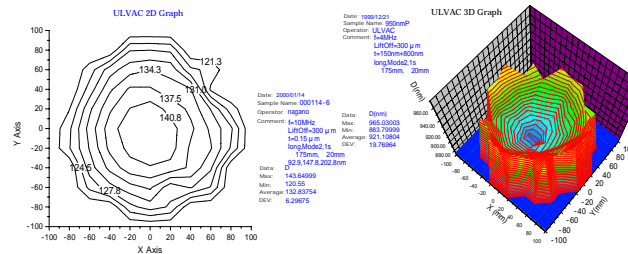


Integrated Metrology System for Metallization Process

MESEC Series



Gai_Chin@ulvac.com

Components Division
ULVAC, Inc.

Introduction

To measure the conductive film thickness on silicon wafer by non-contact and non-destructive method, ULVAC developed the measurement system based on eddy current detecting technology (MESEC).

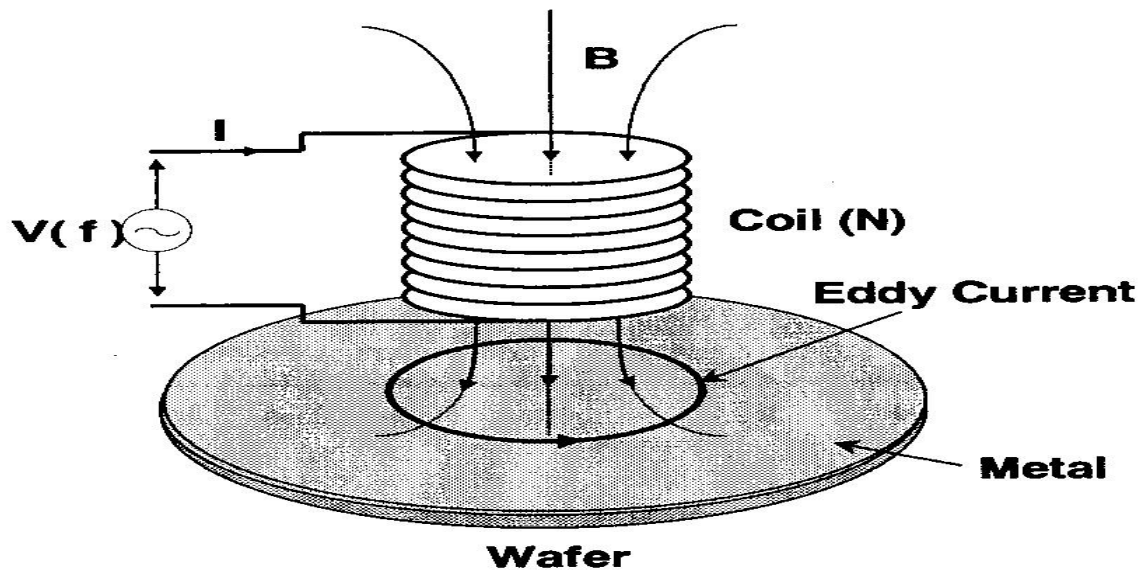
Usually, 4-point probe measurement system is used to measure the conductive film thickness on wafer. The probe contacts the film, and cause damage on the surface. This kind of system is only used for indirect evaluation of semiconductor process on monitor wafers. But MESEC can evaluate directly on product wafers. So it is possible to obtain more reliable data and to reduce the cost on monitor wafers.

ULVAC developed following three kinds of systems,

- Built-in Type (MESEC-BIT) : Integrated onto the deposition systems, such as PVD, CVD and ECD**
- Stand-alone Type (MESEC-SAT) : Used for in-line or off-line measurement.**
- In-situ Type (MESEC-IST) : Under evaluation on CMP equipment**

Measurement Principle

The eddy current technique is based on the principle of magnetic inductance effect. If conductive material, like metal film, is placed in the presence of a changing magnetic field, eddy current is induced on the film. The inductance of detective coil changes with the eddy current. The value of inductance is corresponded with thickness of the conductive film. Therefore, the thickness of the film is possible to be measured by measuring inductance of the coil.



Features

It is possible to measure the thickness of thin metal films on silicon device wafers by using this non-contact and non-destructive technique which enables product wafers to be measured directly.

Small-size eddy current probe and speedy measuring time makes it possible to built this system into PVD, CVD, ECD(plating), and CMP tools, etc.

A capacitance displacement sensor measures the distance between eddy current probe and the wafer surface, ensuring precision and accuracy of film thickness measurements.

Auto dynamic calibration prevents long term drift in the measuring system, helping to ensure excellent repeatability of film thickness measurements.

Users can easily construct a database to calculate thickness of metal alloy films, make it possible to measure thickness of most metal alloy films. (Stand-alone type only)

Powerful data analysis software and flexible graphic functions are available with graphical user interface. (Stand-alone type only)

Outside (Stand-alone Type)



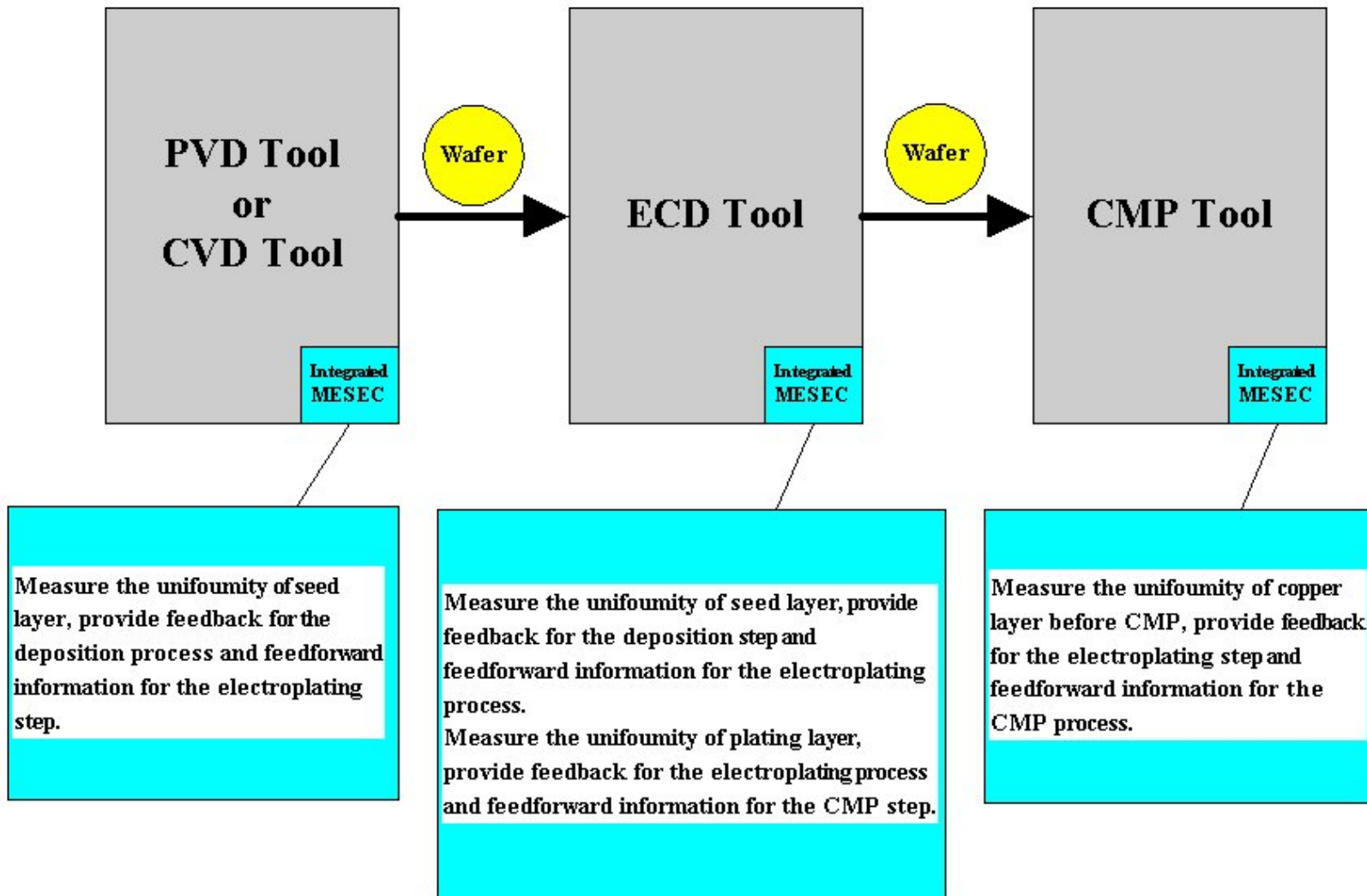
MESEC SAT (Open cassette)

Outside (Stand-alone Type)



MESEC-SAT (FOUP)

Possible MESEC Integration for Dual-damascene Copper Process



Outside (Built-in Type)



MESEC-BIT2000A



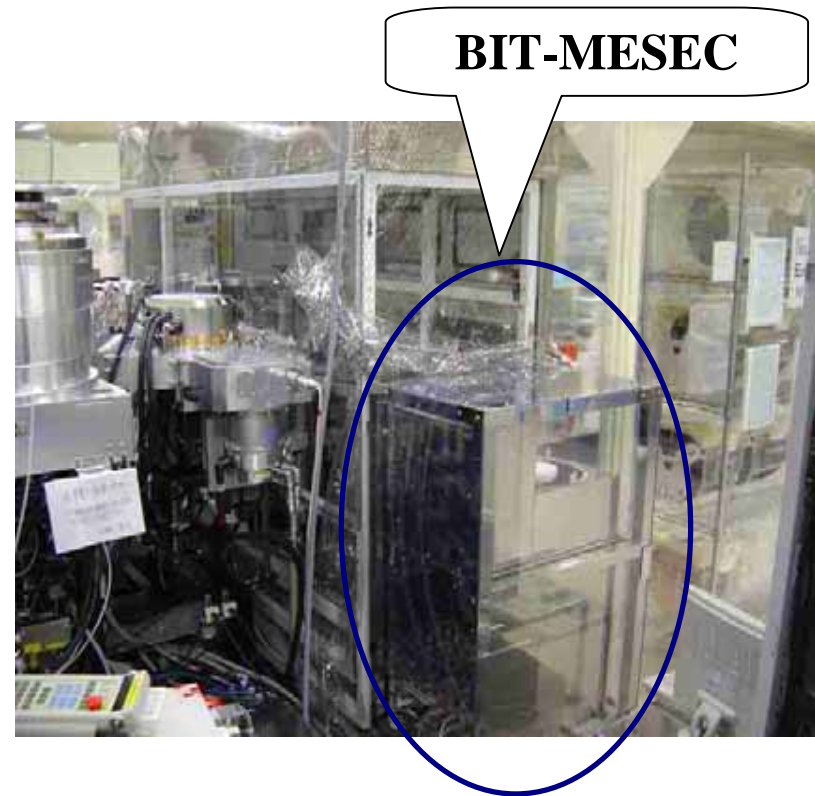
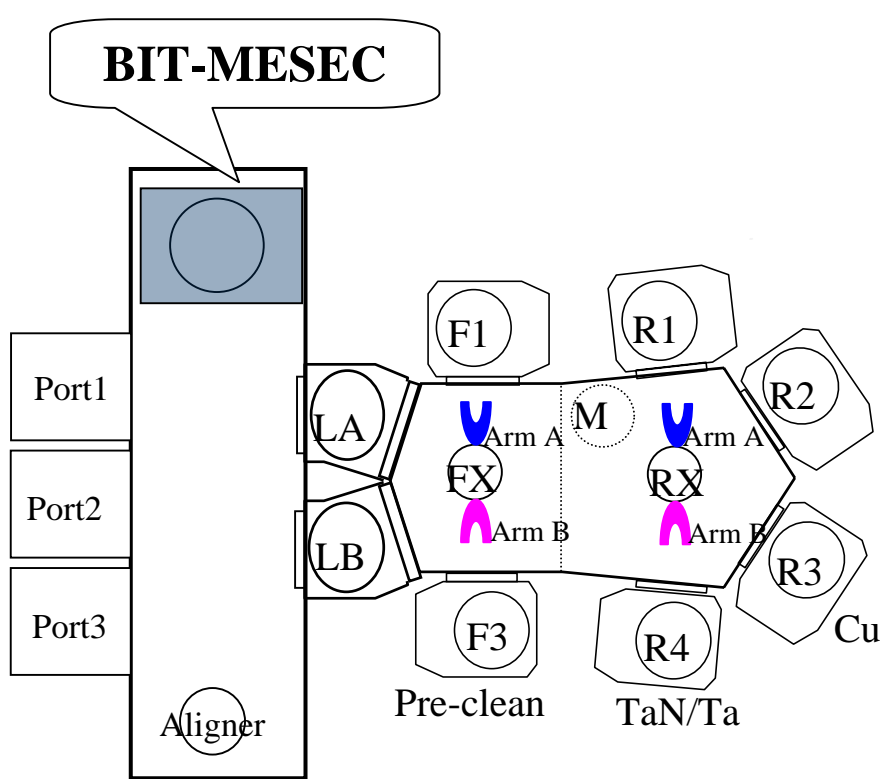
MESEC-BIT2000B



MESEC-BIT3000S

- Evaluation for Cu-seed process -

MESEC Integrated into ULVAC ENTRON W-300 System



Benefits for ECD Suppliers

Integrated metrology is very important for advanced 200mm and all 300mm ECD.

Several ECD suppliers have integrated metrology units in ECD plating tools.

Multiple ULVAC MESEC Integrated Metrology Modules are running in field testing with production ECD copper wafers.

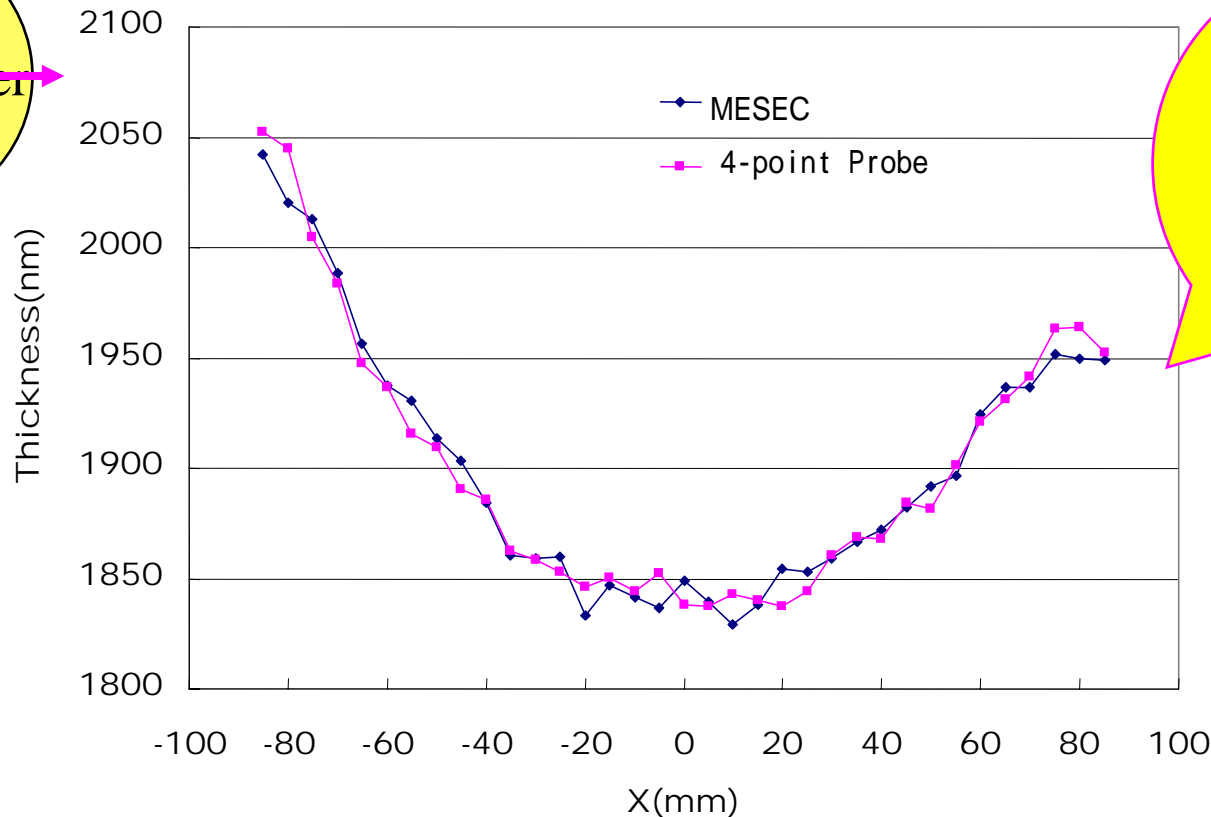
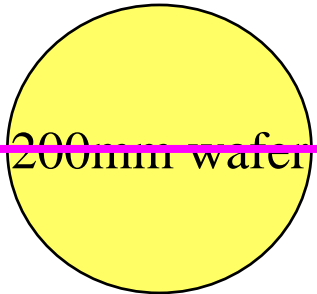
Standard specification

- **Film thickness measurement range:** **0.03 μ m ~ 5 μ m**
- **Measurable material:** **Thin conductive film on silicon wafer**
(Cu, AL, AlCu,etc)
- **Film thickness measurement precision:** **+/- 1% (for calibrated reading)**
- **Film thickness measurement repeatability :** **+/- 0.5% (1)**
(In the case of measuring same point 10 times repeatability)
- **Spatial resolution:** **3mm (Sensor diameter : 2.2mm)**
- **Measuring speed:** **1second/point or less**
(except movement time of stage)
- **Stage size:** **200mm, 300mm**
- **Measurement mode:** **R- mapping, X-Y grid**
- **Software operational environment:** **Windows NT4**

Correlation between MESEC and 4-Points Probe

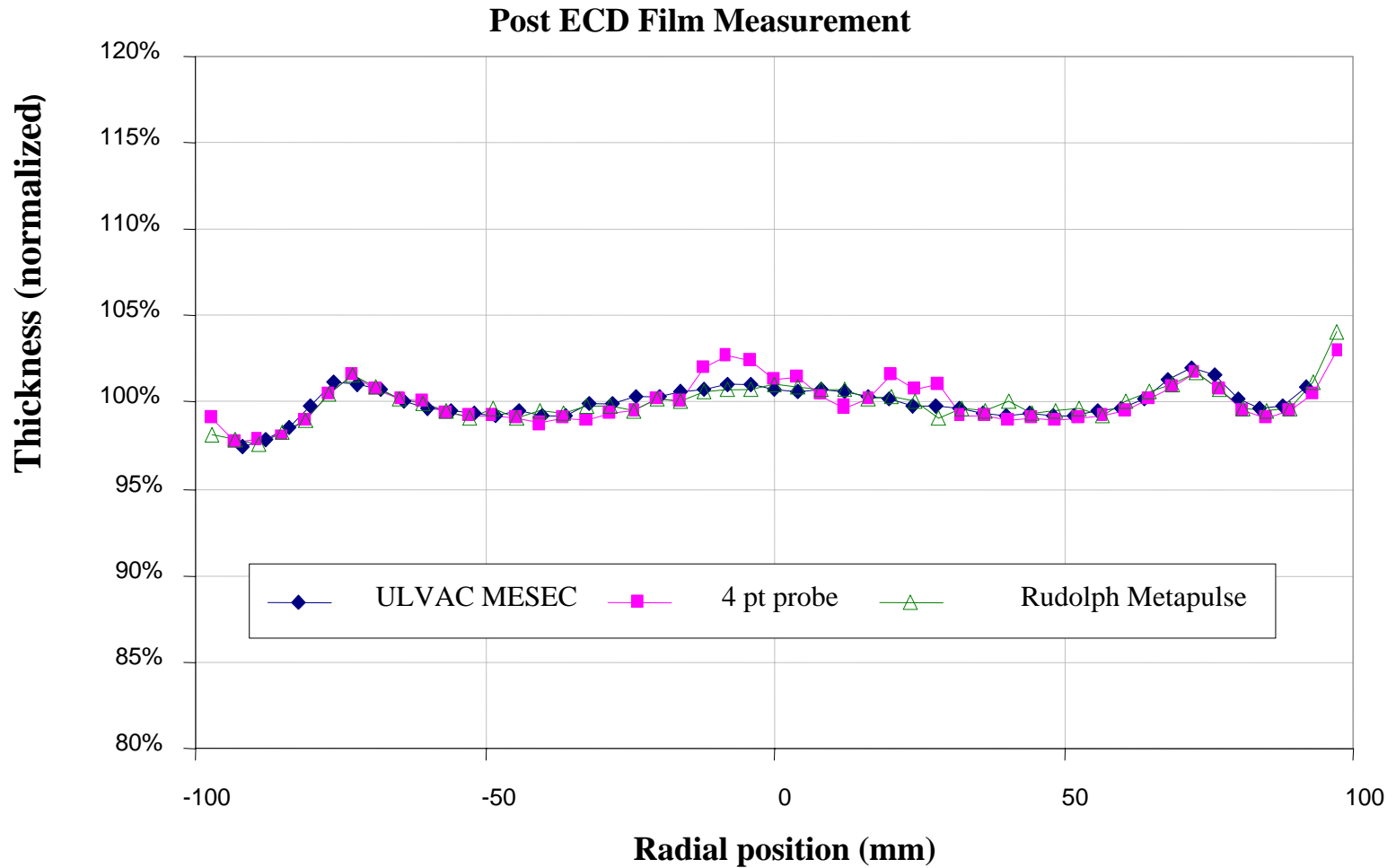
Measured Sample:
Scan Mode:

Cu plating film on 200mm wafer substrate
Diameter scan on wafer, total 37 points with 5mm pitch

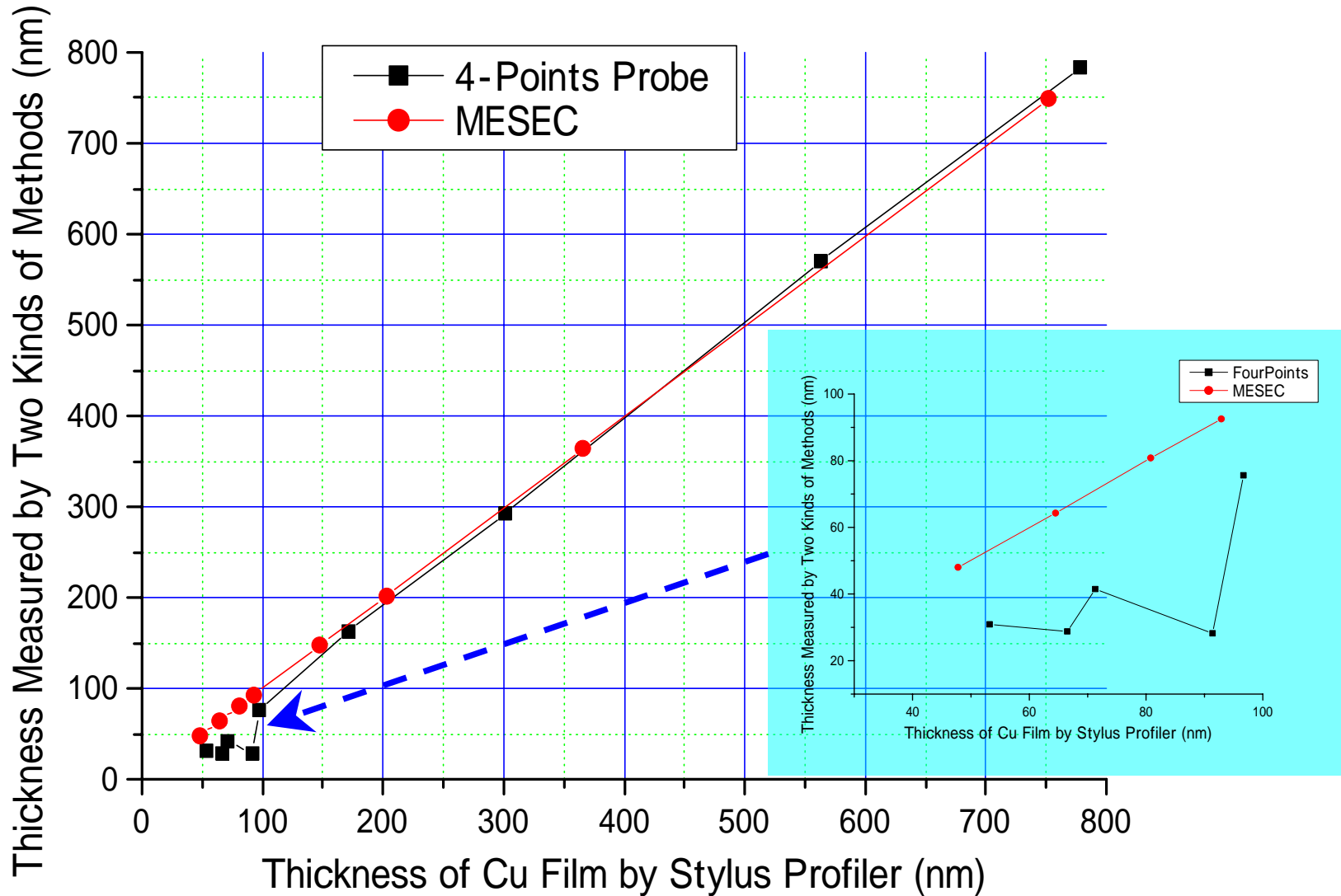


Correlation coefficient is 99%!!

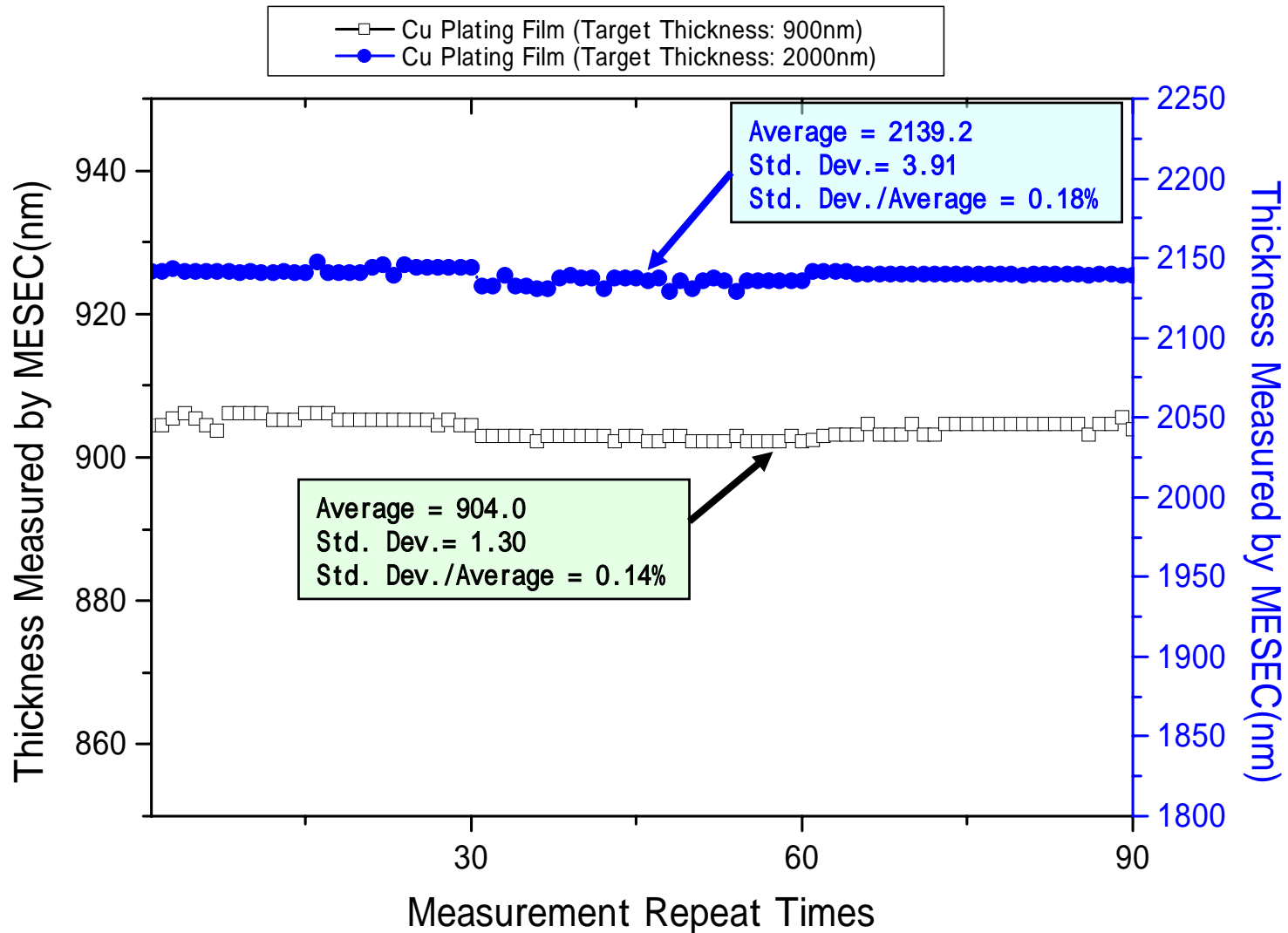
Correlation between MESEC, MetaPulse and 4-Points Probe



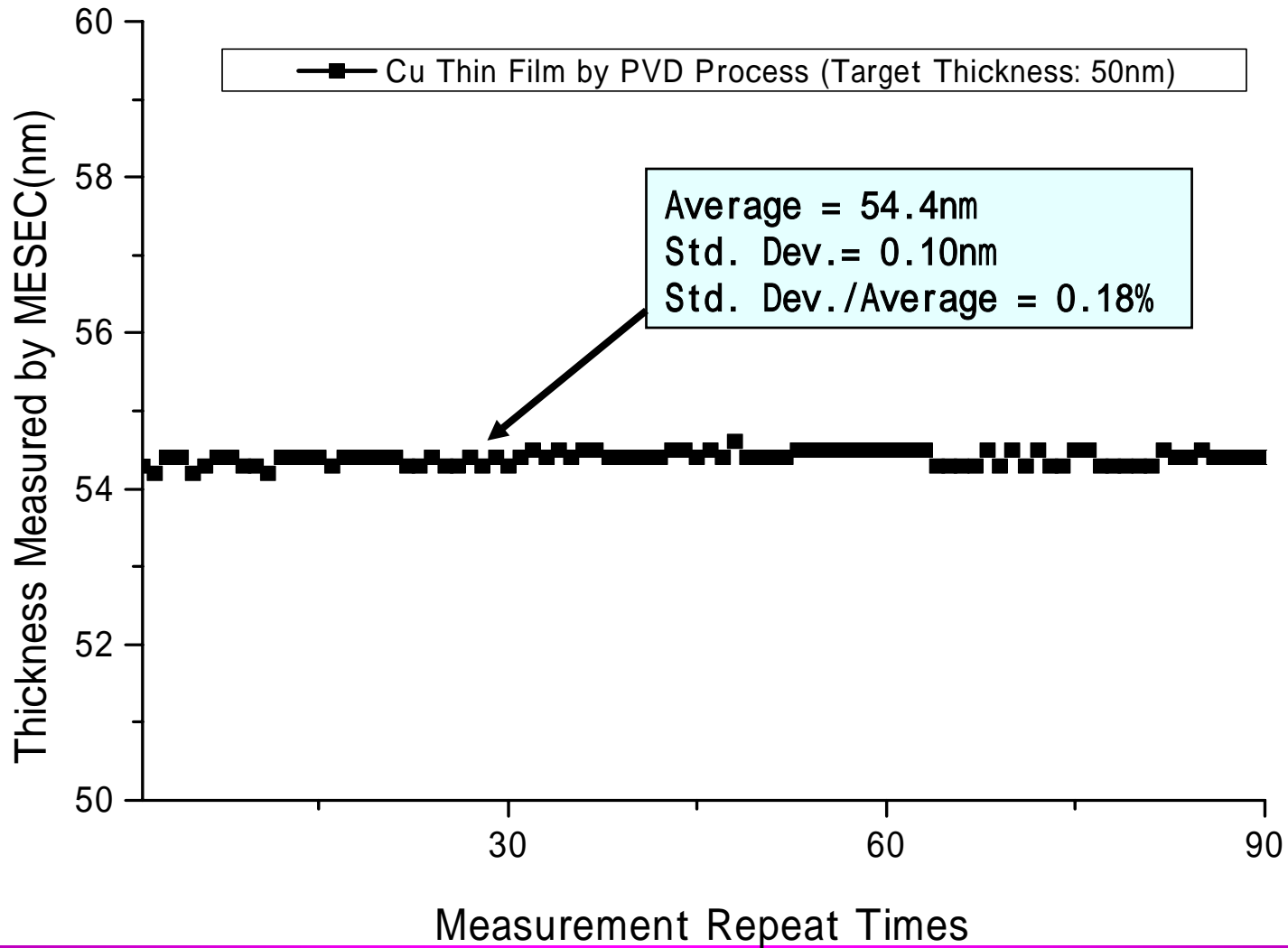
Performance Comparison for 4-Points Probe and MESEC



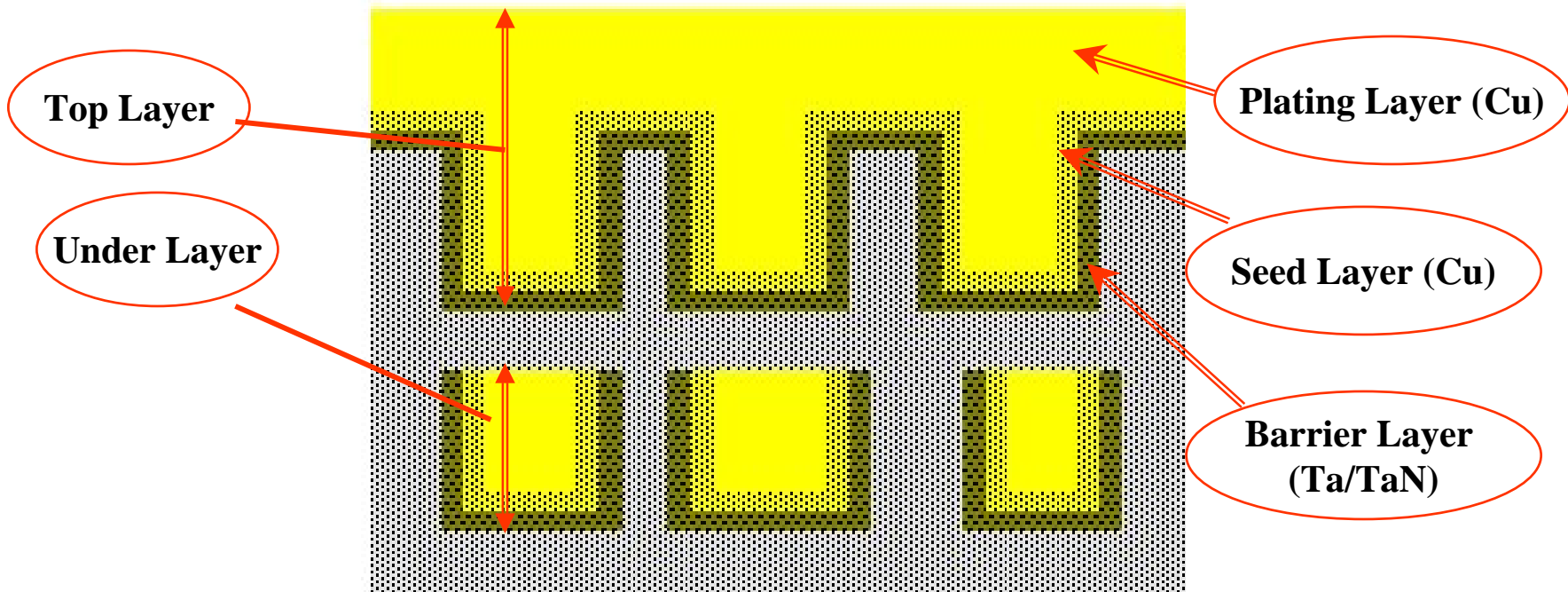
Evaluation on Long Term Stability (Several Days Interval, 30 times/day)



Evaluation on Long Term Stability (Several Days Interval, 30 times/day)



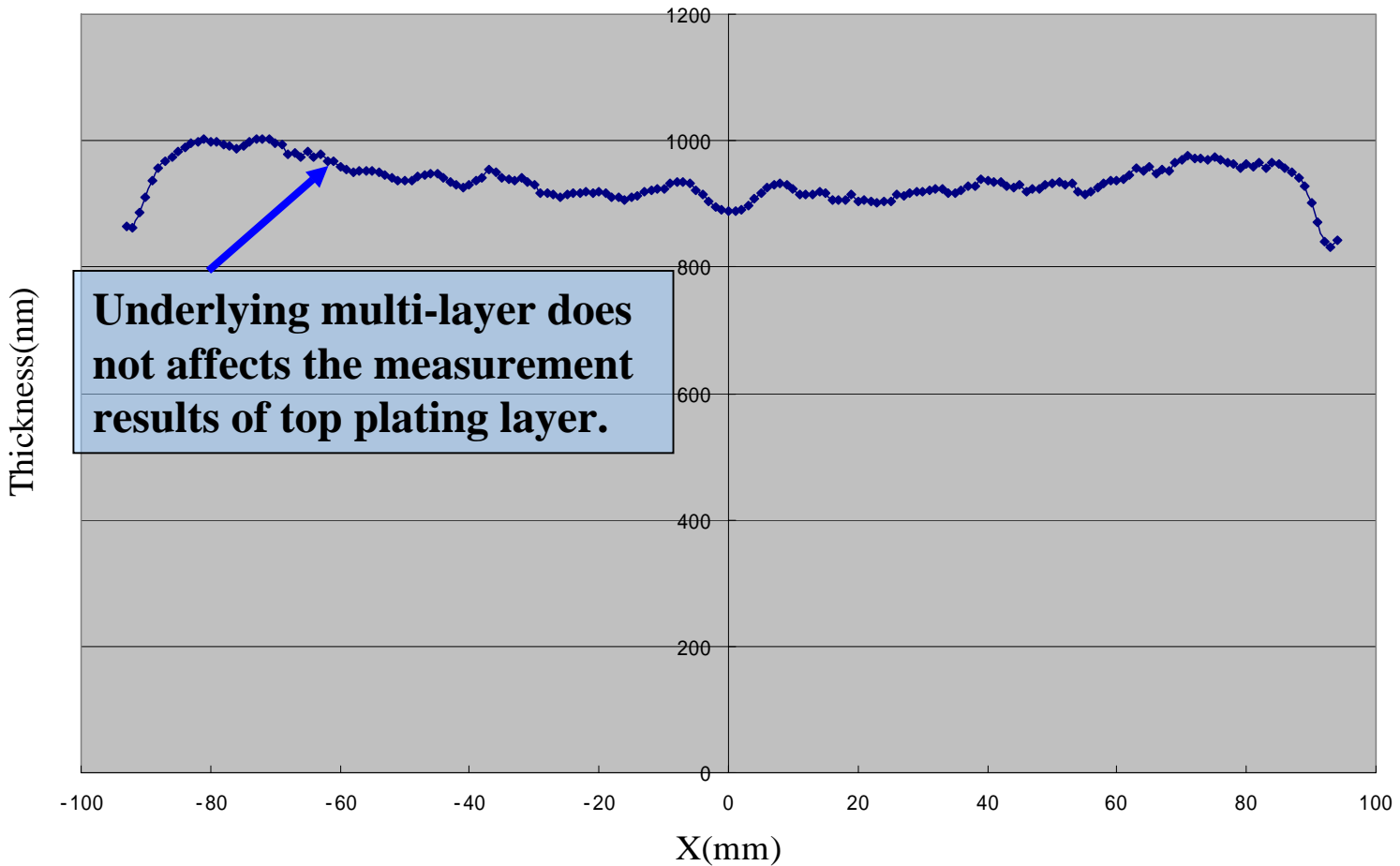
Measurement on Multi-layer Patterned Wafer after ECD Process



The top film is unpatterned and can support eddy current formation. Underlying metal are patterned which breaks up the eddy currents, unless there are large areas of unpatterned metal. These large areas of unpatterned underlying metal may occur on test die or in alignment areas but would not normally be found within an active die area.

Measurement on Multi-layer Patterned Wafer after ECD Process

Diameter Scan on Patterned Wafer (After ECD Process)



Why our customers selected the MESEC ?

- - - Real value of the MESEC

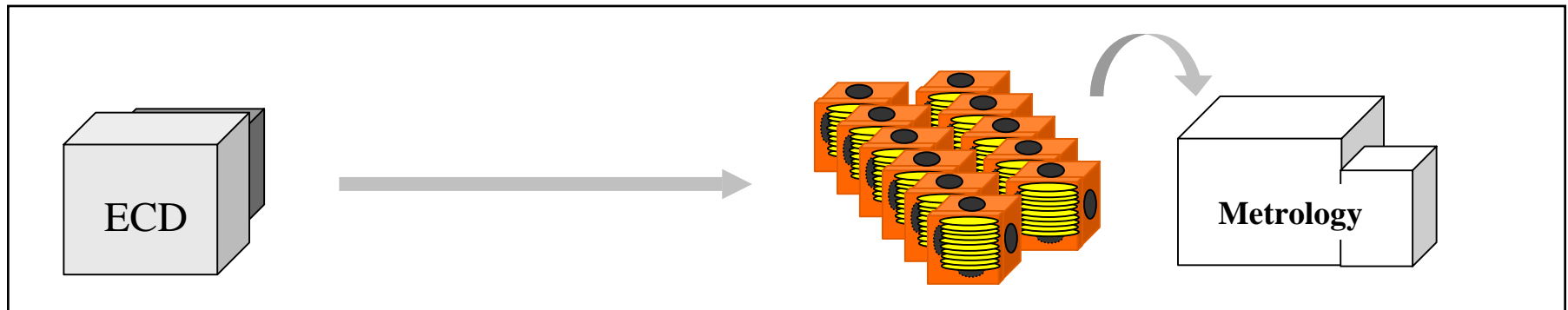
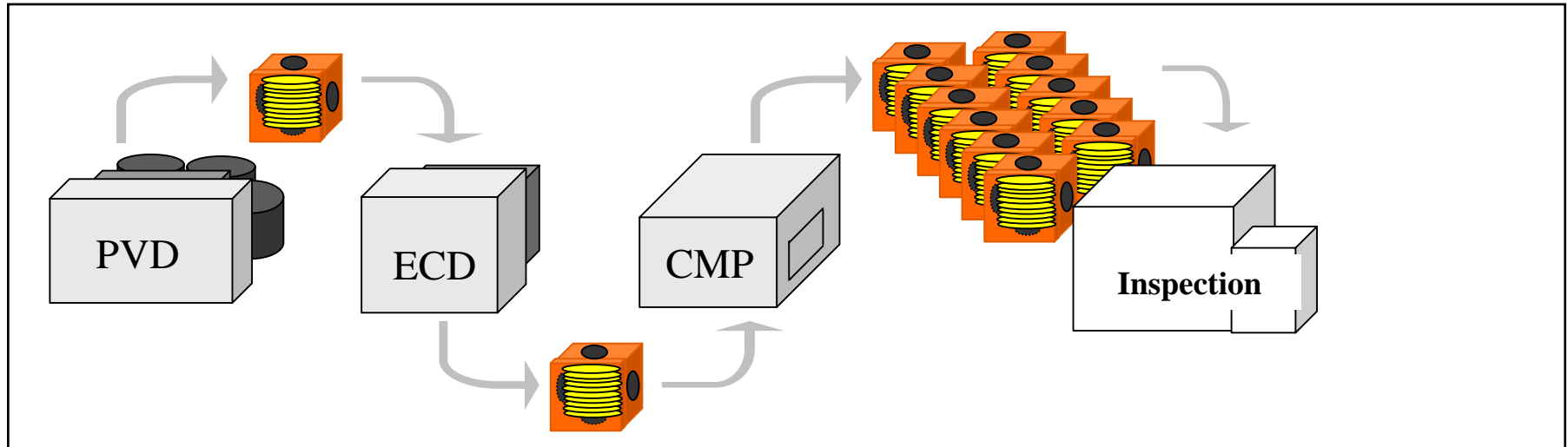
Process Optimization

Improved Reliability

Cost of Ownership Saving

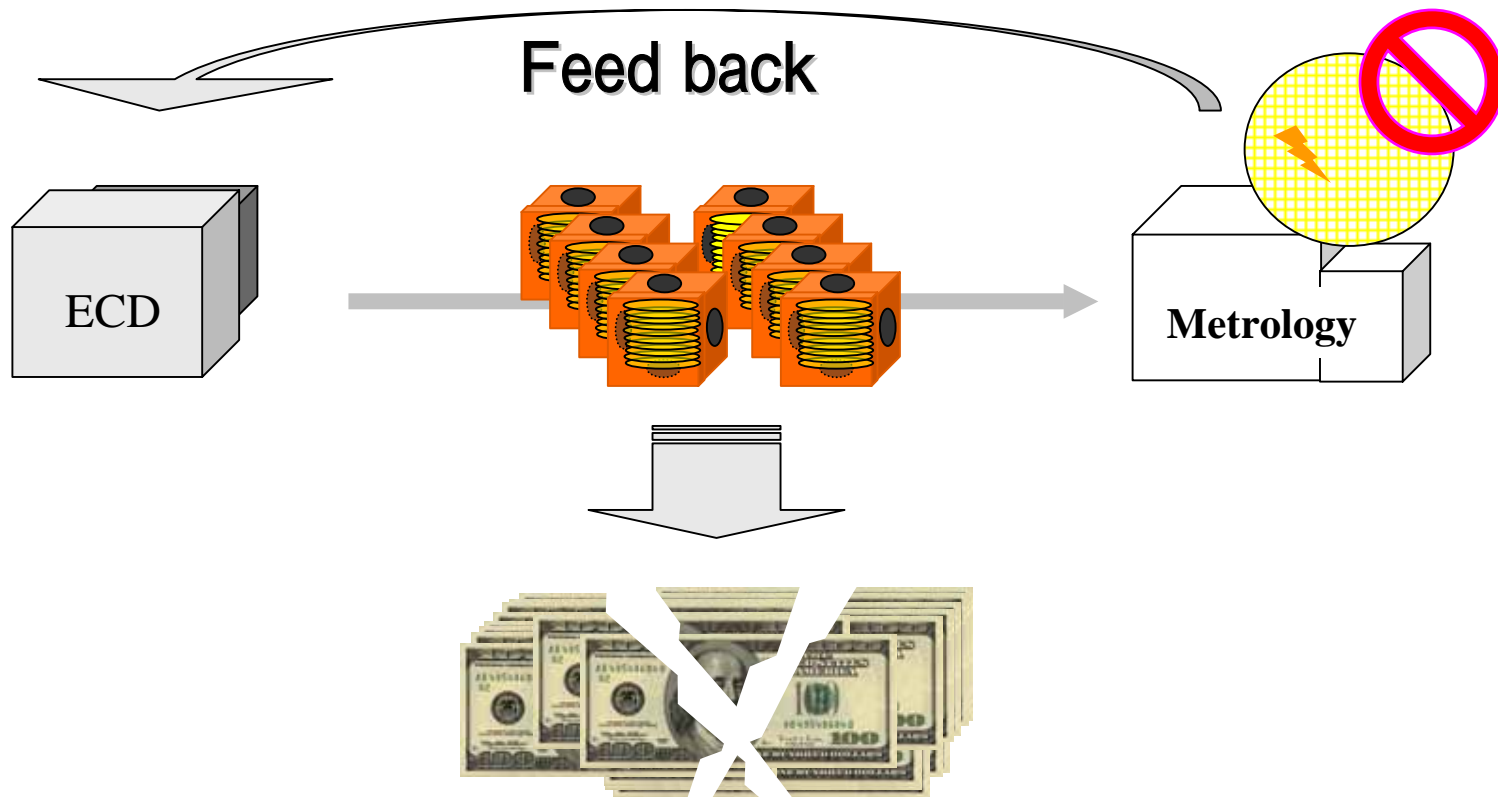
Conventional line ---

The wafers are inspected after all processes. Or even if after each process, they are evaluated all at once.



As a result - - -

When defects are found during metrology measurement, feed back information to the deposition tool is too late.



ULVAC Solution

Integrate the MESEC onto each Cu process line.

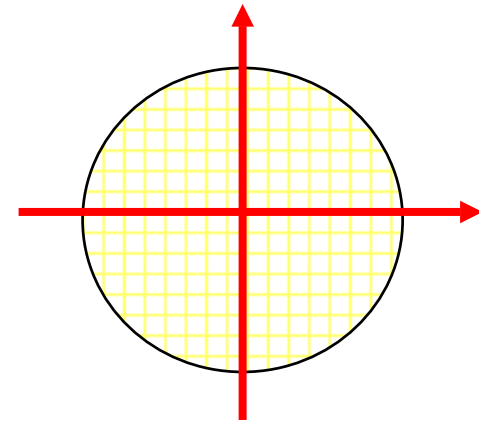
Necessary *to integrate the MESEC*

- *Non-contact* → ✓ *Measurement of all production wafers*
- *Speedy measurement* → ✓ *Measurement of all production wafers*
- *Compact* → ✓ *Easy to integrate*
- *Stability* → ✓ *High reliability*
- *Accuracy* → ✓ *High reliability*
- *Cost saving* → ✓ *Reduce*
 - QC wafers*
 - Indirect inspection time*
 - The waste wafer*

Measurement application

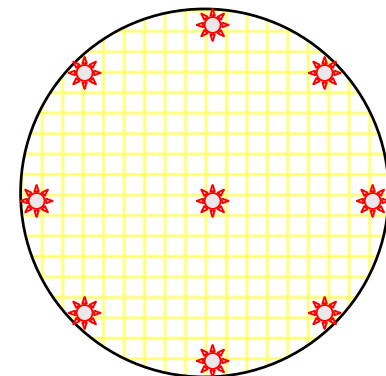
➤ *Diameter Scan*

- ✓ For surface uniformity analysis.
- ✓ To see the result of deposition.



➤ *Overall Scan*

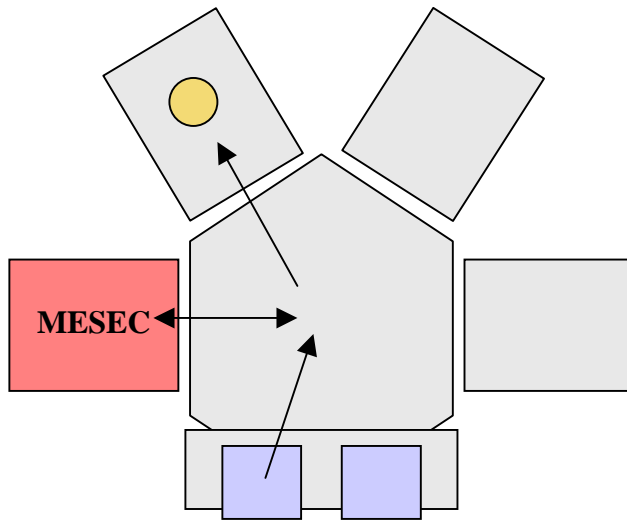
- ✓ For surface uniformity analysis.
- ✓ For Quality Control.
- ✓ For control of the exchange cycle of consumable parts for deposition tool, such as target, bath and pad, etc.



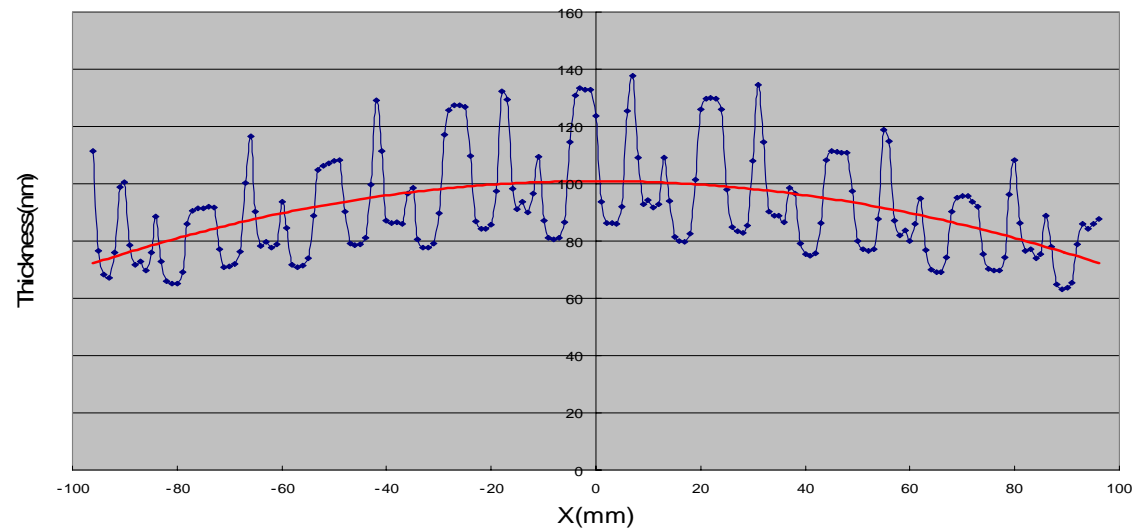
Measuring in-coming wafer

Feed forward the result to select an optimum recipe.

Profile Optimizer



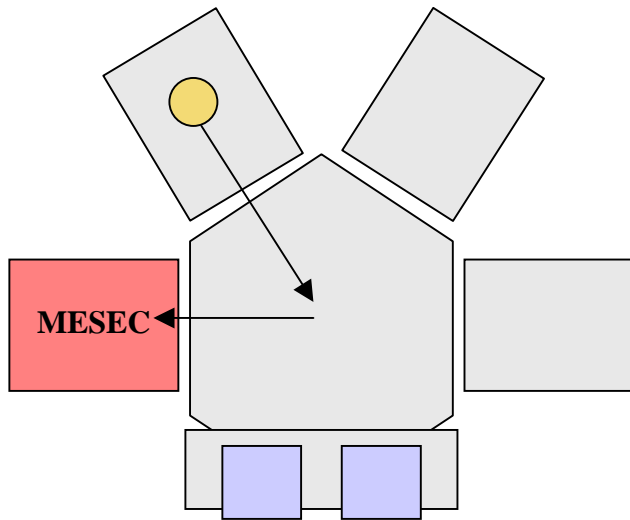
Diameter Scan on Patterned Wafer (Before ECD Process)



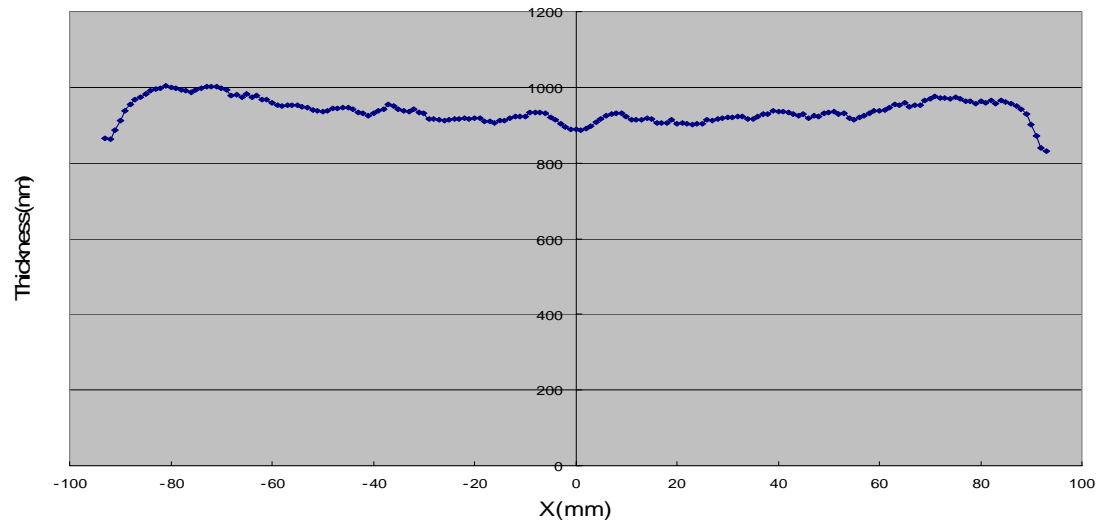
Measuring outgoing wafer

Check results and provide feed back for ECD improvement. Stop producing waste wafers at once !

Profile Keeper



Diameter Scan on Patterned Wafer (After ECD Process)



Why integrated the MESEC

➤ **Advantage for the PVD, ECD and CMP supplier**

- ✓ Optimization of film thickness profile (Feed-forward)
- ✓ Dynamic deposition control (Feed-back)
- ✓ Yes/No decision on the production wafer

➤ **Advantage for the end user**

- ✓ Reduction of QC/monitor wafers
- ✓ On the fly tool qualifications
- ✓ Higher Yield Ratio

Trial calculation

Reduction effect on test wafer expense.

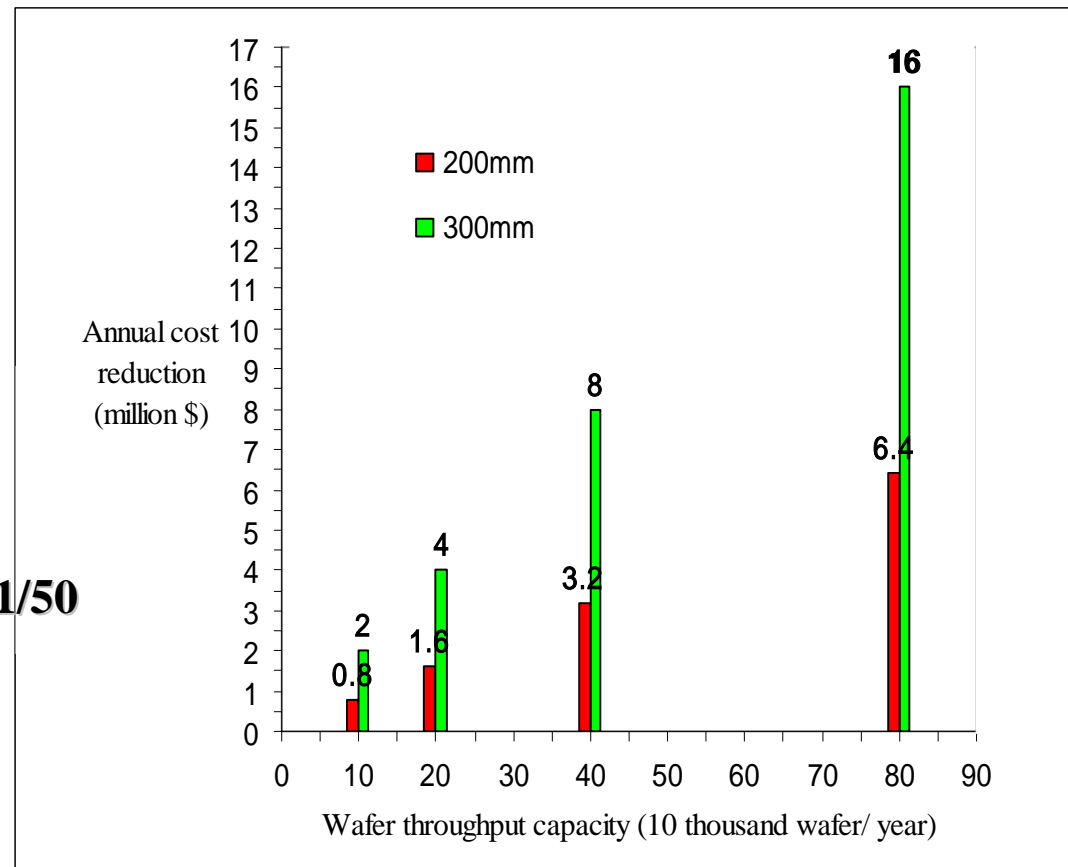
- Condition -

-5 wiring processes / wafer

-Unit price of 200mm wafer: \$ 80.

-Unit price of 300mm wafer: \$ 200.

-Test wafer / Production wafer ratio: 1/50



Performance Comparison with Conductive Film Thickness Measuring Systems

	Eddy Current Type (MESEC)	4-Point Probe Type	Fluorescent X-ray Type	X-ray Interference Type	Pulse Laser Type
Destructive Dangerous	Non-destructive	× Contact	× Radioactive Source	× Radioactive Source	× High Power Laser
Measuring Range	30nm~5 μ m	100nm~10 μ m	10nm~15 μ m	× 10nm~400nm	10nm~3.5 μ m
Measuring Time (Per Point)	Less than 1 second	A few seconds	× A few minutes	× A few minutes	A few seconds
Spatial Resolution	A few mm	A few mm	× A few cm	A few mm	A few μ m

Excellent

Good

× Poor

MESEC Performance

➤ *Advantages:*

- ✓ Non-contact, no wafer damage !
- ✓ Excellent correlation with other measurement methods.
- ✓ Capable of measuring film on top of multi-stacked damascene layers.
- ✓ Minimal loss of production wafers
- ✓ Early detection of deposition tool problem

➤ *User friendly:*

- ✓ Easy to operate.
- ✓ No adjustments.
- ✓ No consumable parts.
- ✓ Maintenance free.
- ✓ Reasonable price.

Low CoO and fast amortization can be realized with continuous use of the MESEC.

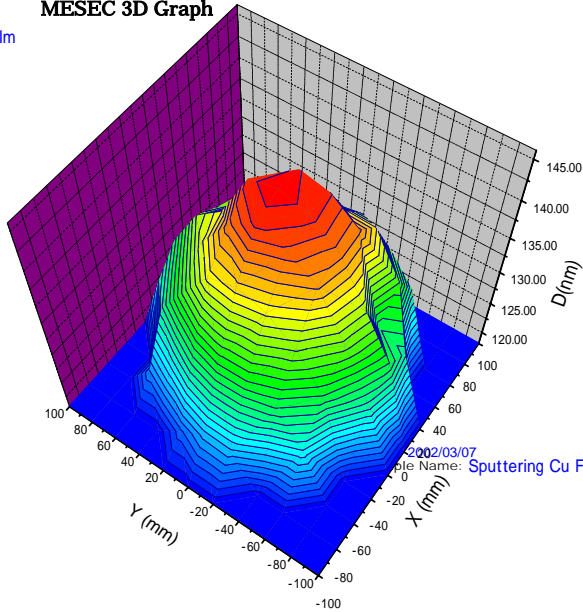
Application Data

Cu Seed Film on 200mm Silicon Wafer

MESEC 3D Graph

Sample Name: Cu Seed Film
Operator: ULVAC

Data: Thickness
Max: 145.64nm
Min: 120.69nm
Average: 134.13nm
DEV: 6.71nm

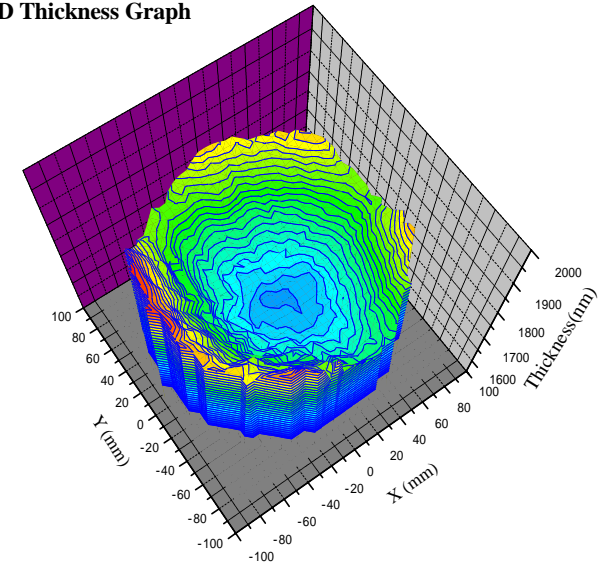


Cu Plating Film on 200mm Silicon Wafer

3D Thickness Graph

Sample: Cu ECD Film
Operator: UJ25830

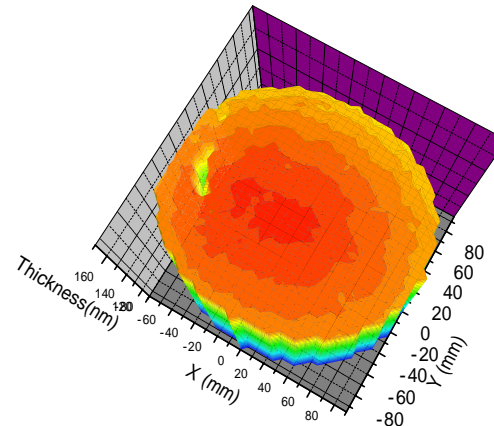
Data: Thickness
Max: 1956.7nm
Min: 1708.3nm
Average: 1804.06nm
STDDEV: 57.83nm



MESEC 3D Graph

202/03/07
Sample Name: Sputtering Cu Film 160nm

Data: Thickness
Max: 164.3nm
Min: 109.2nm
Average: 159.4nm
DEV: 3.75nm



Detecting Scratch on Wafer

Why select the MESEC

**Non-contact, Speedy measurement,
Excellent repeatability, High accuracy**

Cost Effective

**Integrating
into deposition
tool**

**Test all
production wafers**

**Cut cost
(Initial,
Running,
Monitor wafers)**

Optimization for process

Improve reliability

Cost down

Global Network

