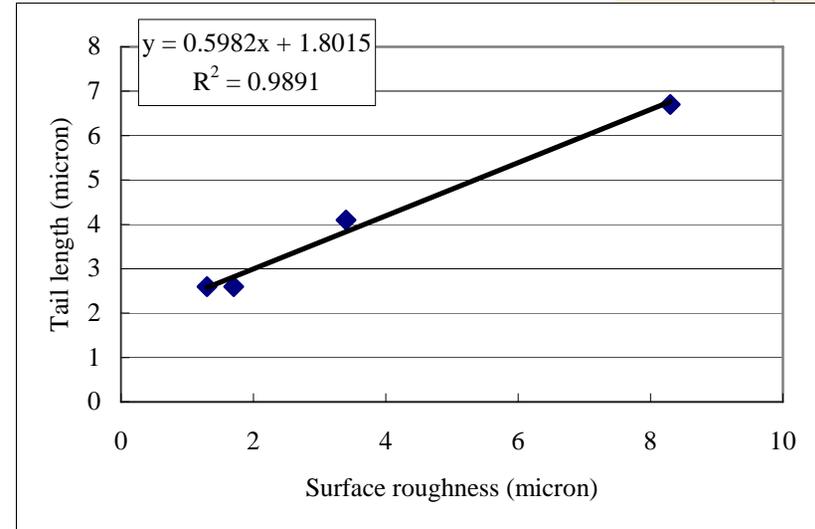
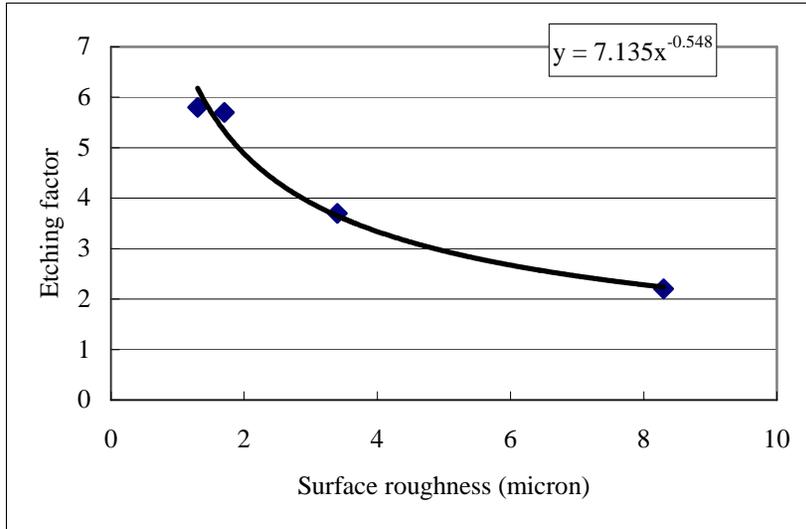
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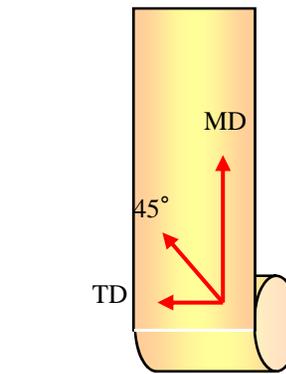
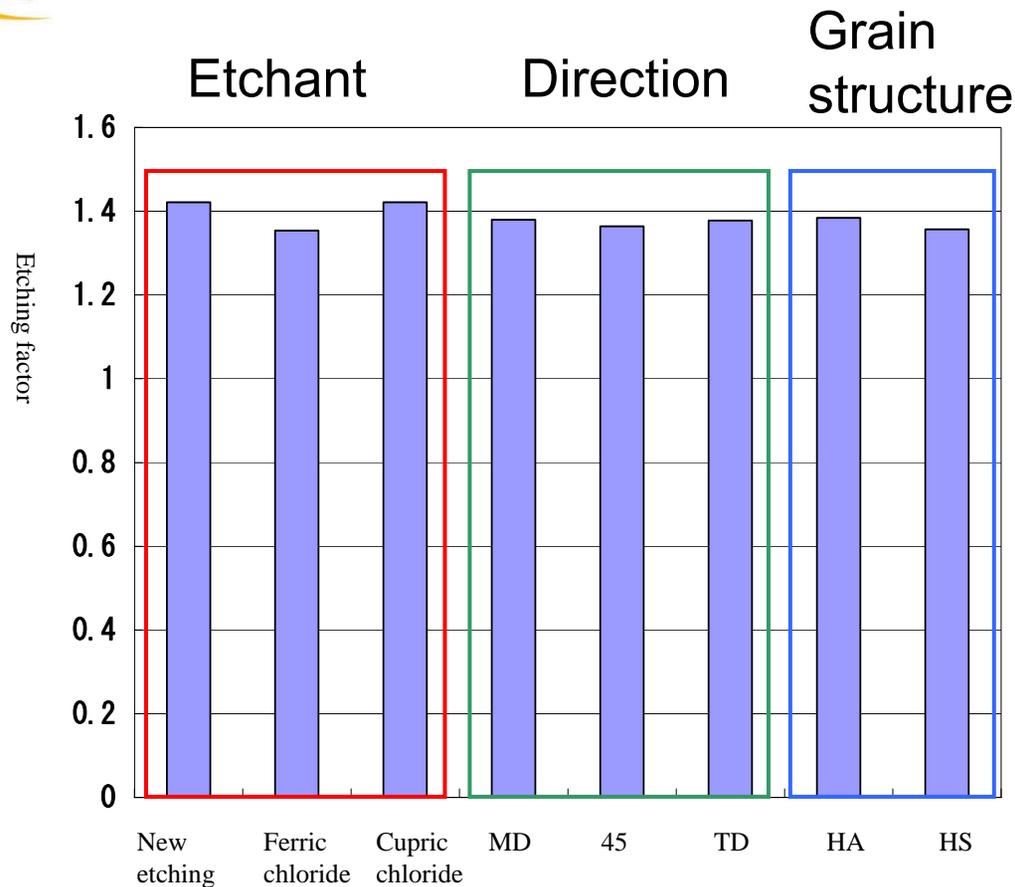
Tail length is related to surface roughness.

Etching factor is inverse proportion to surface roughness.



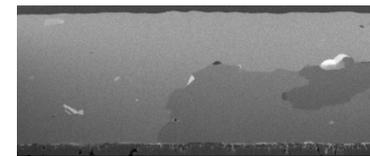
Lower profile is better for etching.

# Etching factor investigation



9 micron RA used  
30 micron pitch

HA foil (RA)



Large re-crystallized structure

HS foil (RA)



As rolled  
(Layered structure)

Etchant : New etching (Anisotropic type), Ferric chloride, Cupric chloride

Direction : MD, 45 degree, and TD

Grain structure: Large re-crystallized and as rolled



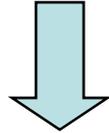
Etching factor could not be changed.

# What is the main factor?

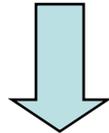
Etchant : New etching (Anisotropic type), Ferric chloride, Cupric chloride

Direction : MD, 45 degree, and TD

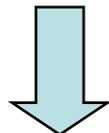
Grain structure: Large re-crystalized and as rolled



Etching factor could not be changed.



Surface roughness of RA may be lowest in mass production basis.



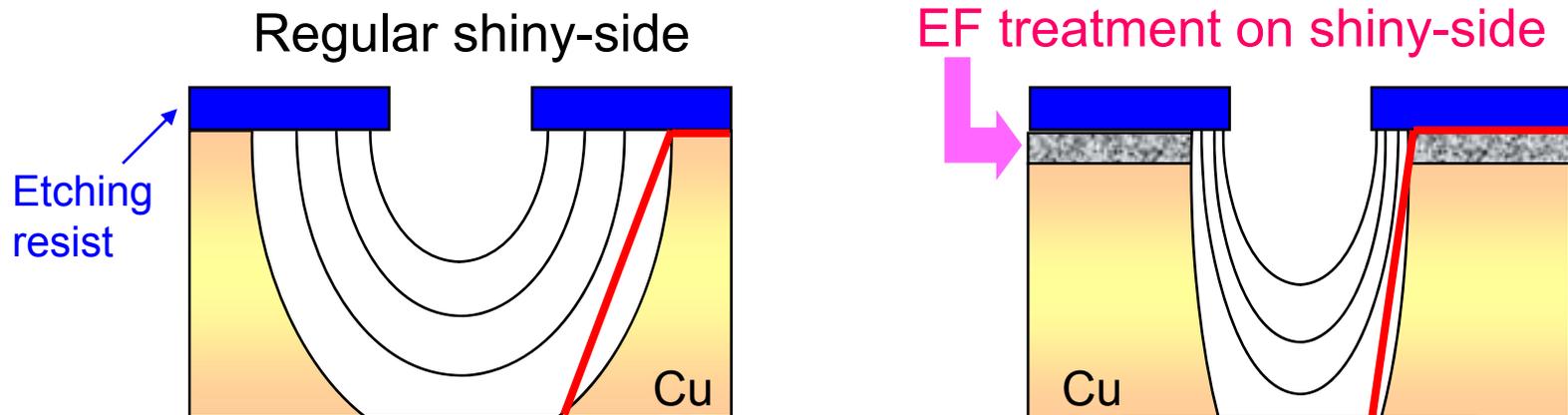
Need to find another approach to improve etching factor on copper foil !

# New approach to improve etching factor using shiny-side treatment

## EF(Etching factor improvement) treatment on shiny-side

EF treatment is a new idea and special treatment on shiny-side of copper foil to improve etching factor.

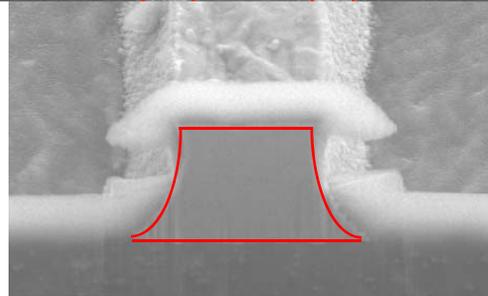
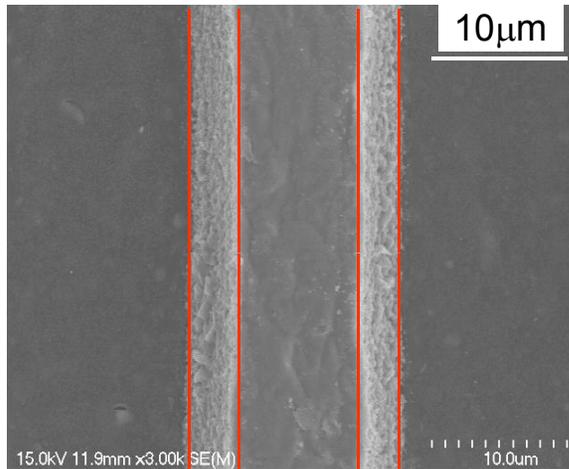
EF treatment prevents side etching by refraining etching rate along a trace wall, minimizing side etching by EF layer which has slightly slower etching speed than Cu.



# Effect of EF treatment (9 micron RA)

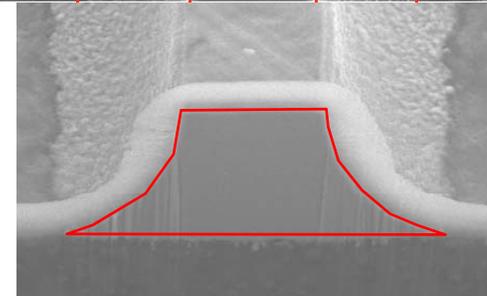
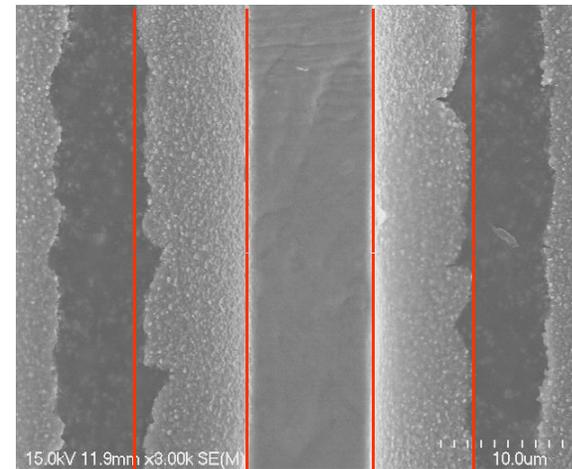
9 $\mu$ m Rolled copper foil / 30 $\mu$ m pitch

EF treatment



**Etching factor : 2.7**  
**Etching tail length : 3.3 $\mu$ m**

Without EF treatment

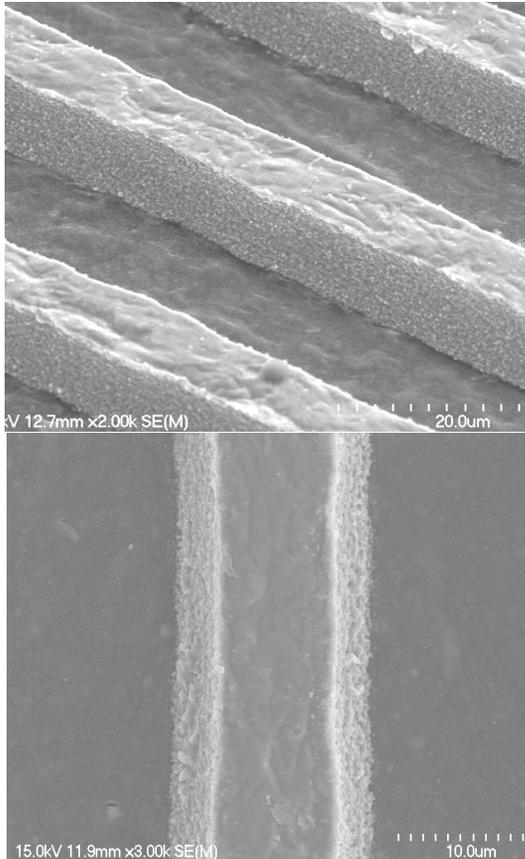


Etching factor: 1.2  
Etching tail length: 7.8 $\mu$ m

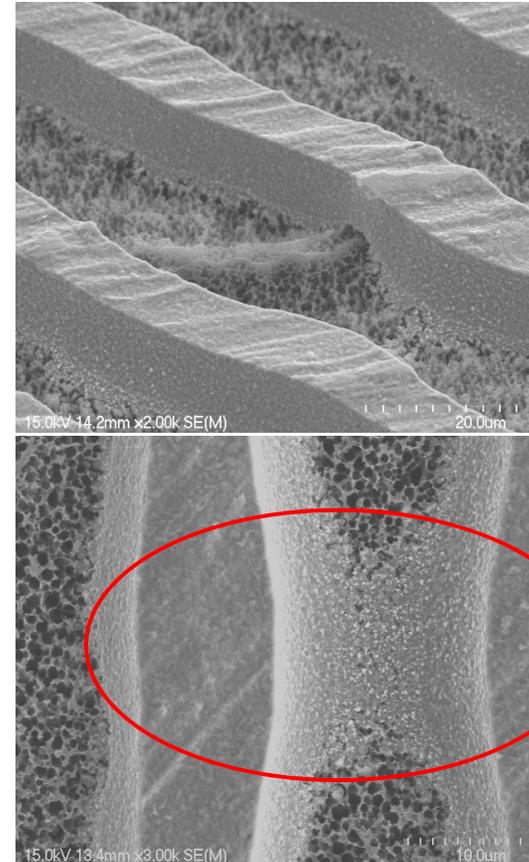
EF treatment on shiny side could make a circuit shape close to “rectangular”.

# Comparison between w/EF on RA and w/o on ED (9 micron thickness, 30 micron pitch)

9µm Rolled copper foil  
with EF treatment



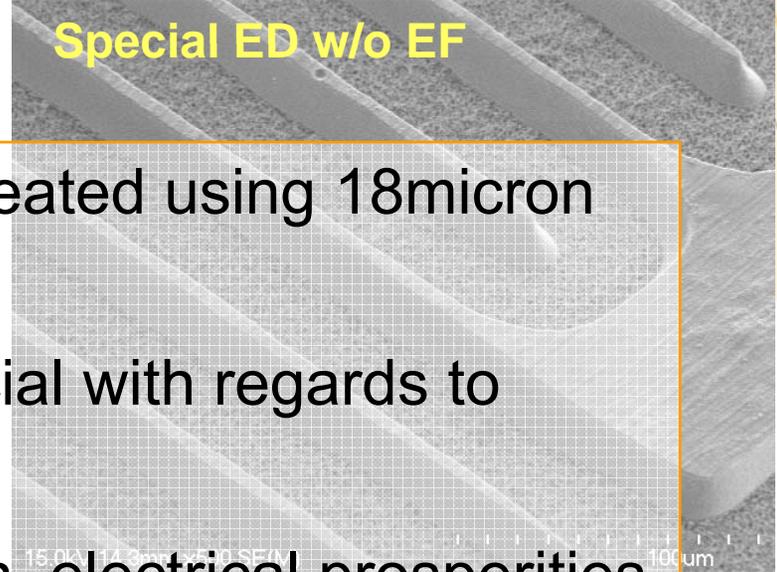
9µm Special ED  
without EF treatment



Short circuit

Smoothest RA foil + EF treatment could be the best material  
for HDI applications compared to regular ED foil.

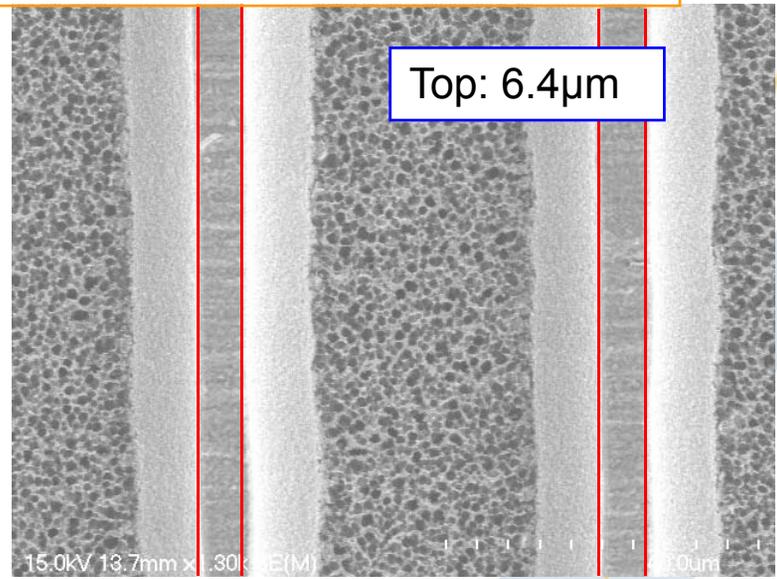
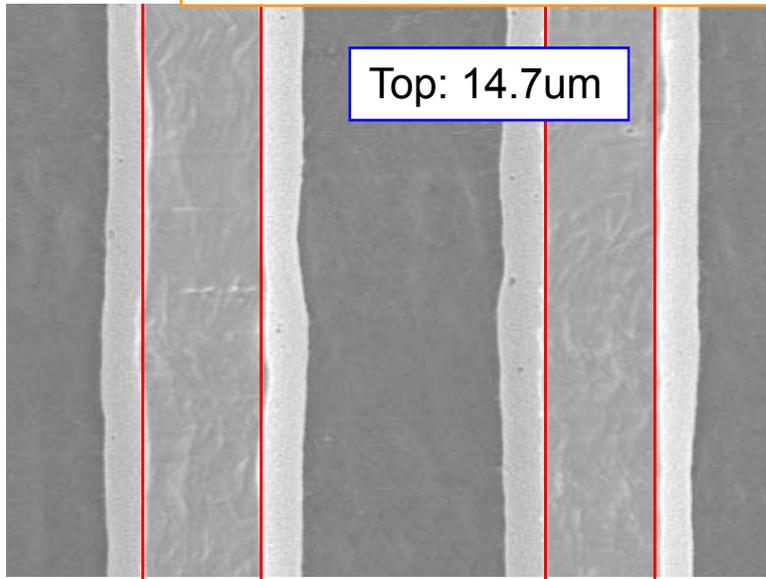
# Comparison between w/EF on RA and w/o on ED (18 micron thickness, 50 micron pitch)



\*50 micron pitch can be created using 18micron copper foil.

\*Wider top width is beneficial with regards to reliability.

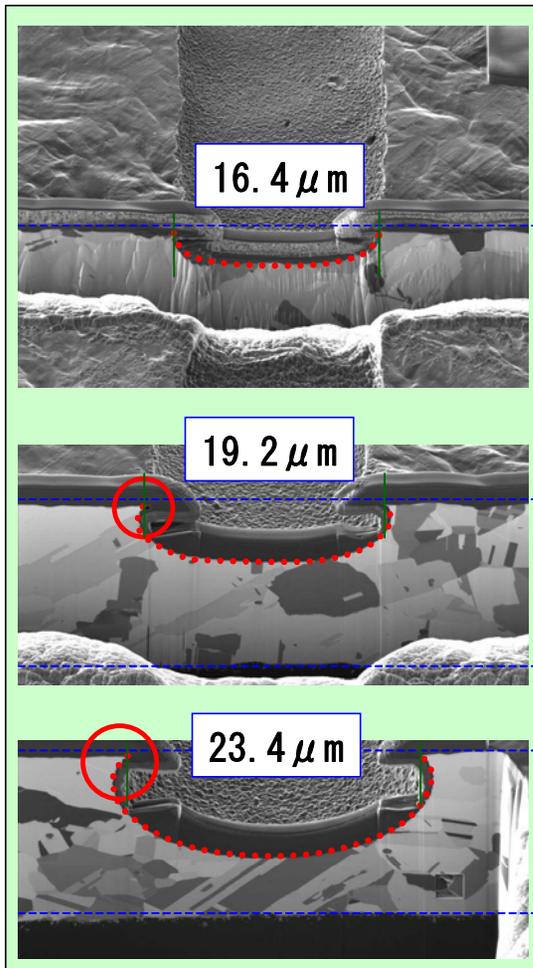
→ Good ACF adhesion, electrical prosperities



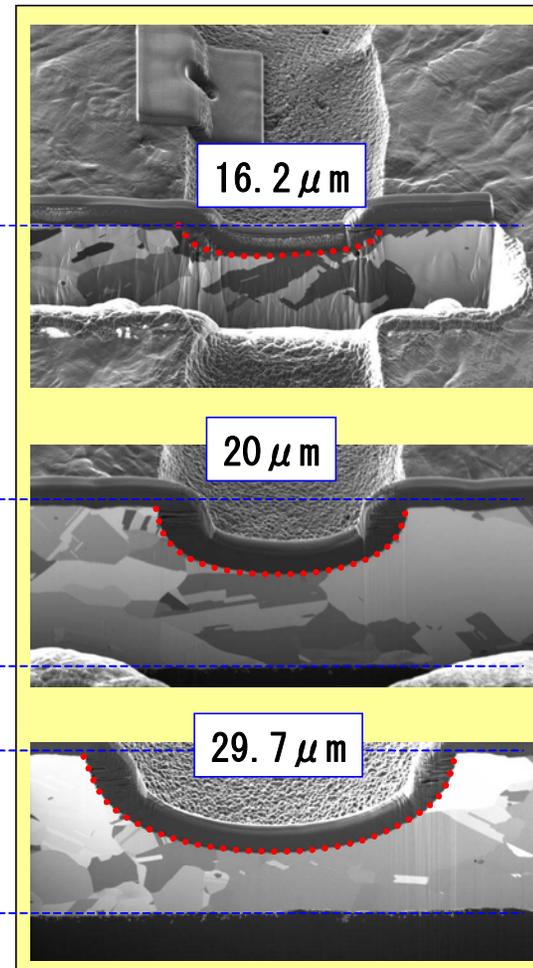
40um

The cross section analysis to compare between EF treatment and without EF treatment on RA during etching process.  
(40 micron pitch pattern, 18 micron thickness)

RA w/ EF



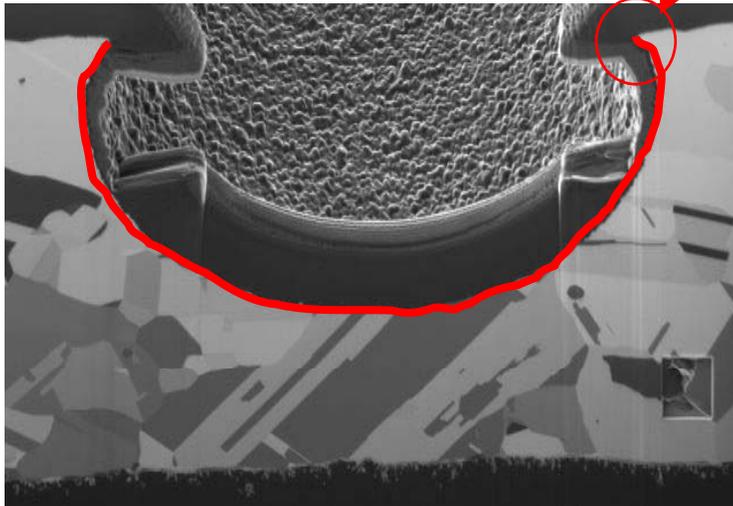
RA w/o EF



# Side etching comparison

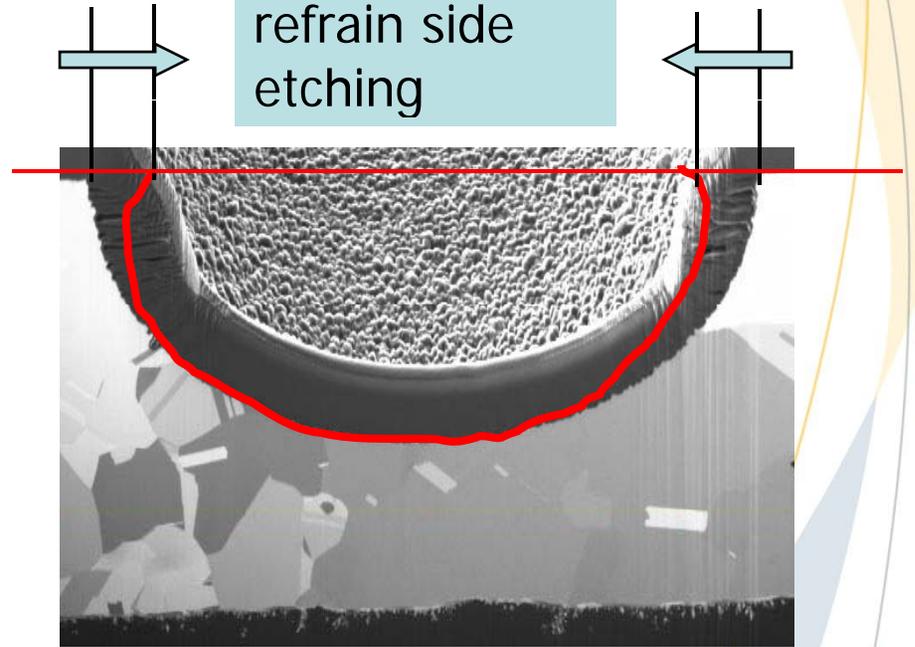
**w/ EF**

EF could not see  
(0.01um)



**w/o EF**

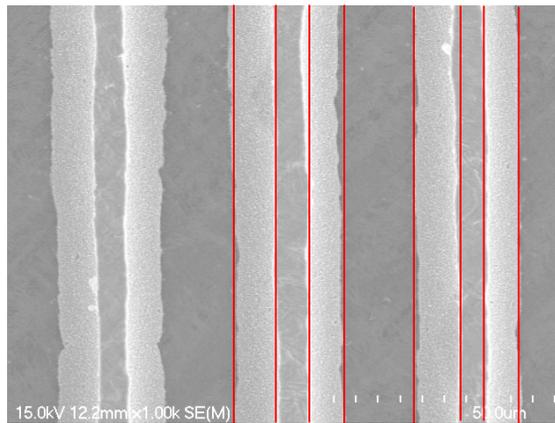
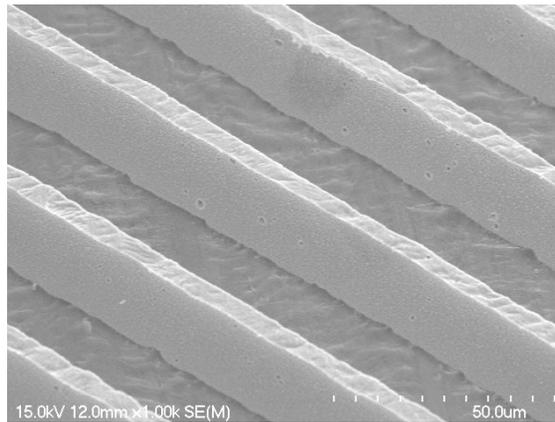
EF could  
refrain side  
etching



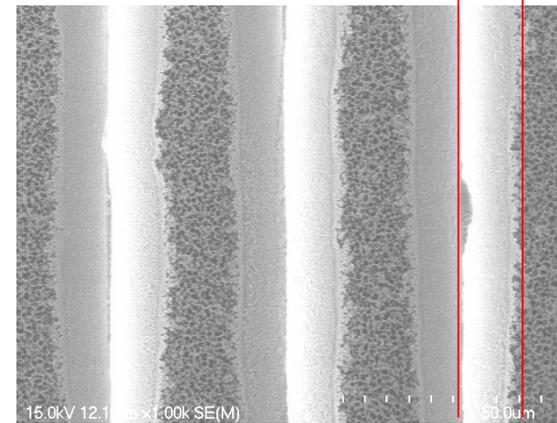
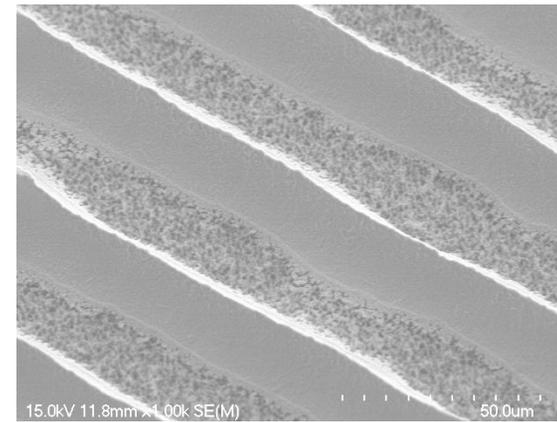
# Potential of EF treatment #1

## 40 micron pitch circuit using 18 micron Copper foil

**With EF on RA**



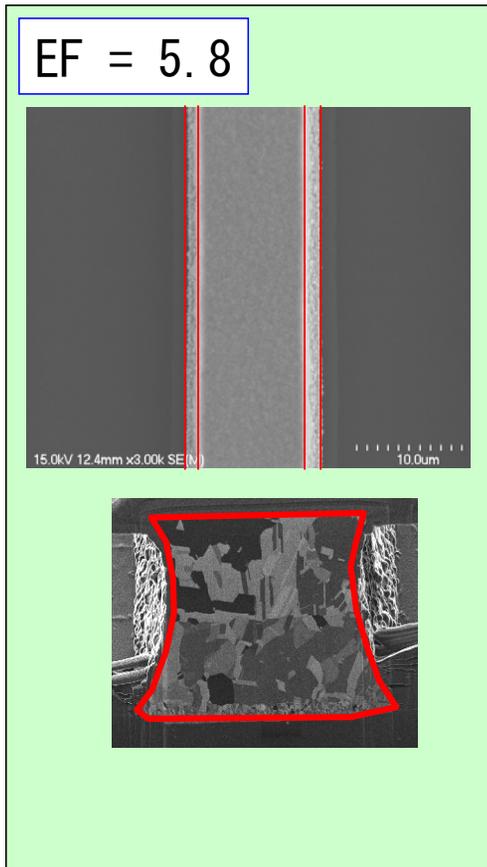
**Without EF on ED**



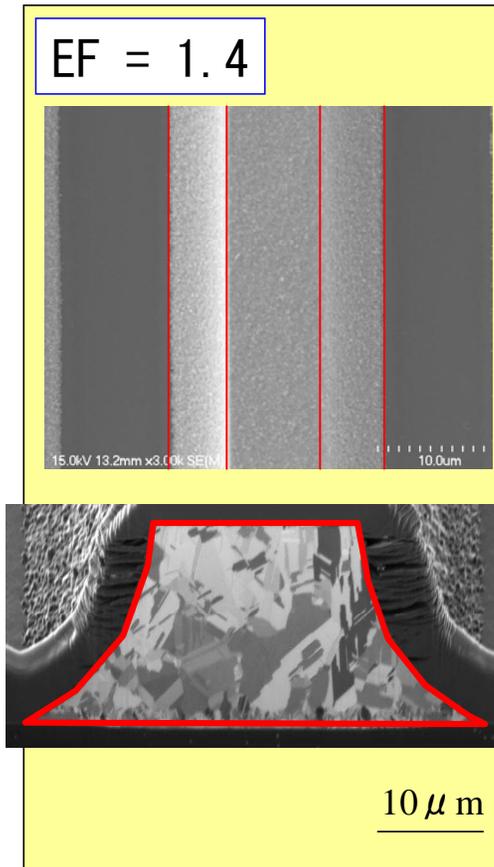
# Potential of EF treatment #2

## 30 micron pitch circuit using 2 layer suppering type FCCL (8 micron Copper)

**With EF**



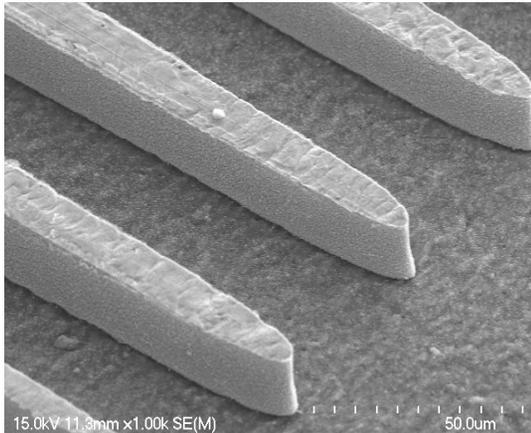
**Without EF**



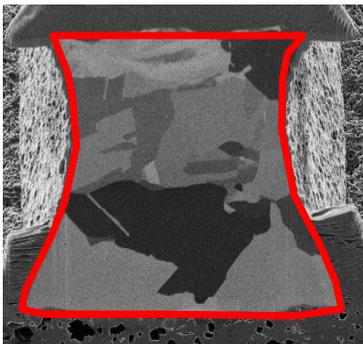
# Potential of EF treatment #3

## 30 micron pitch circuits using 9 micron Cu Sputtering new type “Cliff” treatment superior to EF

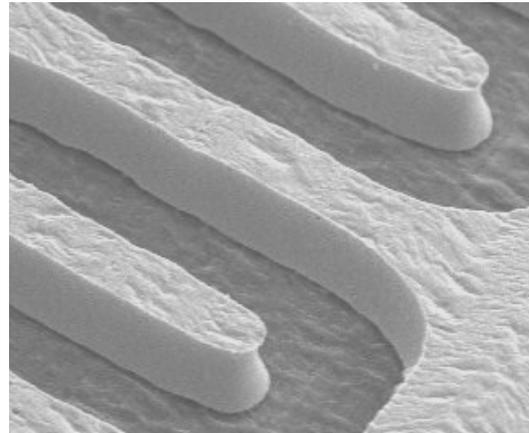
**With Cliff treatment  
(Lab sample)**



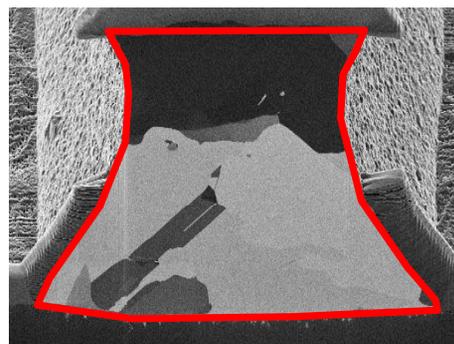
EF = 7.2



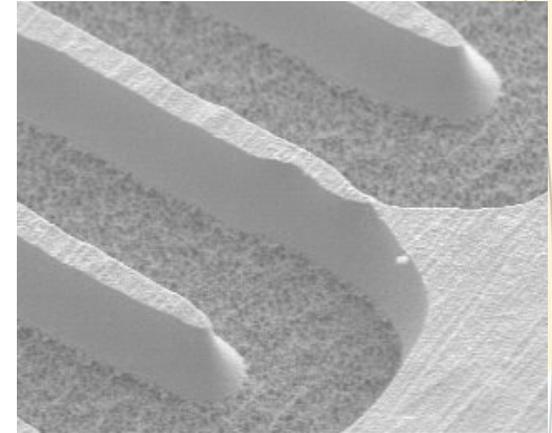
**With EF**



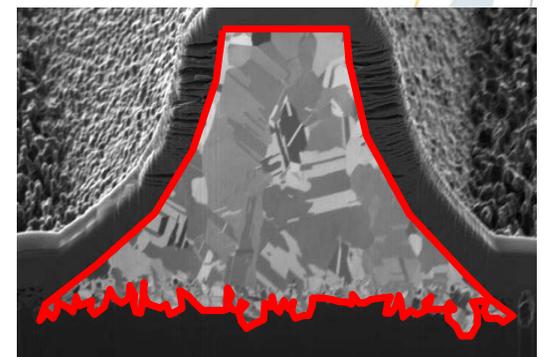
EF = 3.3



**Without EF on ED**



EF = 1.6



# Summery

## 1. Conventional approach to improve etching was reviewed:

- Low profile & small nodule treatment on matte side
- Study of effect of etchant, circuit angle(TD,MD), and grain structure

## 2. New technology

- Etching factor promoter (EF treatment) on shiny side was introduced.
- Using EF treatment, limitation of conventional limitation could be overcome.