

# Preliminary Measurements of Bakelite Sample BS-002

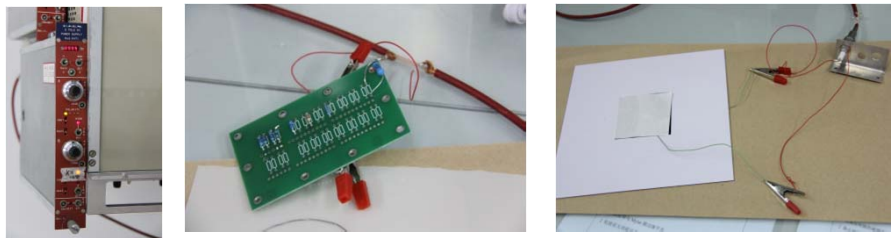
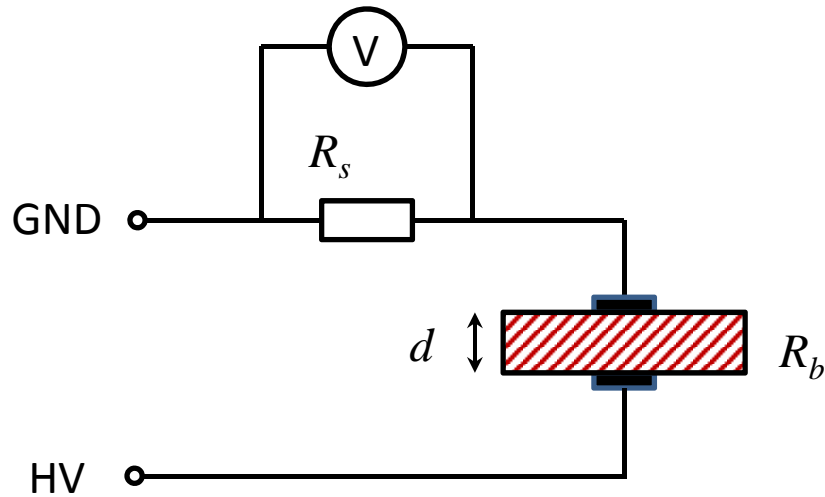
Liang Guan

- Test Method, Calibration, Error analysis
- BS-002 samples measurement
  - Surface defects and topography
  - Thickness uniformity
  - Bulk & Surface Resistivity
- Remarks & comment

# Test Method- Bulk Resistivity

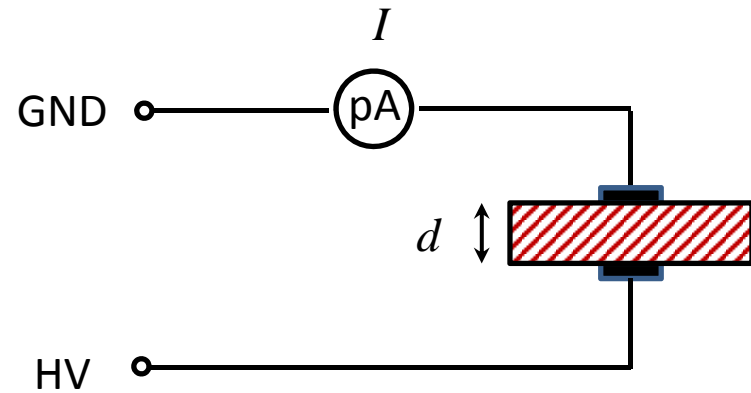
Two general ways to measure current flowing through Bakelite sample test area:

Sampling



$$\rho_v = R_b \frac{S}{d} = \frac{U}{\frac{U_s}{R_s}} \frac{S}{d}$$

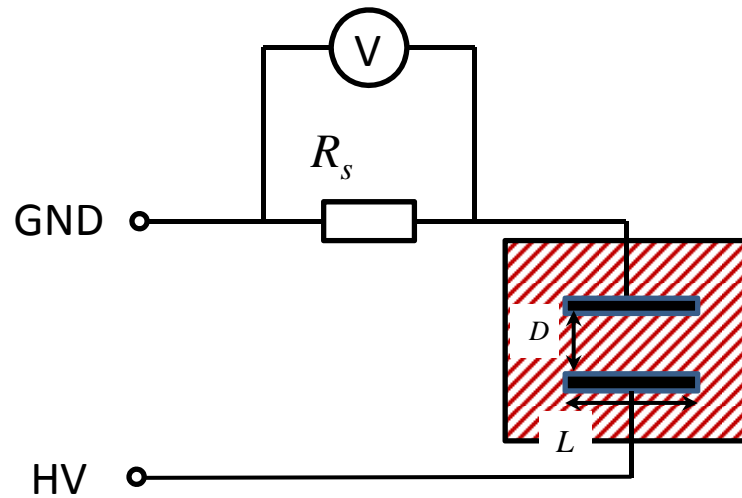
Pico ampere meter



$$\rho_v = R_b \frac{S}{d} = \frac{U}{I} \frac{S}{d}$$

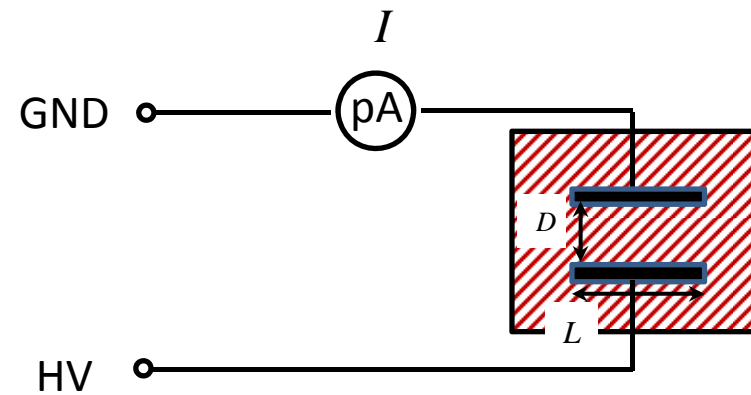
# Test Method- Surface Resistivity

Sampling



$$\rho_s = \frac{U L}{\frac{U_s}{R_s} D}$$

Pico ampere meter



$$\rho_s = \frac{U L}{I D}$$

- $L$  typically ~6.5-7cm;  $D$  typically ~1.5cm

# Test Method

Electrode : carbon film (surface resistivity  $\sim 100 \text{ k}\Omega/\square$ )



Top ( $20.8 \text{ cm}^2$ )



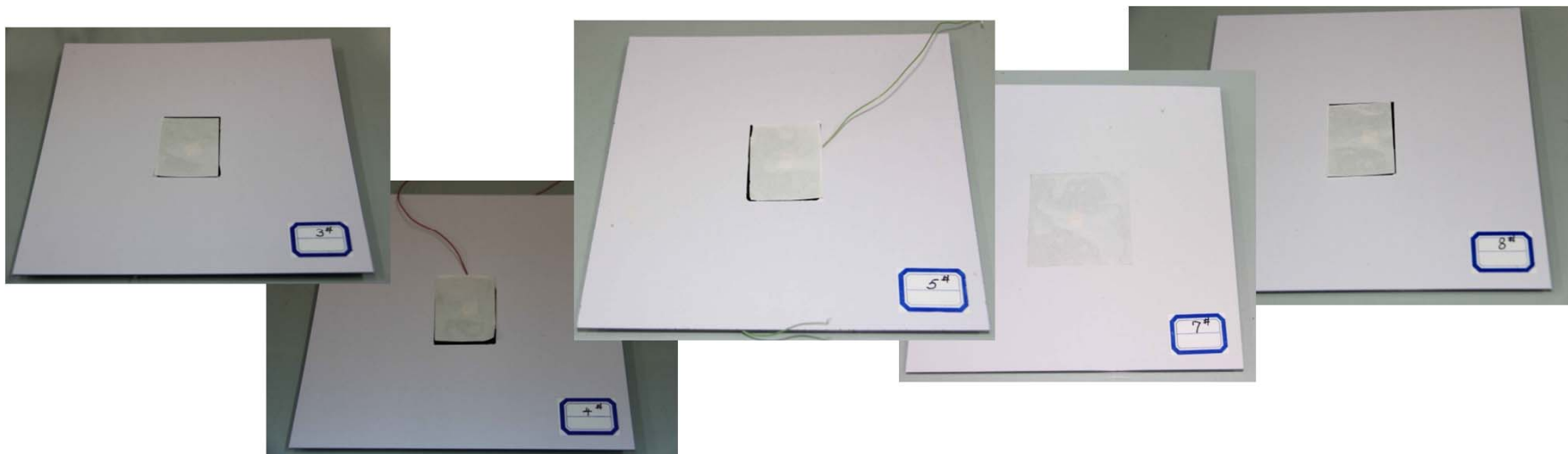
Bottom ( $42.25 \text{ cm}^2$ )



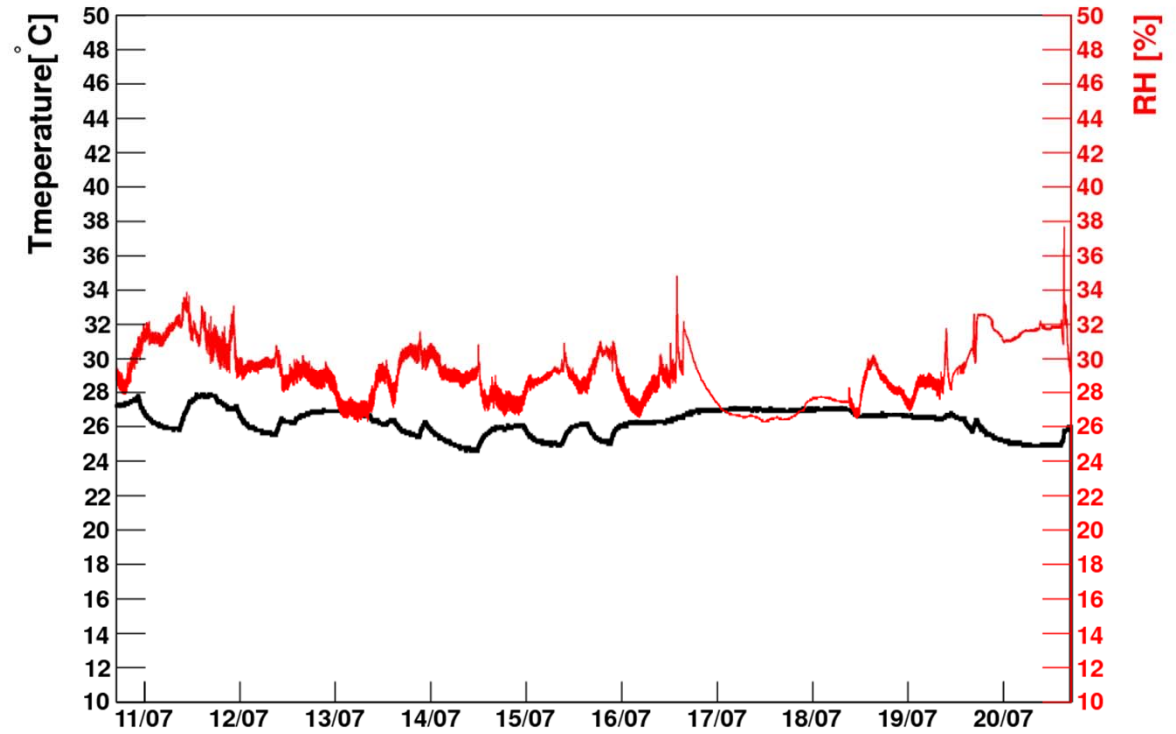
- For surface resistivity test, carbon films are baked to lower down its surface resistivity to  $\sim 50 \text{ k}\Omega/\square$

# Samples

- 10 Bakelite samples Received from Mr. Su @ 10<sup>th</sup> July, 2011
- Composition: melamine + phenol+ melamine (sandwiched structure)  
(melamine only will be tried soon)
- Each with a size of 20 cm × 20 cm and thicknesses around 1.5mm
- Samples are made with different resistivity levels



# Environment monitoring



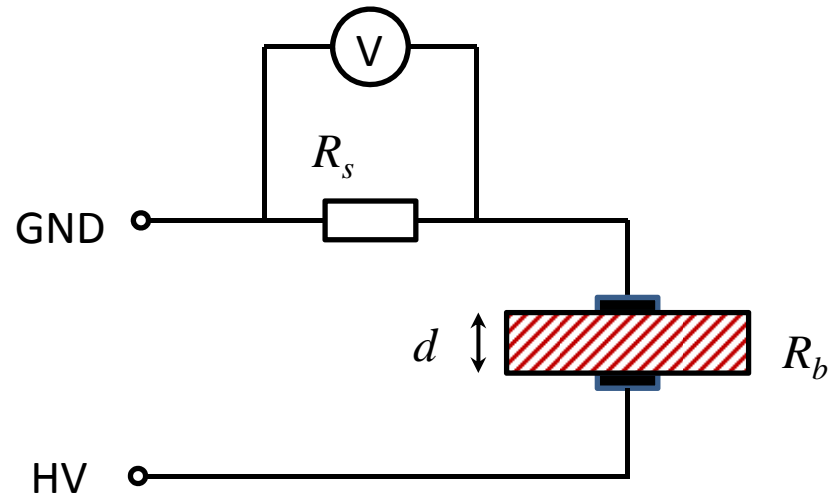
## Error analysis (I)

$$\rho_v = R_b \frac{S}{d} = \frac{U}{\frac{U_s}{R_s}} \frac{S}{d}$$

$U$ : typically 500V

$R_s$ : sampling resistor resistivity

$U_s$ : voltage across sampling resistor



$$\sigma_{\rho_v} = \sqrt{\left(\frac{\partial \rho_v}{\partial U}\right)^2 \sigma_U^2 + \left(\frac{\partial \rho_v}{\partial S}\right)^2 \sigma_S^2 + \left(\frac{\partial \rho_v}{\partial U_s}\right)^2 \sigma_{U_s}^2 + \left(\frac{\partial \rho_v}{\partial R_s}\right)^2 \sigma_{R_s}^2 + \left(\frac{\partial \rho_v}{\partial d}\right)^2 \sigma_d^2}$$

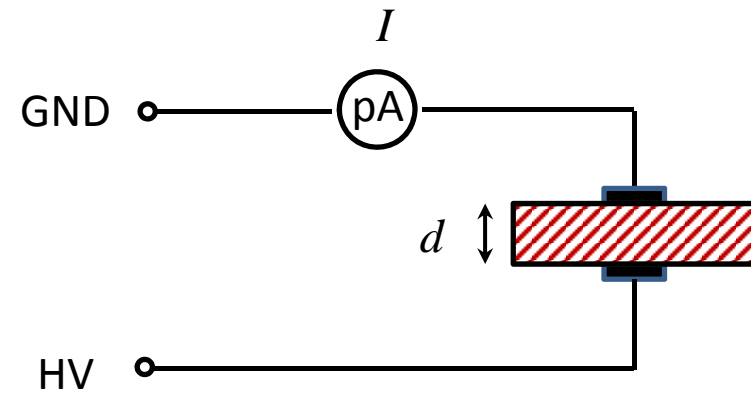
$$\delta_{\rho_v} = \sqrt{(\delta U)^2 + (\delta U_s)^2 + (\delta S)^2 + (\delta R_s)^2 + (\delta d)^2}$$

	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	
	0.2%-1%	0.5%-1%	8%	0.1%	5-10%	$\Rightarrow$ total ~10%

- Electrode **contact** is the main source of measurement error
- Other systematic errors: temperature, humidity variations; charging time etc.

## Error analysis (II)

$$\rho_v = R_b \frac{S}{d} = \frac{U S}{I d}$$



- Current:  $100, 100 \times 10^{-1}, 100 \times 10^{-2}, 100 \times 10^{-3}, 100 \times 10^{-4}, 100 \times 10^{-5} \mu\text{A} \dots$
- Resolution:  $2, 2 \times 10^{-1}, 2 \times 10^{-2}, 2 \times 10^{-3}, 2 \times 10^{-4}, 2 \times 10^{-5} \mu\text{A} \dots$
- Depending on the range,  $I$  contribute to the error of measurement at a level of **1%-10%**.

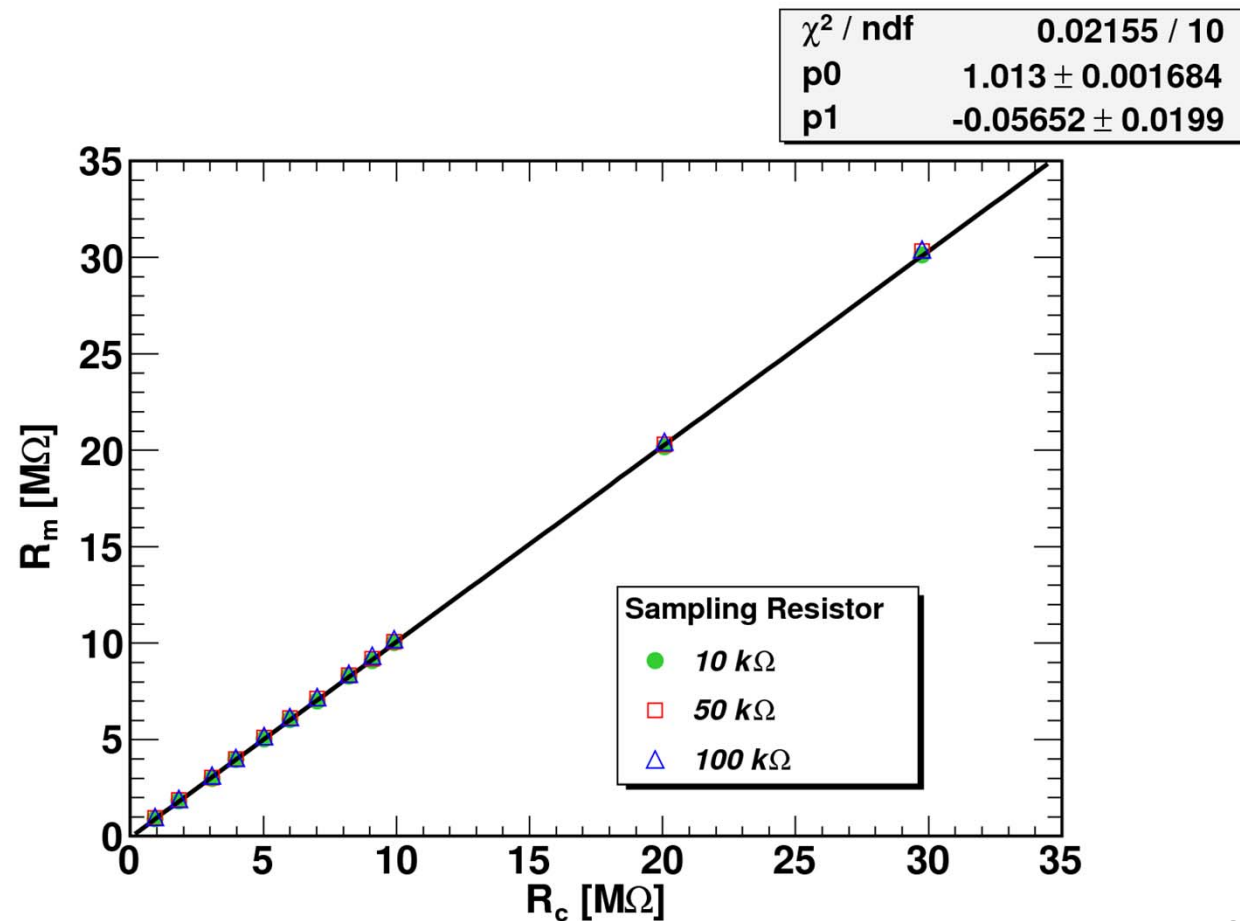


# Calibration

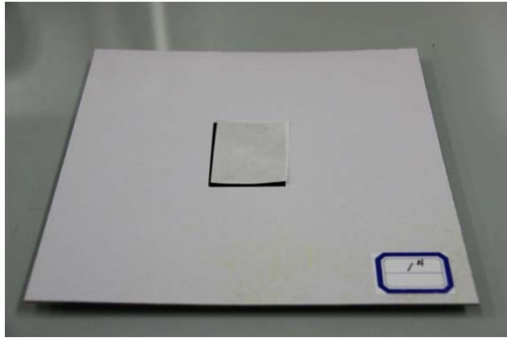
- Assume test electrode is circular( $\phi 5\text{cm}, S \sim 20\text{cm}^2$ ), HV=500V

Interest bulk resistivity of Bakelite plate is in the range  $10^8$ - $10^9 \Omega \cdot \text{cm}$

Equivalent resistor  $R_b$  in the test chain is 0.5-50 M $\Omega$

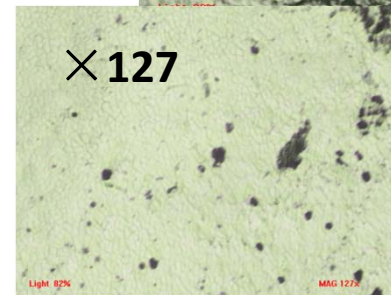
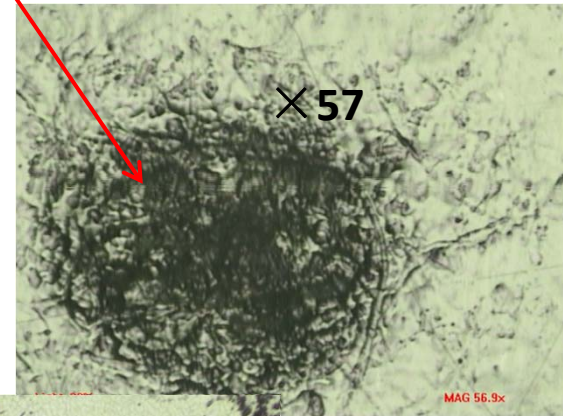


# Defects (I)



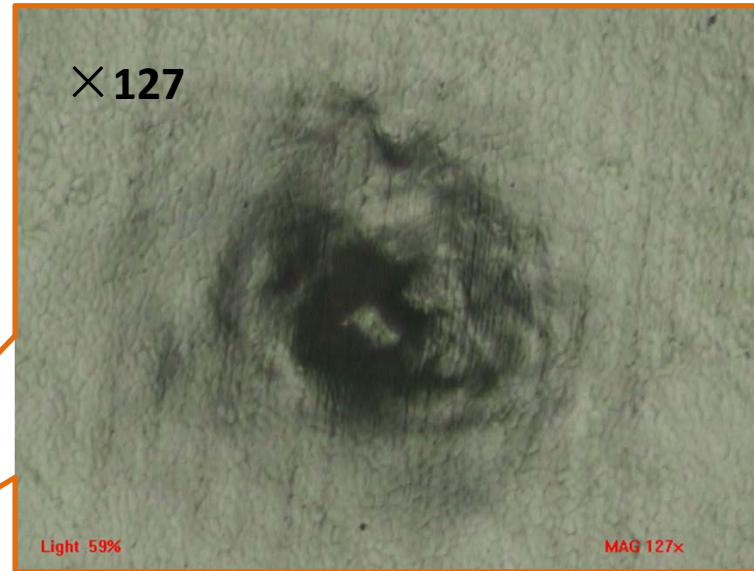
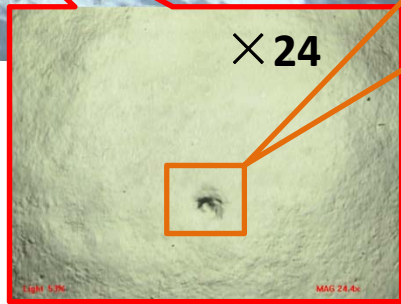
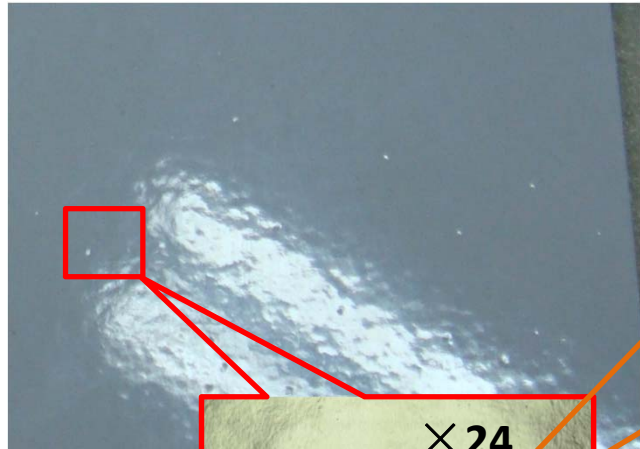
Warpage

## Contamination

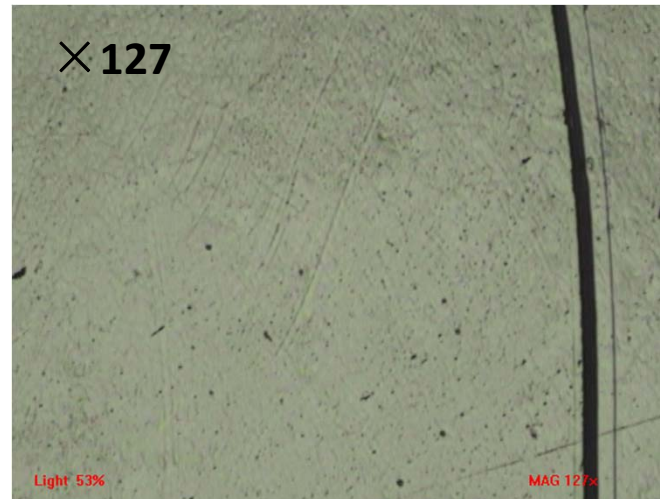


# Defects (II)

## Holes

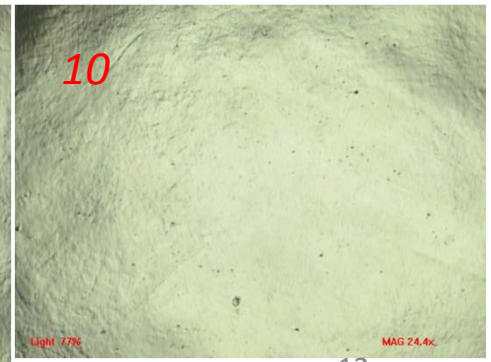
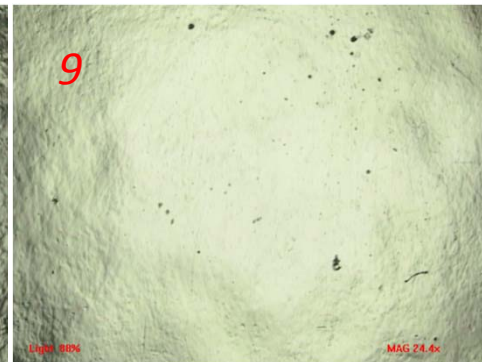
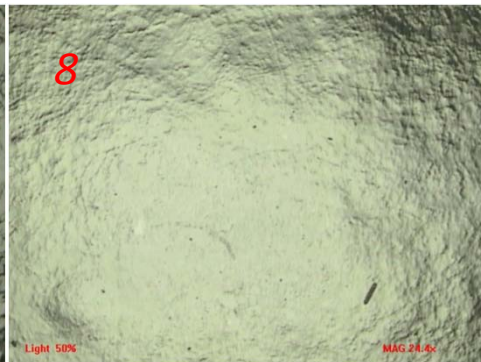
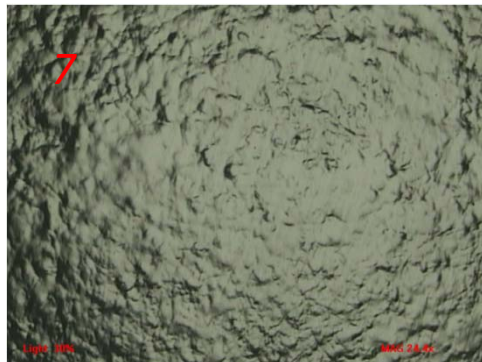
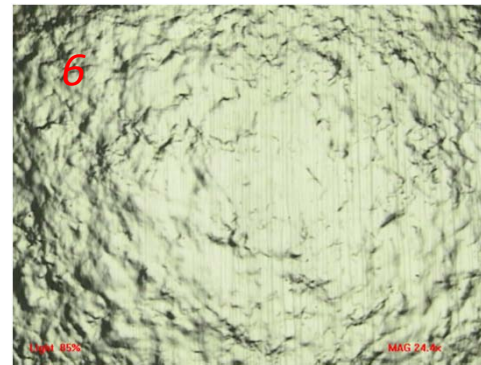
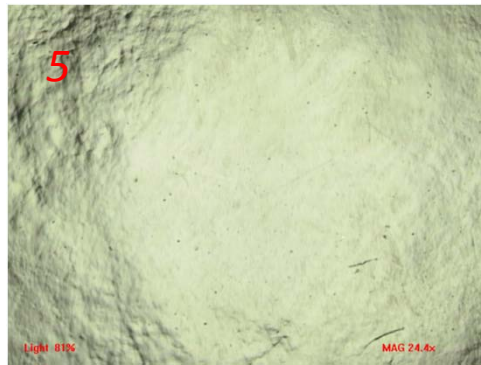
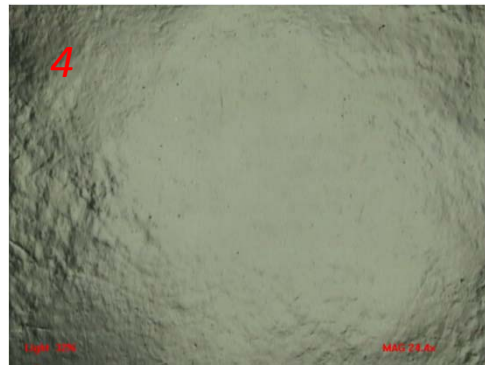
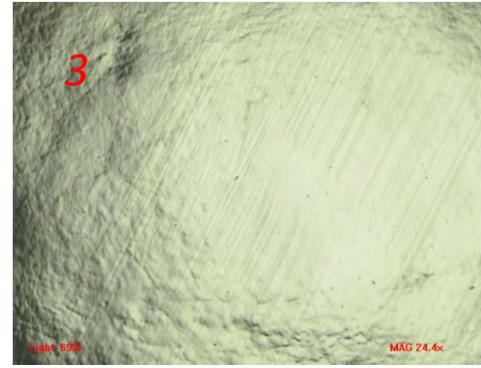
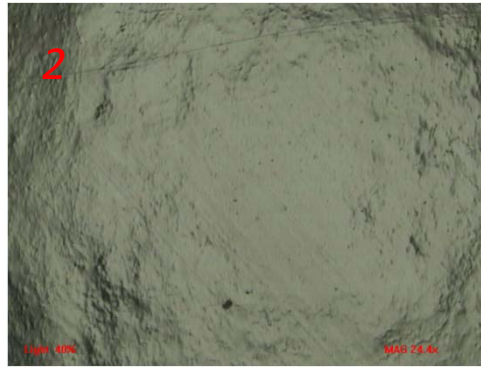
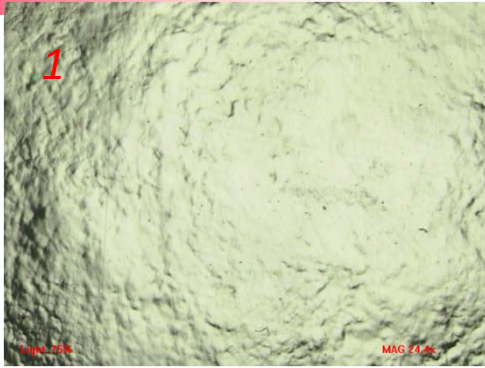


## Nick

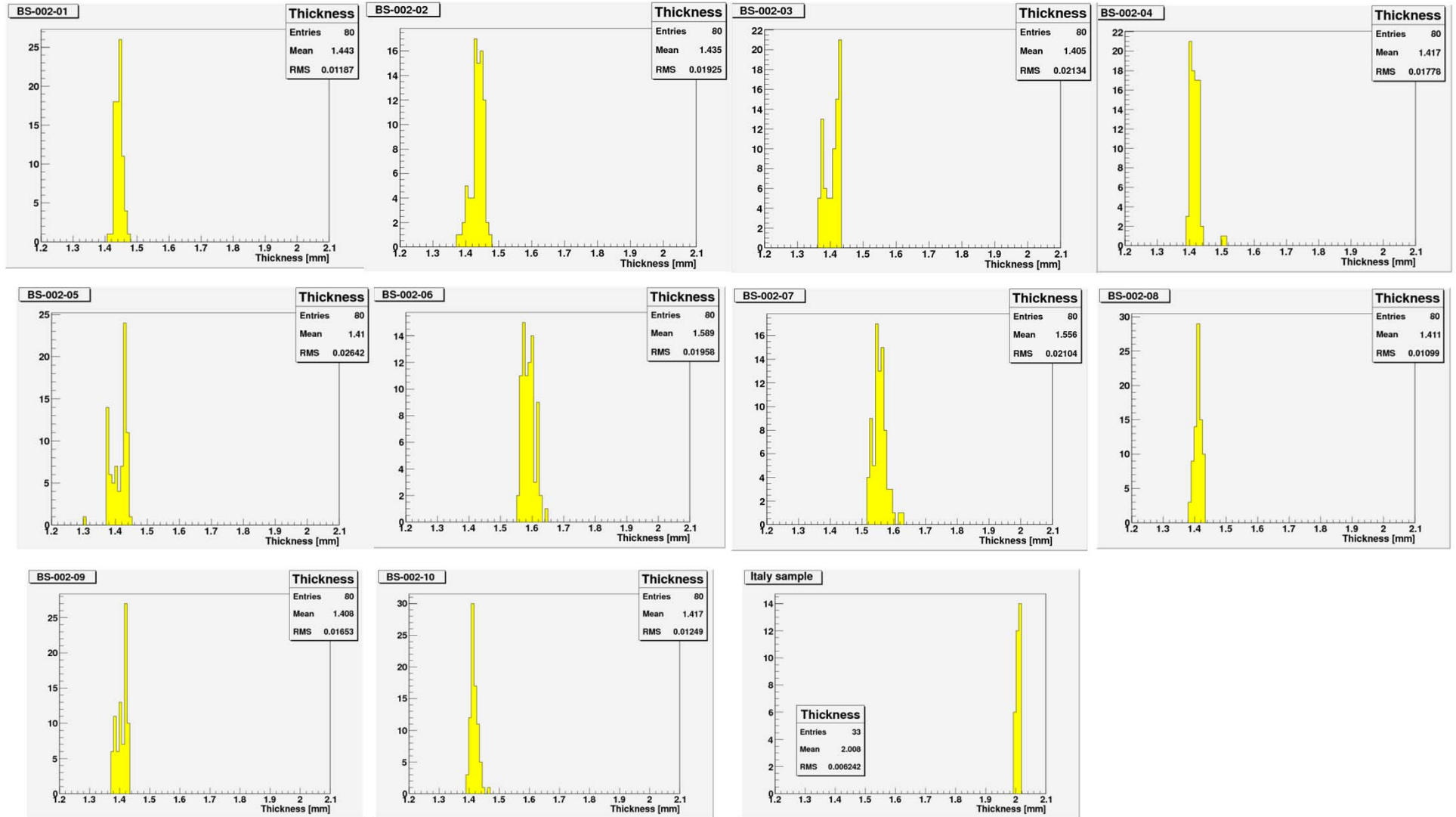




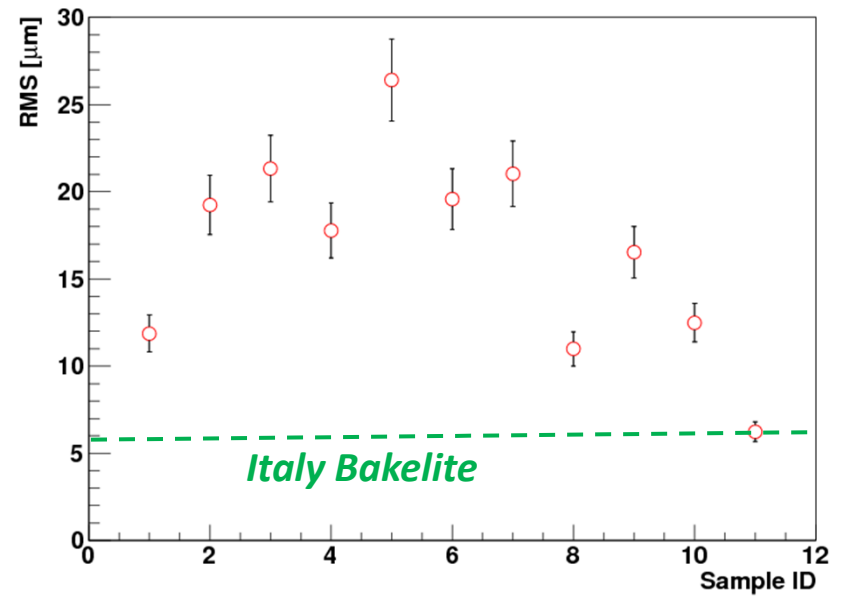
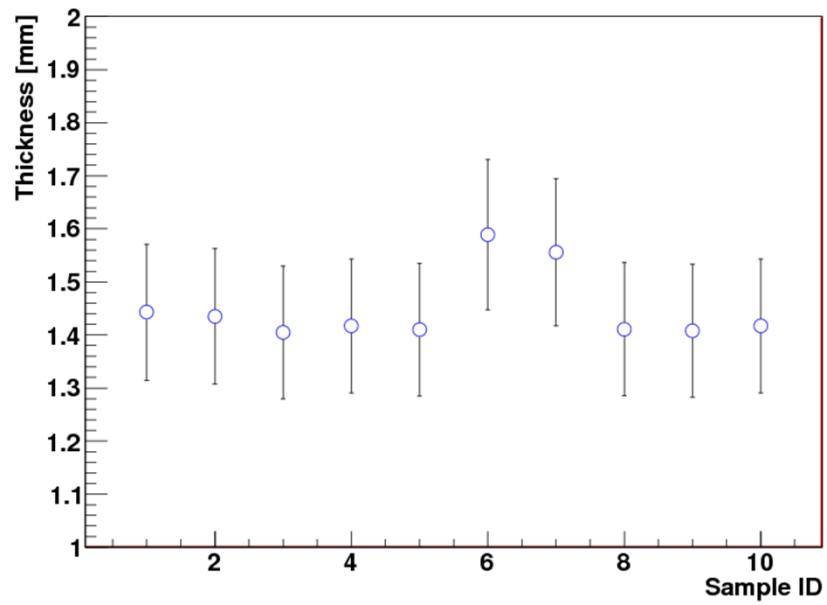
# Surface topography



# Thickness (I)

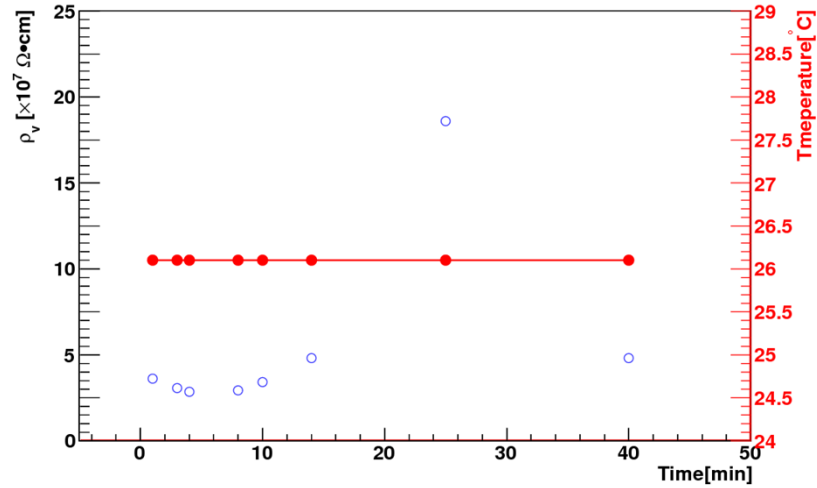


# Thickness (II)

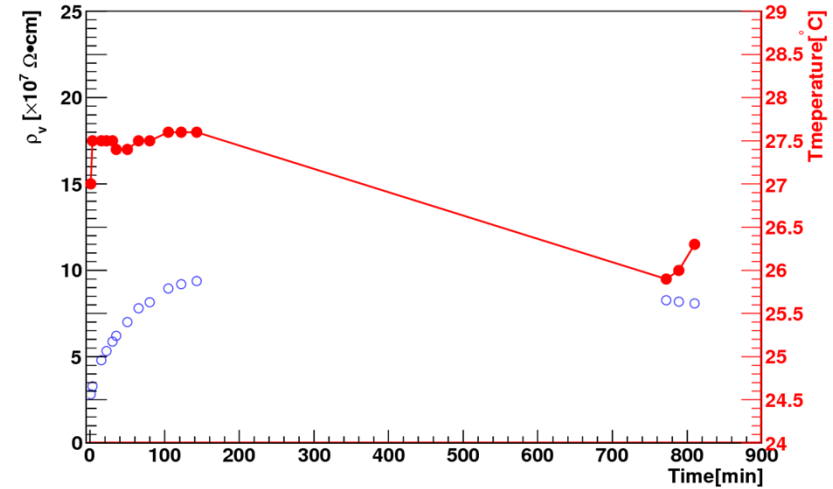


# Bulk Resistivity (I)

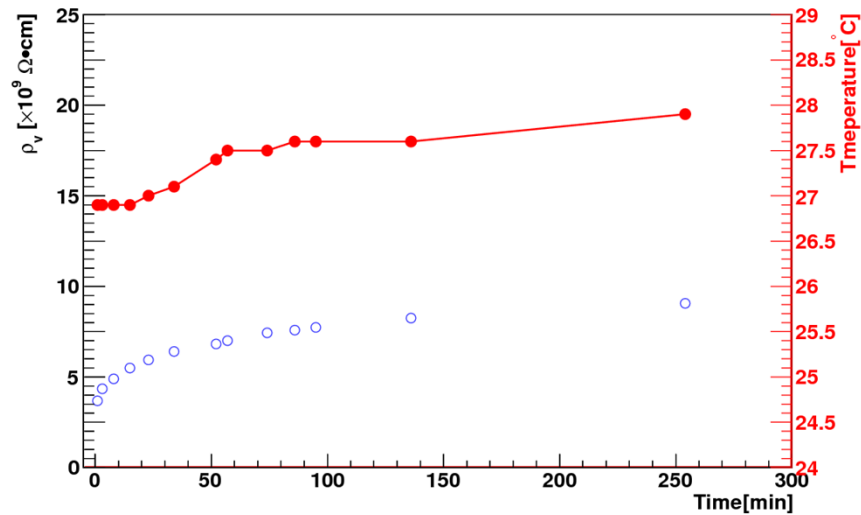
BS-002-01



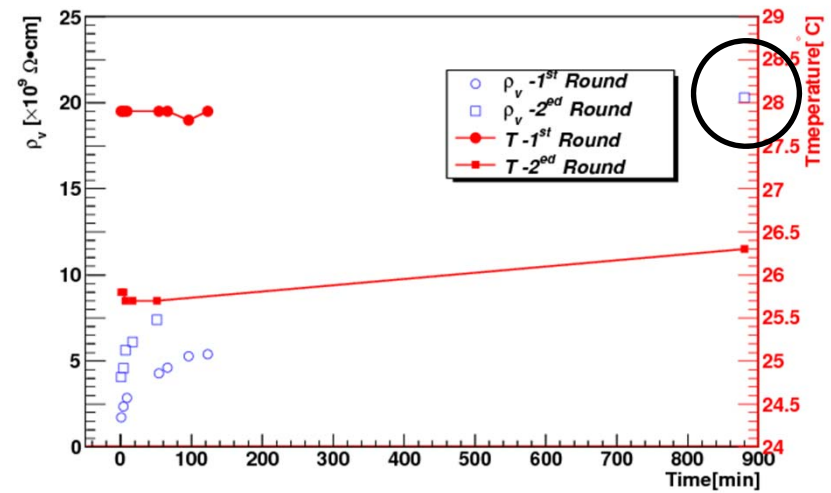
BS-002-02



BS-002-03

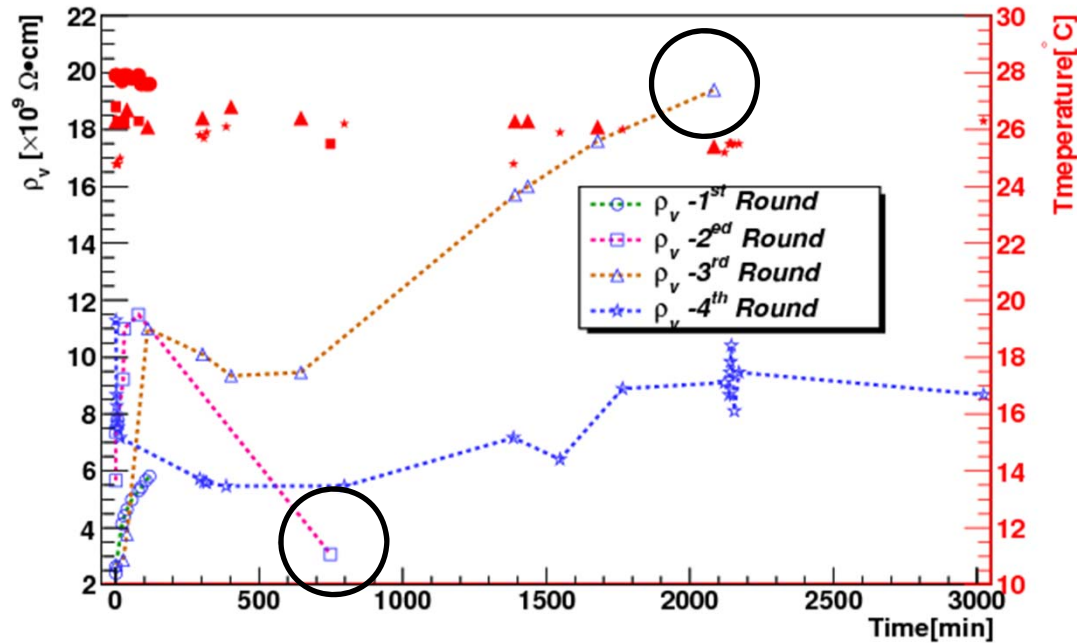


BS-002-04



# Bulk Resistivity (II)

BS-002-05



Cross-check of two kinds of measurement:

- 1, 3,4 Round test : voltage sampling
- 2ed Round test: Pico ampere meter
- Weird point and variation trends present in the original several round tests

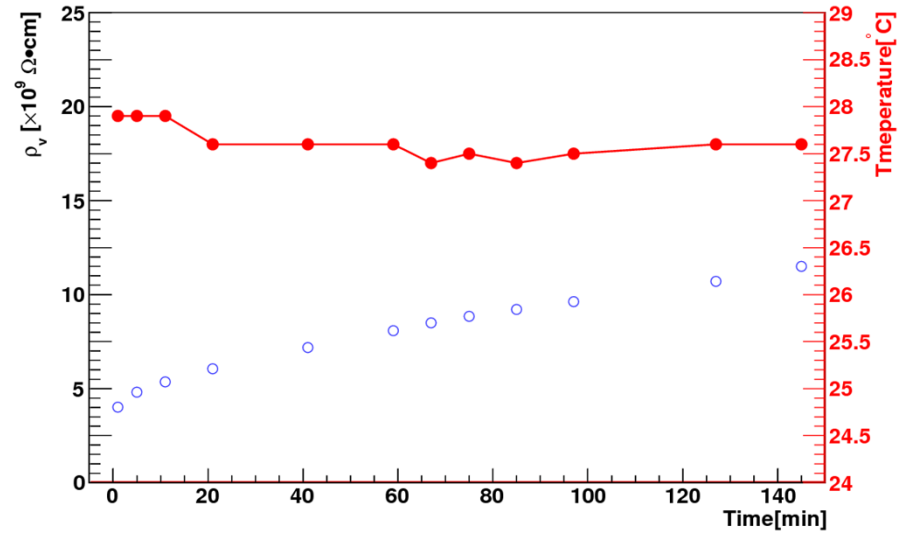


We do not understand why test results are significantly different from round to round for low resistivity sample ( $<10^{10} \Omega \cdot \text{cm}$ ) *need continuous long-term measurements.*

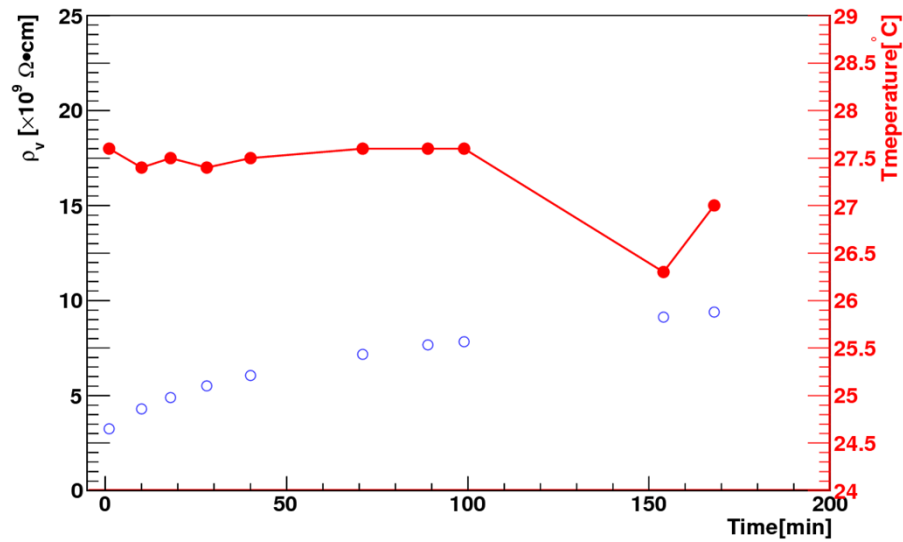


# Bulk Resistivity (III)

BS-002-06

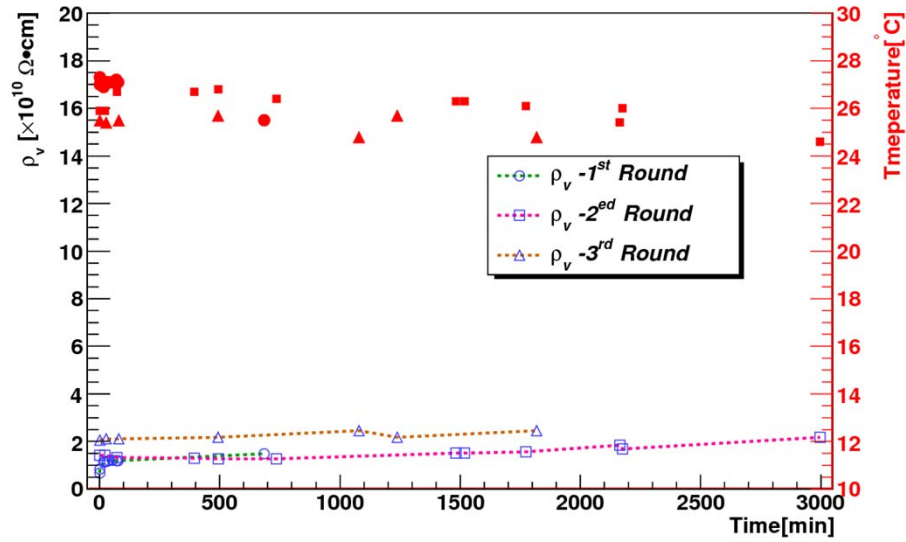


BS-002-07

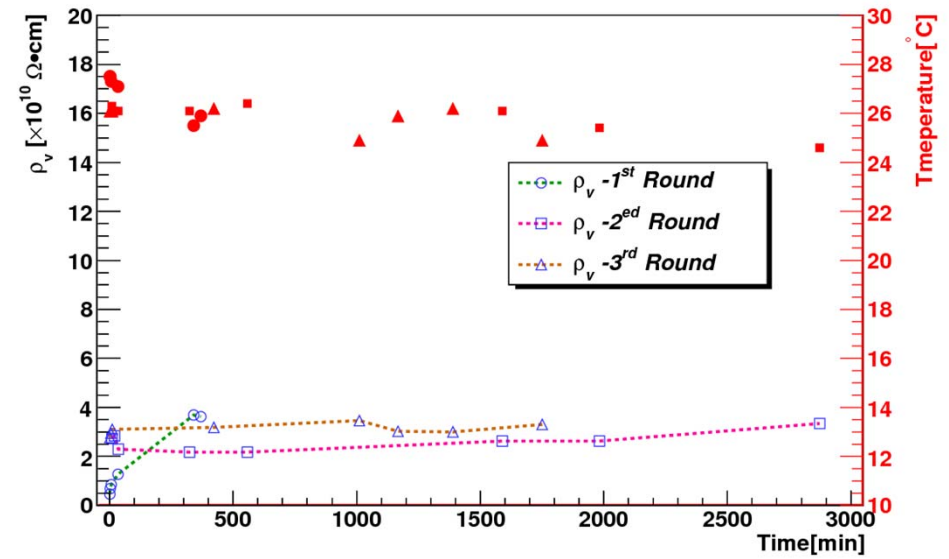


# Bulk Resistivity (IV)

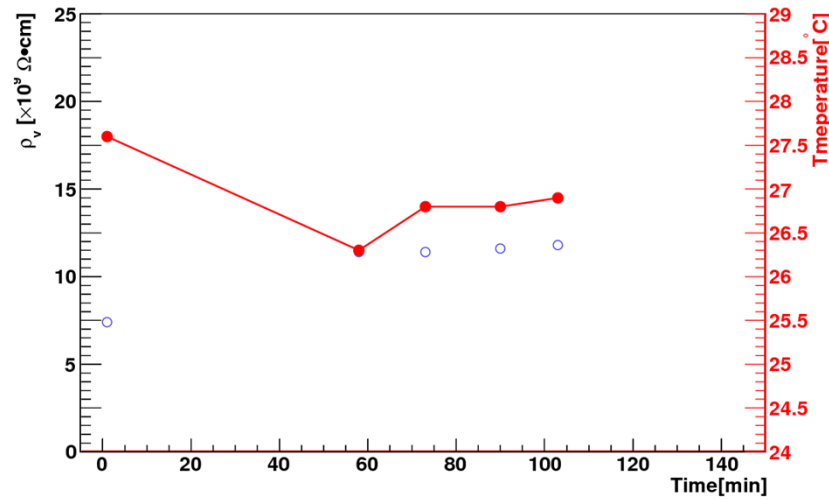
BS-002-08



BS-002-09



BS-002-10

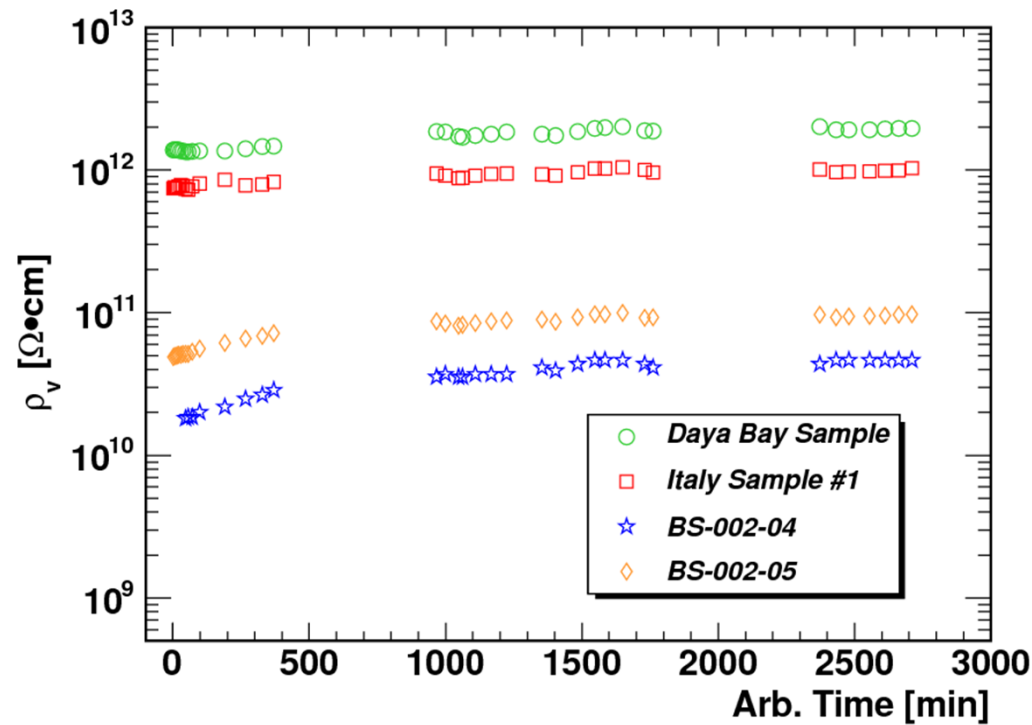


# Bulk Resistivity (V)

## Summary

Sample ID	30C 31%RH	25-26C 31%RH	25-27C 40%RH
	Factory test $\rho[\Omega.cm]$	1 <sup>st</sup> Round test $\rho[\Omega.cm]$	Latest Round test $\rho[\Omega.cm]$
1	$2.42 \times 10^7$	$3.00 \times 10^7$	
2	$3.12 \times 10^7$	$8.67 \times 10^7$	
3	$6.15 \times 10^9$	$8.46 \times 10^9$	
4	$5.84 \times 10^9$	$5.11 \times 10^9$	$2.03 \times 10^{10}$
5	$6.20 \times 10^9$	$5.46 \times 10^9$	$8.68 \times 10^9$
6	$8.12 \times 10^9$	$1.22 \times 10^{10}$	
7	$8.33 \times 10^9$	$9.50 \times 10^9$	
8	$9.47 \times 10^9$	$1.39 \times 10^{10}$	$2.46 \times 10^{10}$
9	$1.55 \times 10^{10}$	$3.47 \times 10^{10}$	$3.31 \times 10^{10}$
10	$1.23 \times 10^{10}$	$1.10 \times 10^{10}$	

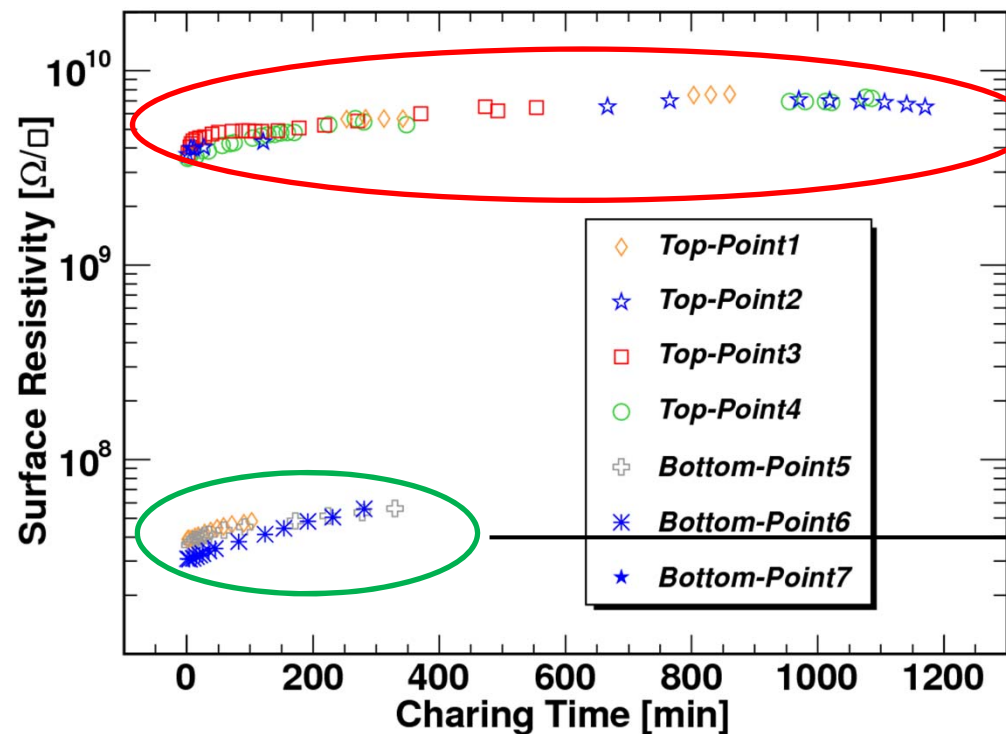
# Bulk Resistivity Recent Comparisons



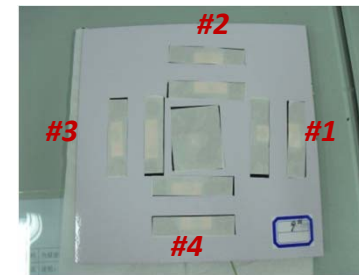
- Both DayaBay sample & Italy sample show good stability after 3 days continuous measurements
- Low resistivity samples increase their bulk resistivity value roughly by an factor of two!

# Surface Resistivity (I)

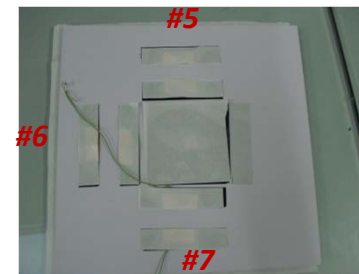
## □ Uniformity study



BS-002-09



Top

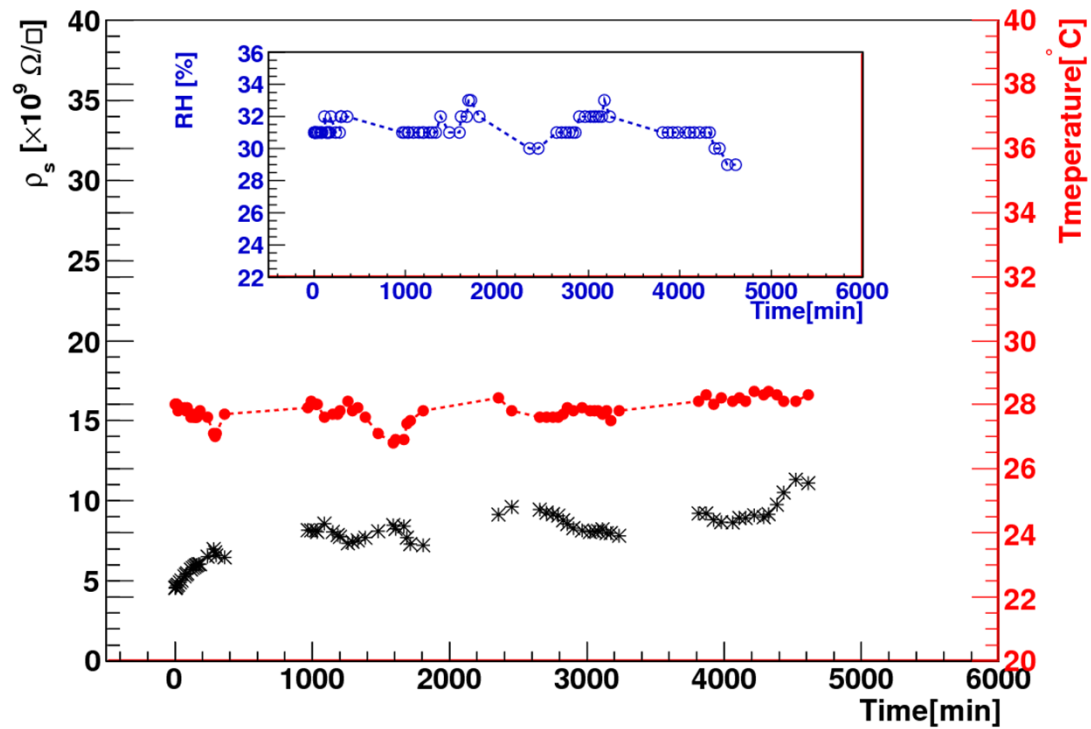


Bottom

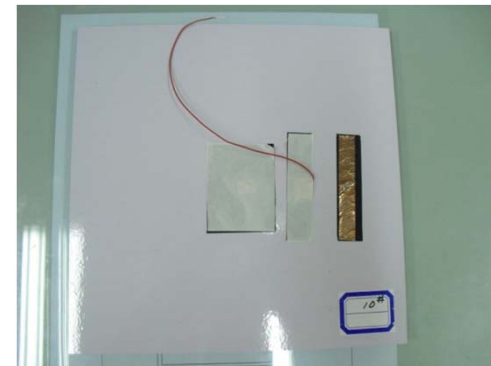
- Surface resistivity( $\rho_s$ ) of the points from the same side are uniform and show similar variation trends with time
- Surprisingly found surface resistivity of #9 on one side are **two order of magnitude larger than the other side!**

# Surface Resistivity (II)

- Long term stability



BS-002-10



## Comments & Summary

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- Total 10 Bakelite samples received @ the beginning of July. Continuous measurements are done within past 3 weeks.
- Surface investigations show the presence of different types of defects on the boards (contamination, nick, hole ). This defects closely relate to the fabrication process.
- It is convenient to simply use sampling method to measure bulk resistivity around  $10^9$  Ohm.cm.
- Bulk resistivity study shows the ones with higher resistivity ( $>10^{10}$  Ohm.cm) are more stable than those low resistivity ones.
- Surprisingly found the surface resistivity on two sides of one typical sample can be different by two orders of magnitude.