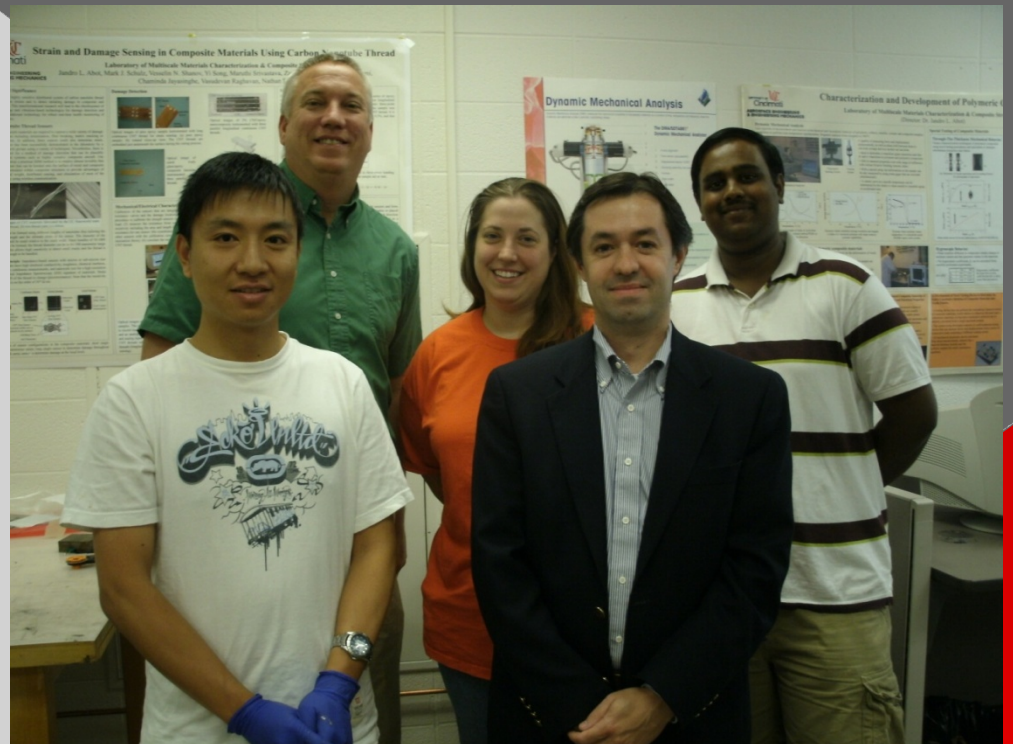


# Project #3 Nanostructured Composite Materials

## Strain Monitoring in Composite Materials Using Carbon Nanotube Thread

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GA's: Yi Song,  
Sandeep Medikonda  
RA: Nathan Rooy  
Teachers:  
Michael Day  
Sarah Woodward



# Objective and Scope

Evaluate the ability of carbon nanotube threads to monitor the state of strain in composite material.

# CNT Thread Characterization

- Length (L)
- Diameter (d) to find Area (A)

$$A = \frac{\pi d^2}{4}$$

- Resistance (R)
- Resistivity ( $\rho$ )

$$\rho = \frac{R * A}{L}$$



# Carbon Nanotubes Up Close...

The  
Good...

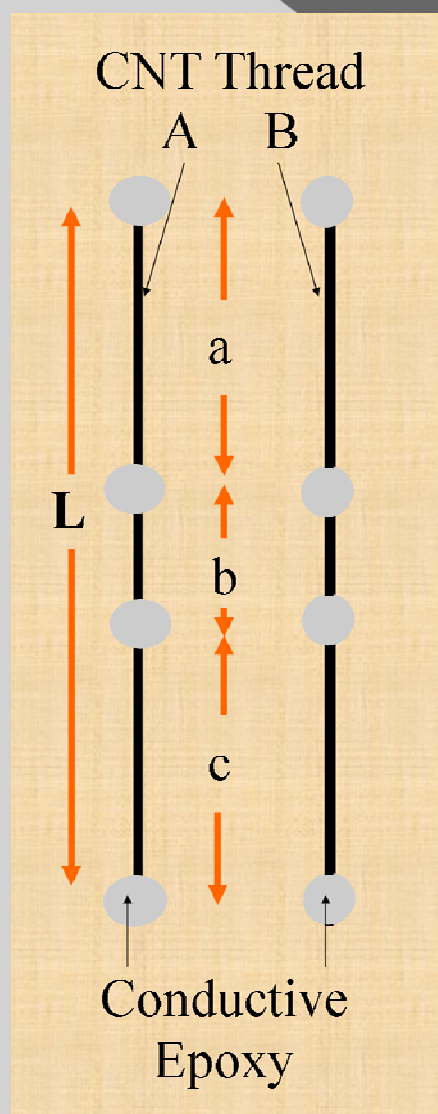
The  
Bad...

And  
The  
Ugly...





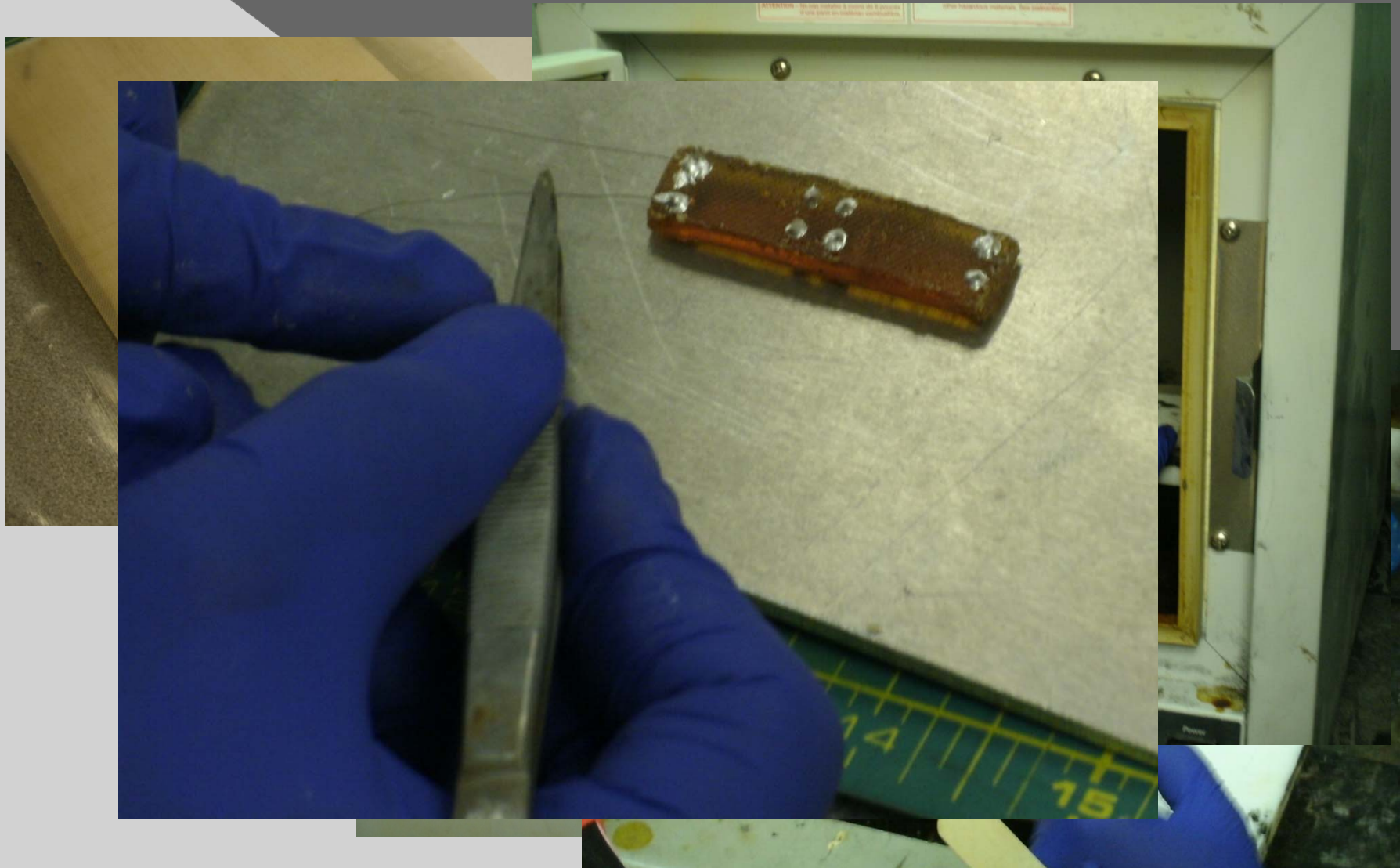
# CNT Thread Characterization



## Sample II Data

	Length	Resistance Before Casting Sample	Resistance After Casting Sample
Units:	mm	ohms	ohms
II.A.L	35.69	2130	2490
II.A.a	17.51	1540	1280
II.A.b	5.14	320	330
II.A.c	12.31	830	960
II.B.L	34.08	2100	2600
II.B.a	17.04	1140	1320
II.B.b	4.79	260	350
II.B.c	11.36	830	940

# Fabrication of Self-Sensing Composites



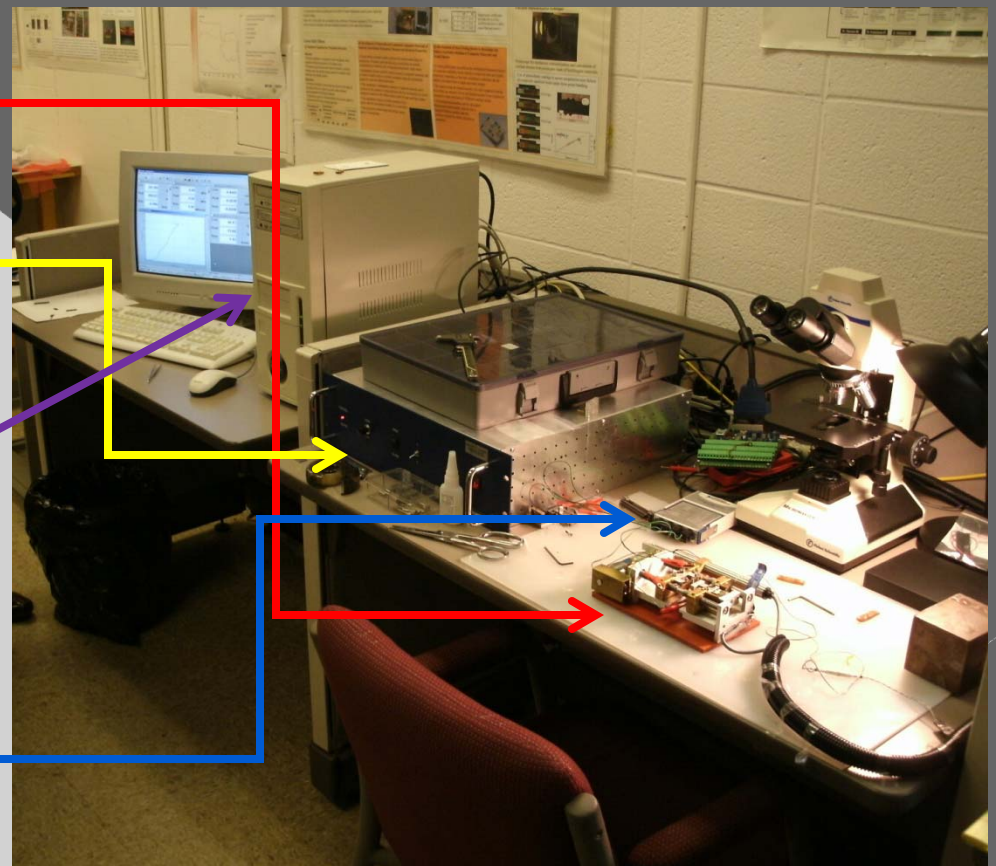
# Mechanical and Electrical Characterization of Self- Sensing Composites

Mechanical

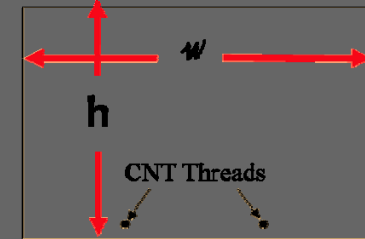
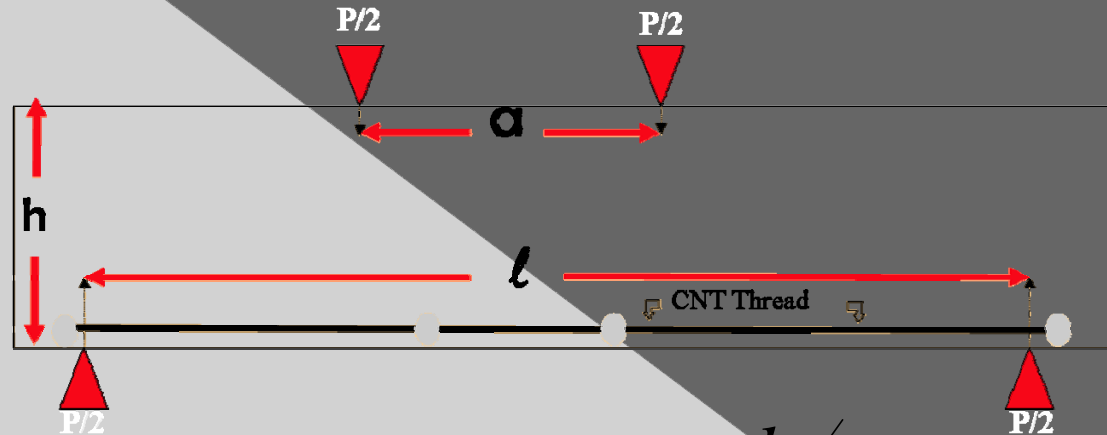
- ④ 4-point Bending
- ④ Displacement Control
- ④ Acquire Load (P)

Electrical

- ④ Acquire Resistance (R)



# Data Analysis: Calculation of Strain



$$\epsilon_{\max} = \frac{P * (l - a) * h / 2}{(4 * E * I)}$$

Euler-Bernoulli  
beam theory

P: Load (acquired from experiment)

I: Moment of Inertia

$$I = \frac{w * h^3}{12}$$

E: Elastic Modulus

$$E = 3.2 \text{ GPa}$$



# Data Collection and Analysis

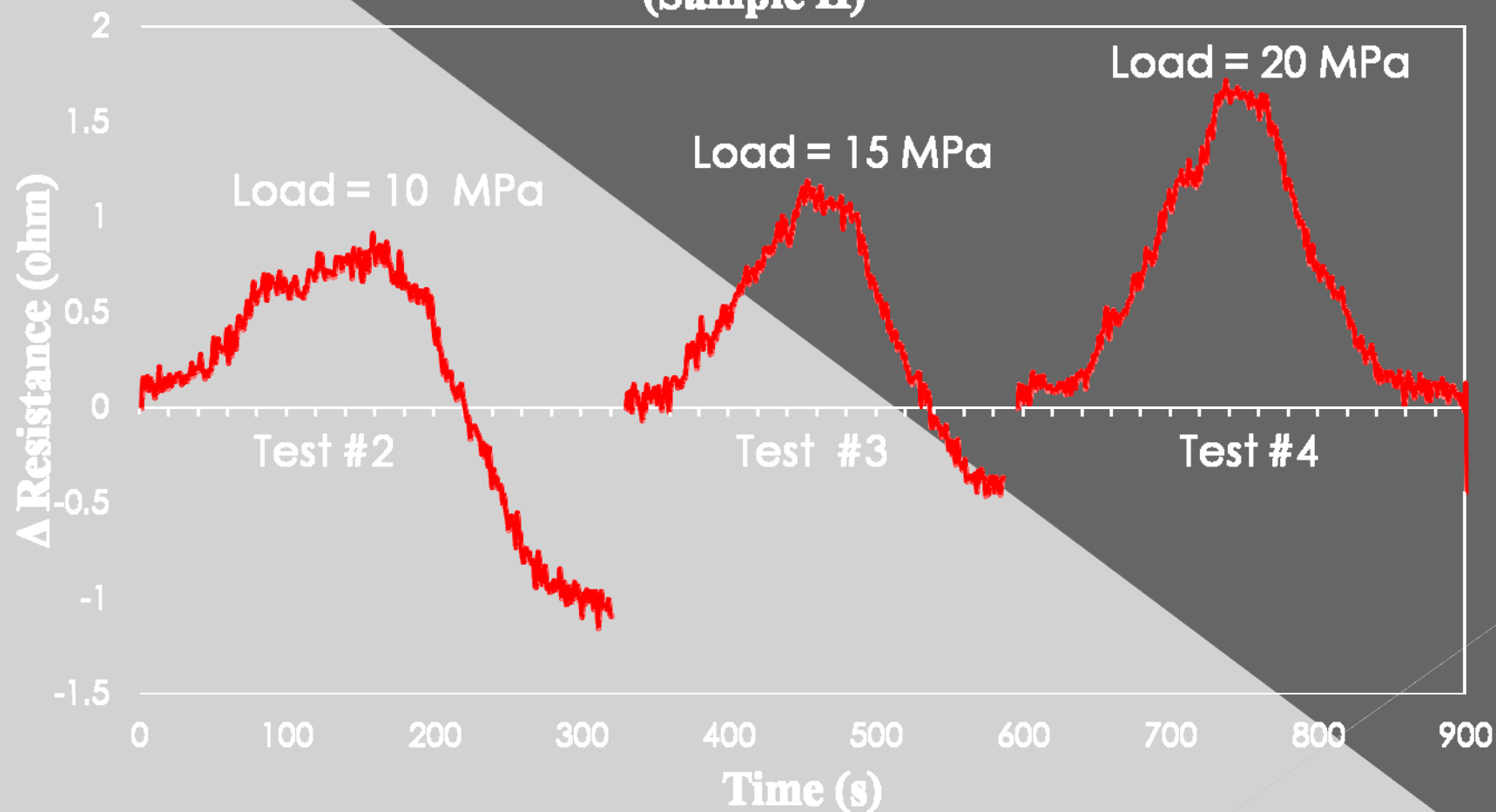
Load (N)	Time (s)	R <sub>A</sub> (ohm)	R <sub>B</sub> (ohm)	$\Delta R_A$ (ohm)	$\Delta R_B$ (ohm)	Strain	Smooth Strain	Smooth R <sub>B</sub> (ohm)
204.744	139	2009.875	2128.646	15.78641	39.19253	0.006059	0.007061	2131.304
200.931	140	2009.377	2128.049	15.28886	38.5961	0.005946	0.006961	2131.038
197.103	141	2008.712	2127.492	14.62358	38.03909	0.005832	0.006859	2130.739
192.547	142	2008.153	2126.763	14.0647	37.30935	0.005698	0.006757	2130.415
187.293	143	2007.414	2126.268	13.3262	36.81493	0.005542	0.006651	2130.05
182.241	144	2006.654	2125.597	12.56579	36.14339	0.005393	0.00654	2129.671
177.715	145	2005.953	2124.606	11.86484	35.15268	0.005259	0.006425	2129.264
173.066	146	2005.3	2123.649	11.21146	34.19575	0.005121	0.006309	2128.798
167.858	147	2004.768	2123.091	10.68011	33.6375	0.004967	0.00619	2128.283
162.078	148	2004.222	2122.221	10.13374	32.76757	0.004796	0.006068	2127.764
157.072	149	2003.61	2121.641	9.521664	32.18803	0.004648	0.00594	2127.21
152.686	150	2002.89	2120.694	8.801938	31.2405	0.004518	0.005811	2126.653

...

Data from Sample XI, Test 4, fabricated on 7-23-09.

# Data Analysis

## $\Delta$ Resistance History vs. Time (Sample II)

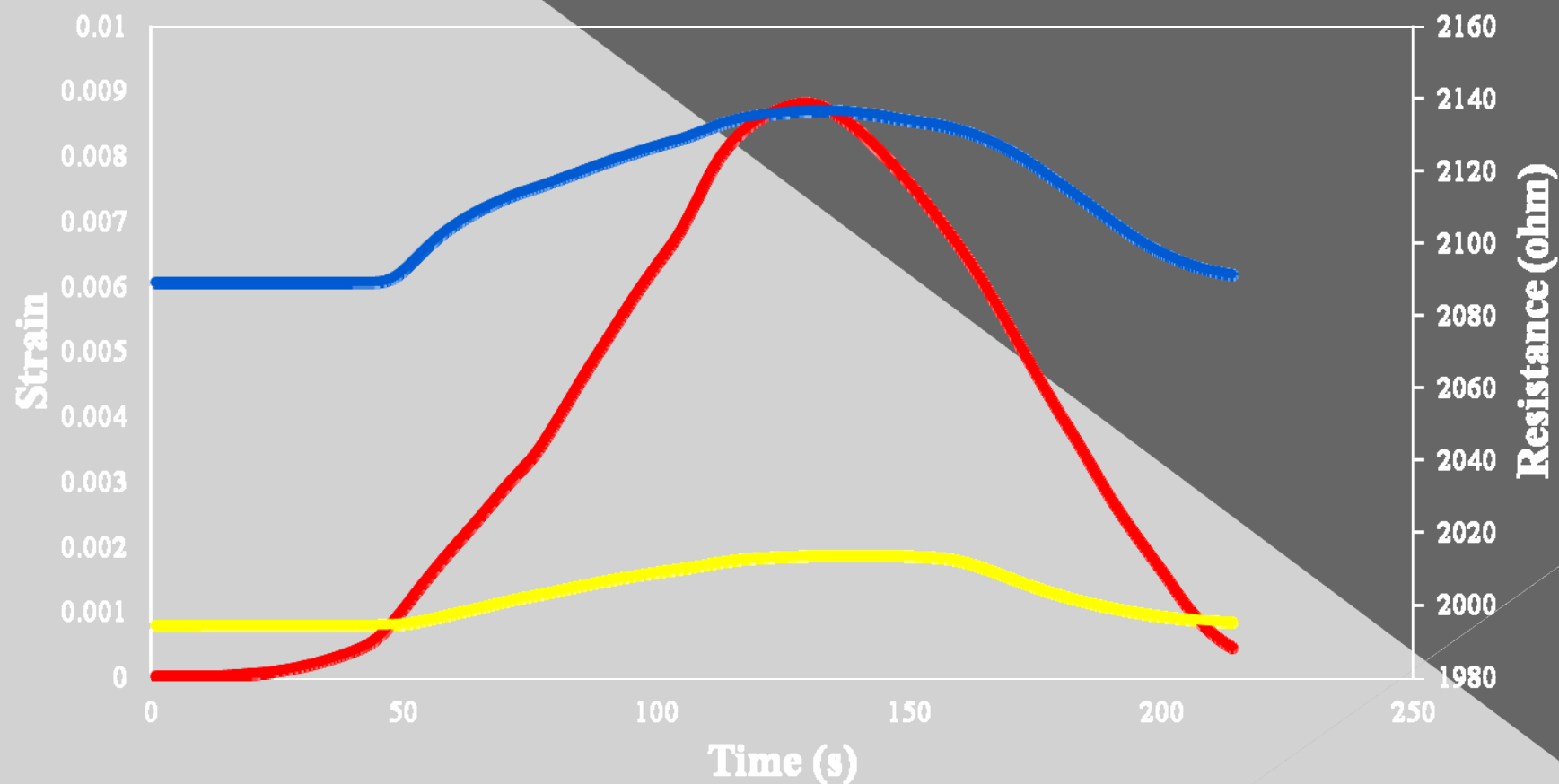


# Data Analysis

## Resistance, Strain vs. Time

(Sample XI, Test 5, Thread A, B)

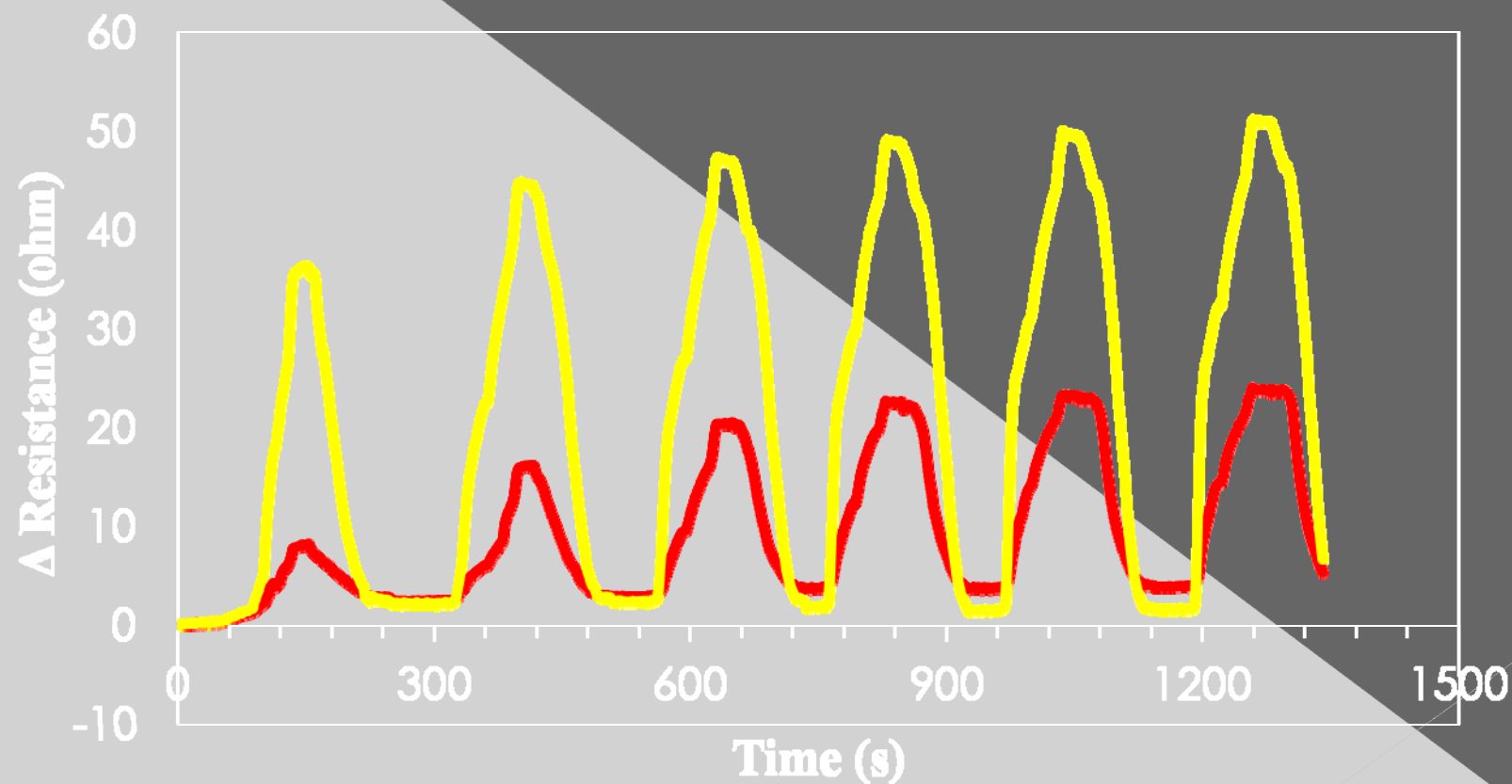
— Strain — Thread B — Thread A



# Data Analysis

## History of $\Delta$ Resistance vs Time (Sample XI)

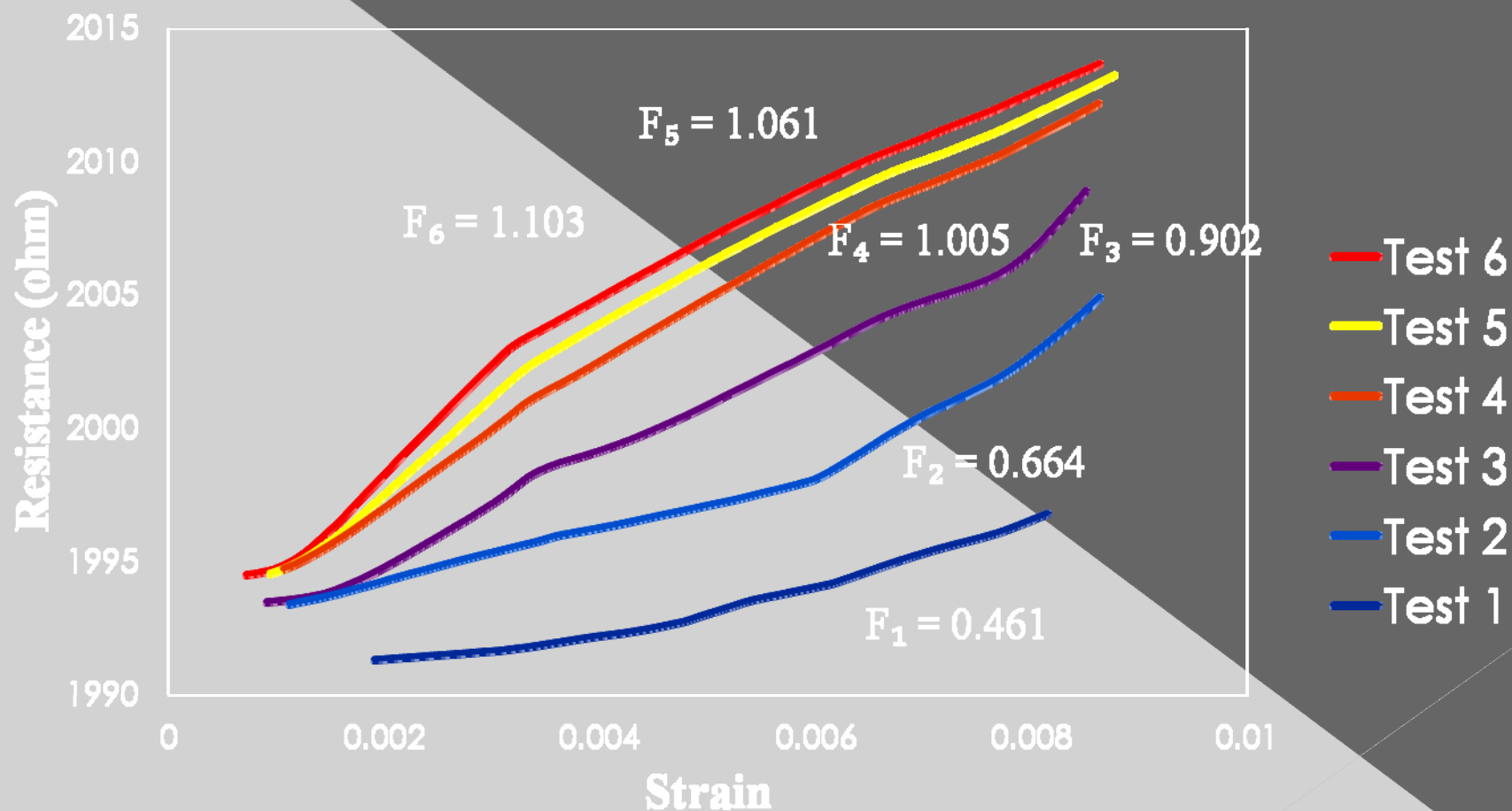
—  $\Delta$  Res B From Start    —  $\Delta$  Res A From Start





# Data Analysis

## Gage Factor (Sample XI)





# Acknowledgements

Thanks to the Department of  
Aerospace Engineering and Mechanics  
Engineering

Research PI: Jandro Abot, PhD;  
Yi Song, Graduate Assistant;  
Sandeep Medikonda Graduate Assistant