Conductivity Measurements for Bipolar Plates and Plate Material

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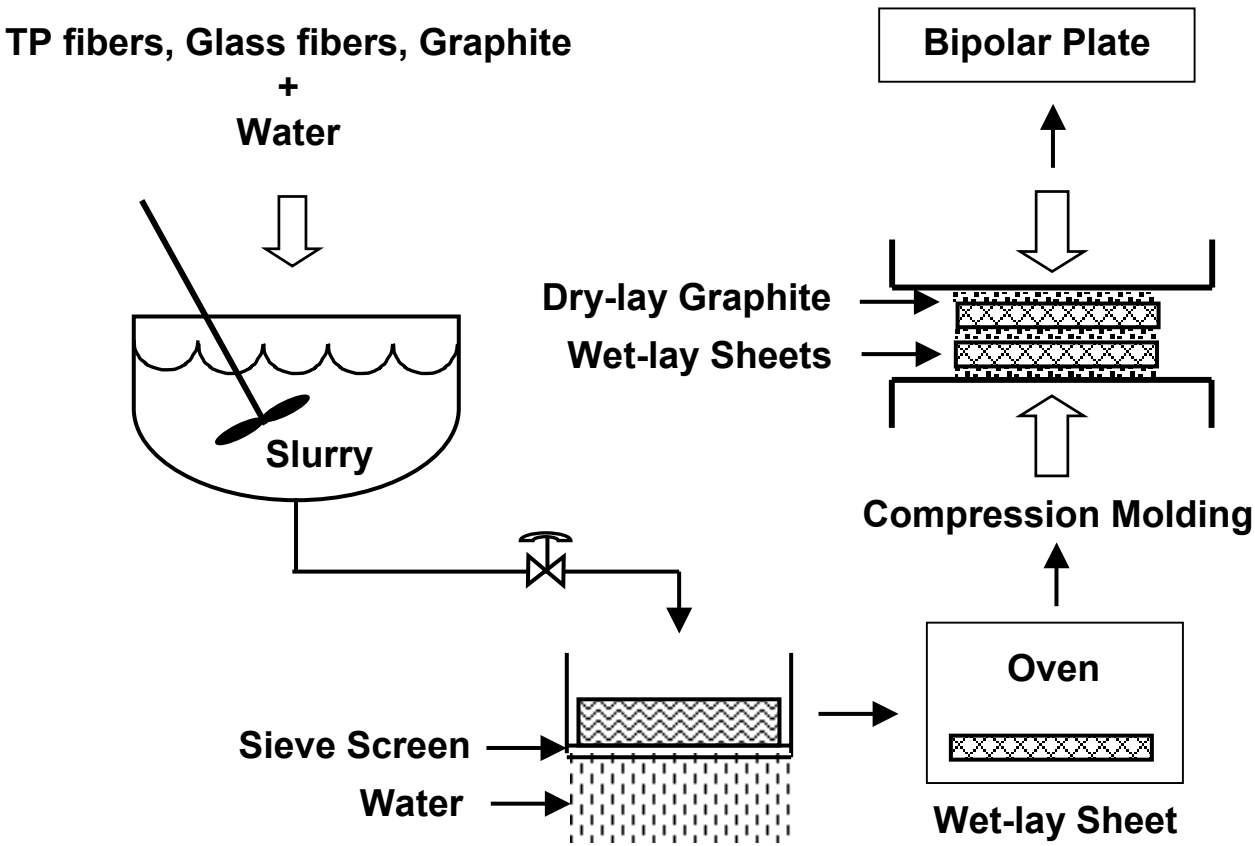
VT Monopolar/Bipolar Plates Research Objectives

- Develop thermoplastic composite materials for producing bipolar plates with high performance and low cost (moldable and conductive).
- Evaluate the properties and study the structure - property relationship of the materials.
- Investigate the compression molding of bipolar plates with mold-in flow channels.
- Evaluate and improve the performance of bipolar plates in fuel cells.

Manufacturing process for wet/dry lay monopolar/bipolar plate

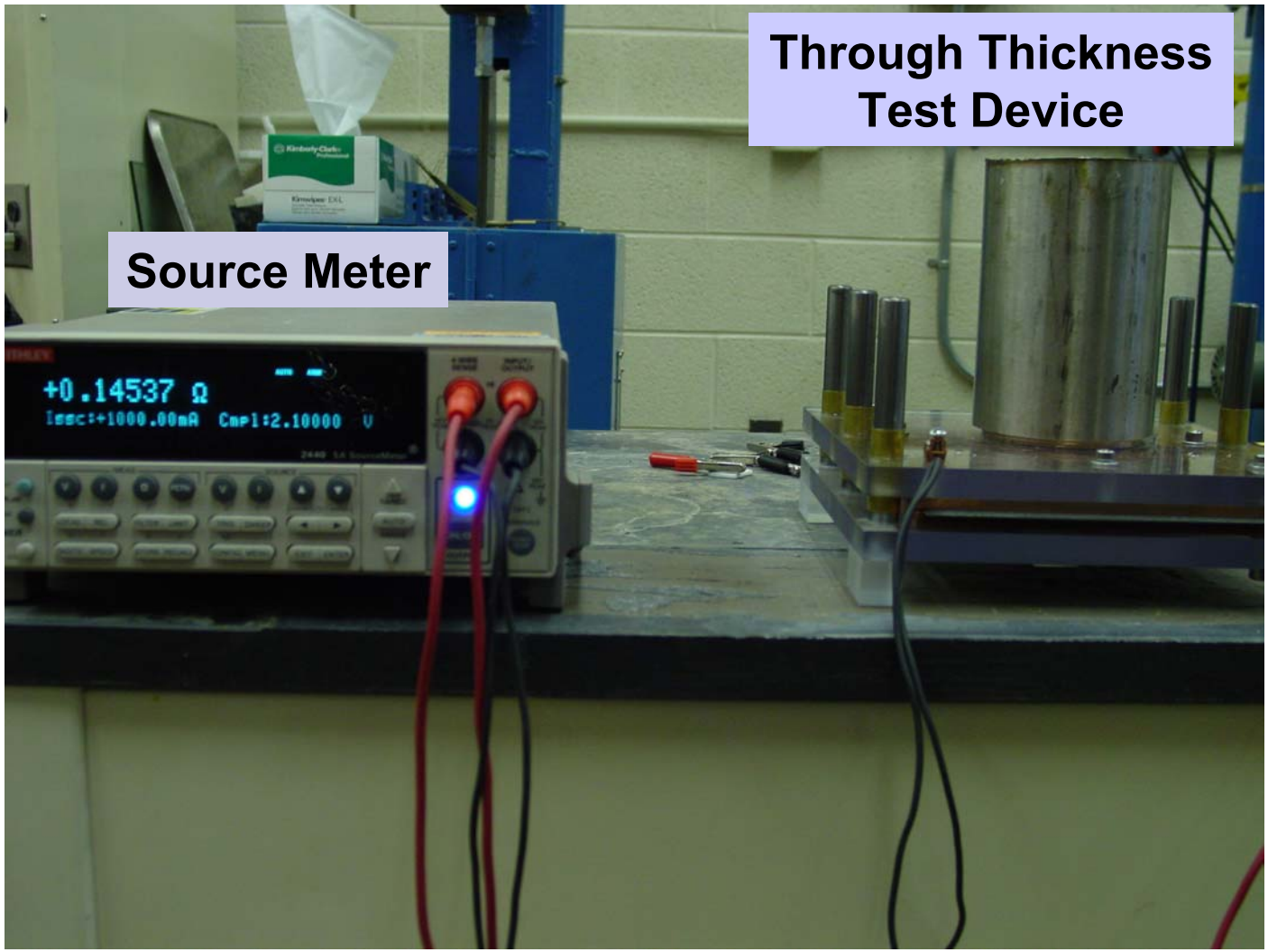


Composite Plates from Industrial Supplier

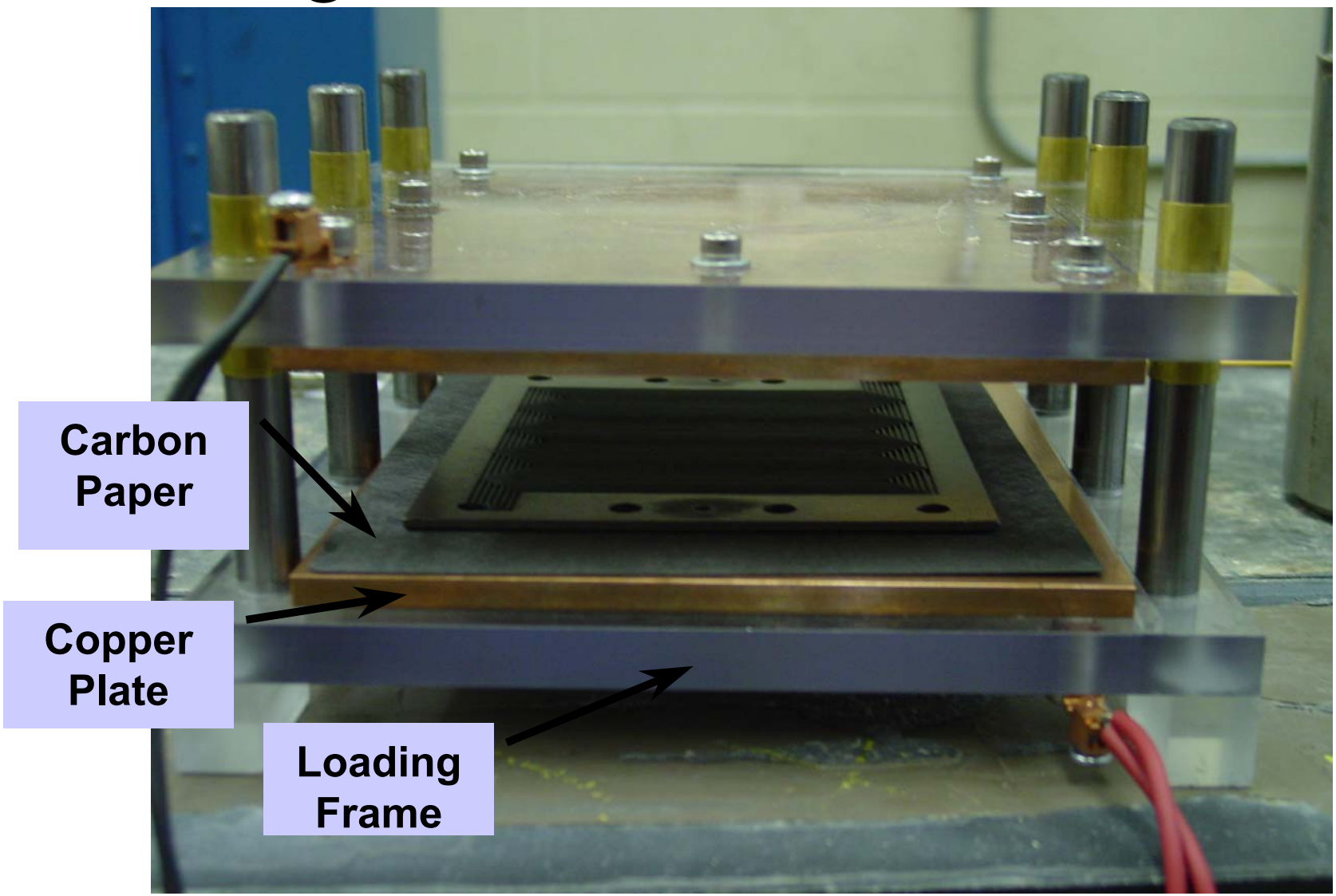
- Two variations
  - 85/15 fabricated using a polymer tool
  - 70/30 fabricated using a metallic tool
- **Conductivity Measurements**
  - **In-plane: ASTM F76**
  - **Through thickness: Rough bulk estimate**
- Mechanical Properties
  - Tensile stiffness, strength, and failure strain

Conductivity

Through Thickness Conductivity



Through Thickness Conductivity



In-Plane Conductivity

Conductivity/ Resistance

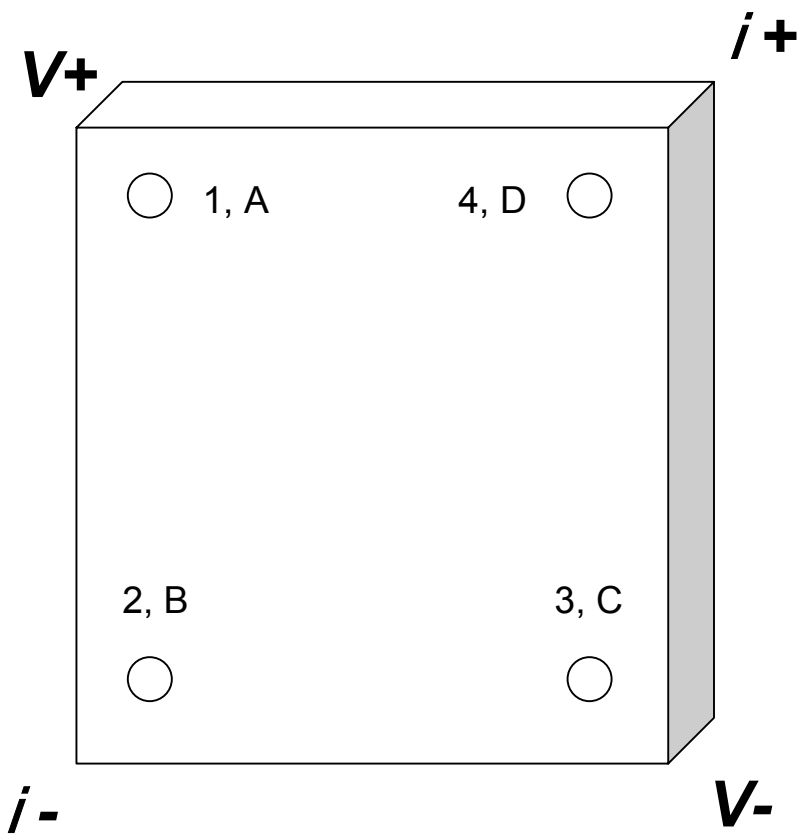
- DC Electrical conductivity – ASTM F76
- In-plane resistance/conductivity measurement (opposite of fuel cell orientation).
- Source Meter with 4 wire configuration

$V = I \times R_{A/B}$

$\rho = 1.333(R_{AC} + R_{CA}) * t$

Where "t" represents the thickness

$\sigma = 1/\rho$



Property Comparison For Composite Bipolar Plates

Company/Patent	Resin	Graphite wt%	Cond. (S/cm)	Strength (MPa)	
				Flexural	Tensile
US 6,248,467 (LANL)	Vinyl Ester	68	60	29.6	23.4
Commercial	Unknown	/	105	20.7	19.3
Premix Inc.	Vinyl Ester	68	85	28.2	24.1
BMC Inc.	Vinyl Ester	69	30	37.9	26.2
Plug Power	Vinyl Ester	68	55	40.0	26.2
Plug Power Target			85	58.6	41.3
US 4,339,322 (GE)	Fluoropolymer	74	109	42.7	/
US 5,942,347 (GTI)	Phenolic	77.5	53	/	/
US 6,171,720 (ORNL)	C/C (Phenolic)	/	200-300	/	/
This Work (VT)	Polyester	65	230	53.0	36.5

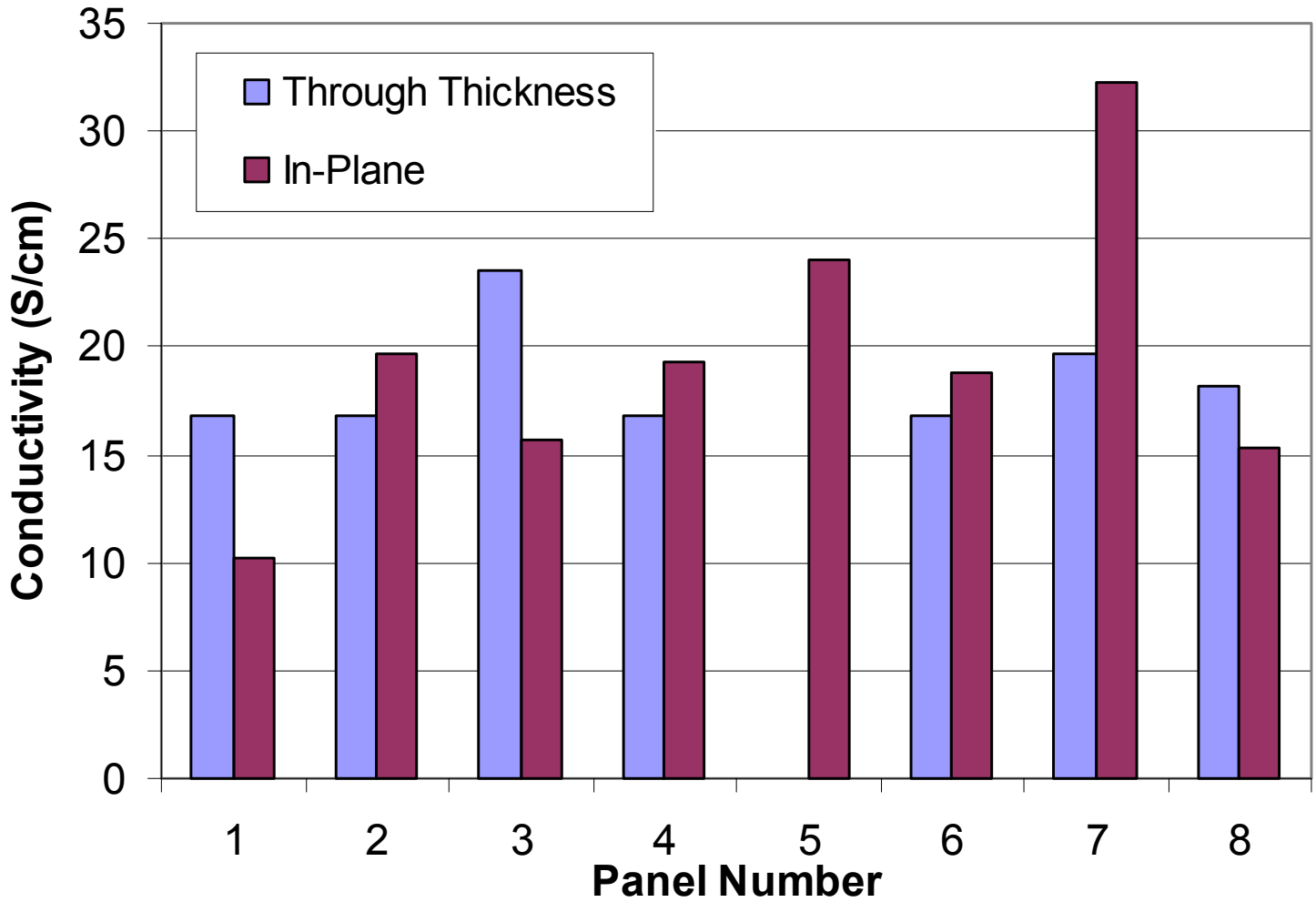
Conductivity Comparison 85/15

85/15 Plate #	Thickness (cm)	Through Thickness Resistance (μΩ)	Through Thickness Conductivity (S/cm)	In-Plane Resistivity (Ω•cm)	In-Plane Conductivity (S/cm)
1	0.2	40	29.76	-	-
2	0.207	45	27.38	-	-
3	0.233	70	30.82	-	-
4	0.445	65	37.84	0.001035	966
5	0.445	65	40.75	0.000951	1052
6	0.445	65	40.75	0.0009385	1066
Average			***34.6***		***1028***
STD			***5.9***		***54***

Conductivity Comparison 70/30

70/30 Plate #	Thickness (cm)	Through Thickness Resistance (μΩ)	Through Thickness Conductivity (S/cm)	In-Plane Resistivity (Ω•cm)	In-Plane Conductivity (S/cm)
1	0.198	60	19.64	-	-
2	0.198	60	19.64	-	-
3	0.198	70	16.84	0.09772	10.2
4	0.198	70	16.84	0.05085	19.7
5	0.198	50	23.57	0.06354	15.7
6	0.198	70	16.84	0.05178	19.3
7	-	-	-	0.0417	24.0
8	0.198	70	16.84	0.05301	18.9
9	0.198	60	19.64	0.03103	32.2
10	0.198	65	18.13	0.06508	15.4
Average			***18.4***		***19.4***
STD			***2.5***		***6.5***

Conductivity Measurement Comparison: 70/30

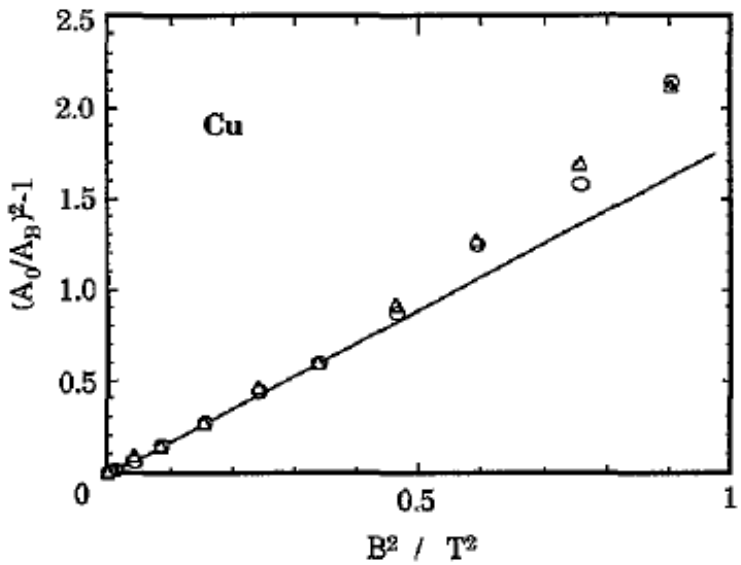


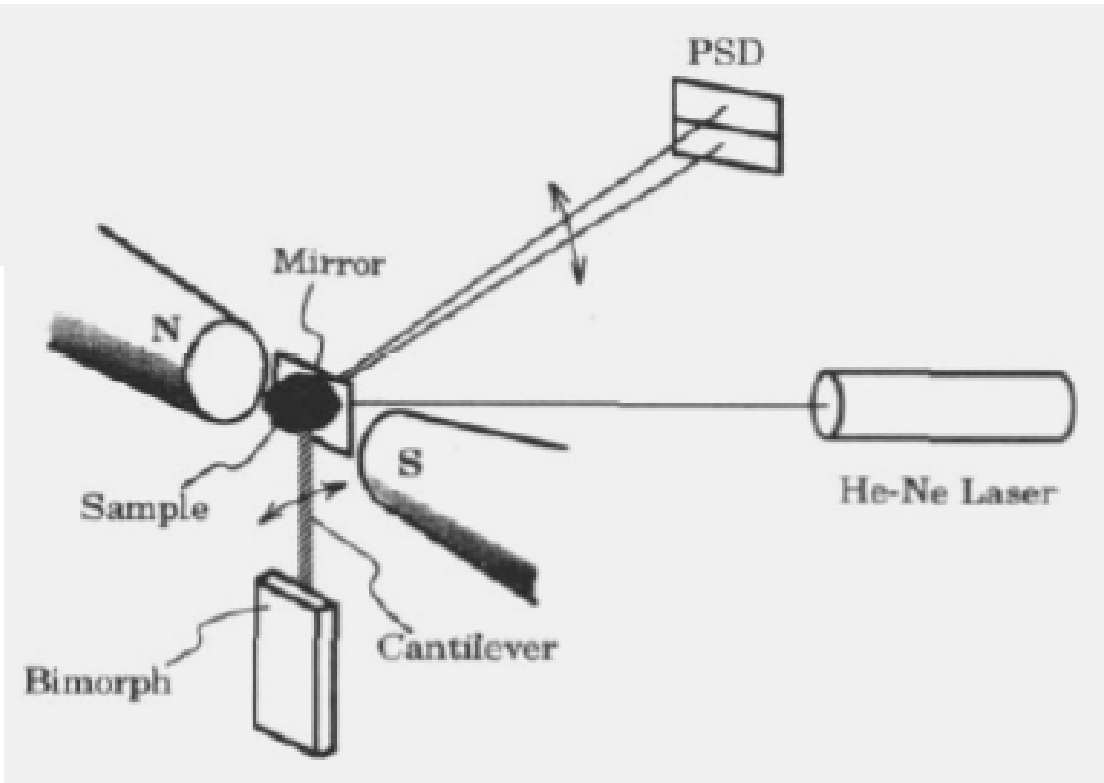
Conductivity Measurements

- In-plane vs. Through thickness
- Contact resistance complicates measurement: Question results
- Industrial Plates
  - Question about through thickness comparison as no published standard exists
  - In-plane conductivity appears to be a percolation limit between 70/30 and 85/15
- Evaluating a noncontact method

Noncontact Conductivity Measurement Technique

$$\left(\frac{A_0}{A_B}\right)^2 - 1 = \left(\frac{\sigma V \tau/(2m)}{1+\pi/Q}\right) B^2.$$





Lsonot and Kotan, ***Meas. Sci. Technol***., ***6*** (1995) 1429-1432.

Ongoing Efforts

- Validating non-contact measurement of conductivity with comparison to know values
- Improving signal-to-noise ratio for conductivity measurements
- Relating to processing conditions (and to resulting fuel cell performance)