Precise High Temperature Dielectric Measurement System

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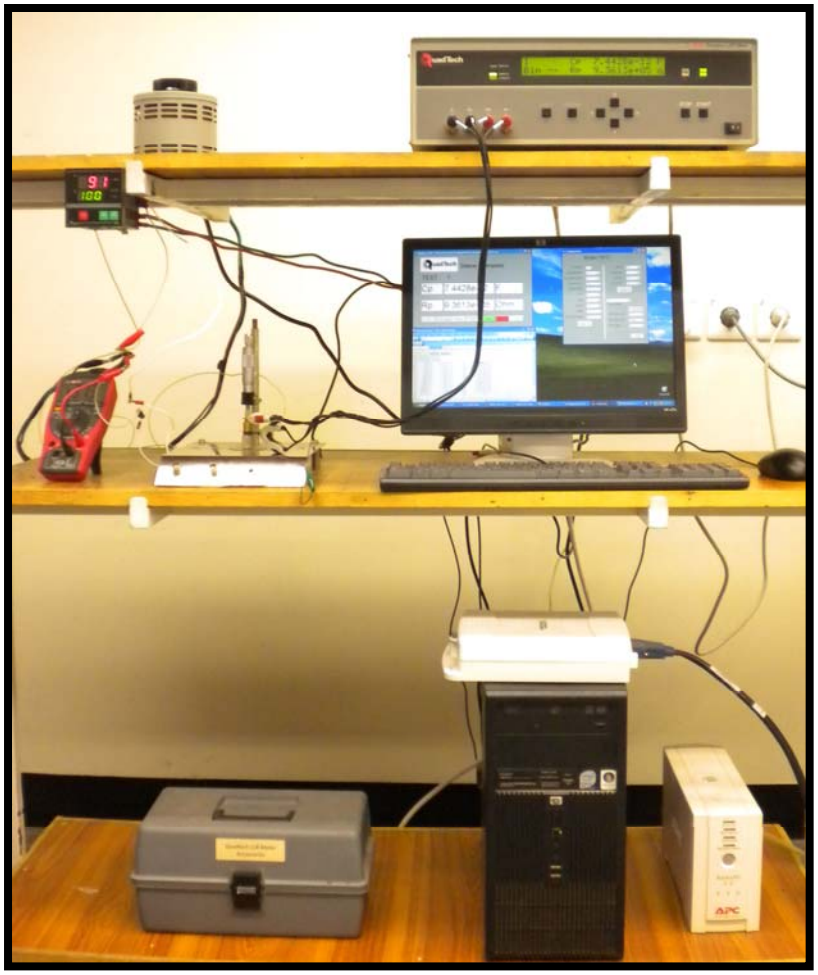
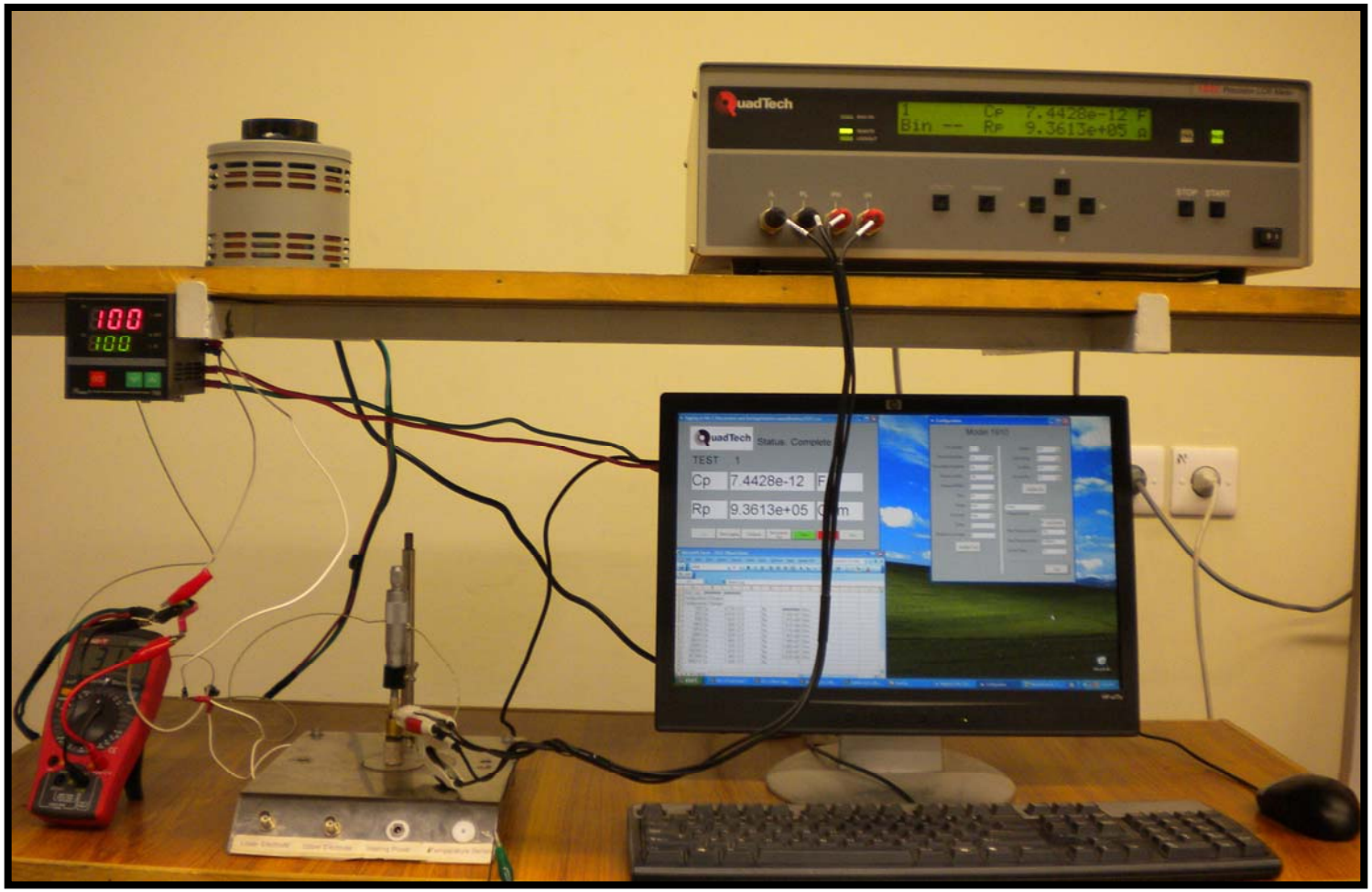
Layout

- Mechanical details of Dielectric Cell
- Design and Ratings of Dielectric Cell heater
- Setting up Temperature Controller
- Interfacing LCR meter with Computer
- Measurement of Dielectric Properties

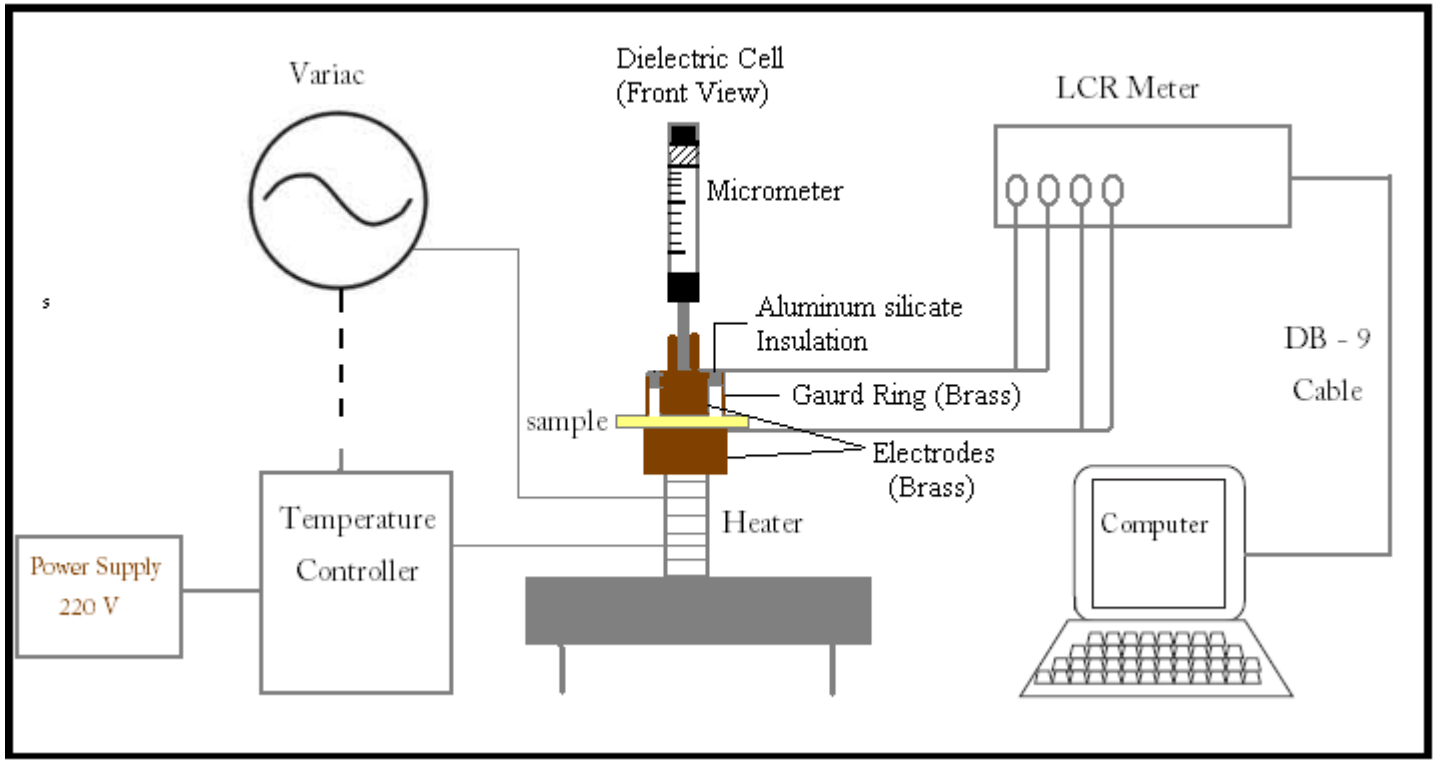
Dielectric Setup in Physlab



Dielectric Setup in Physlab (Cont…)

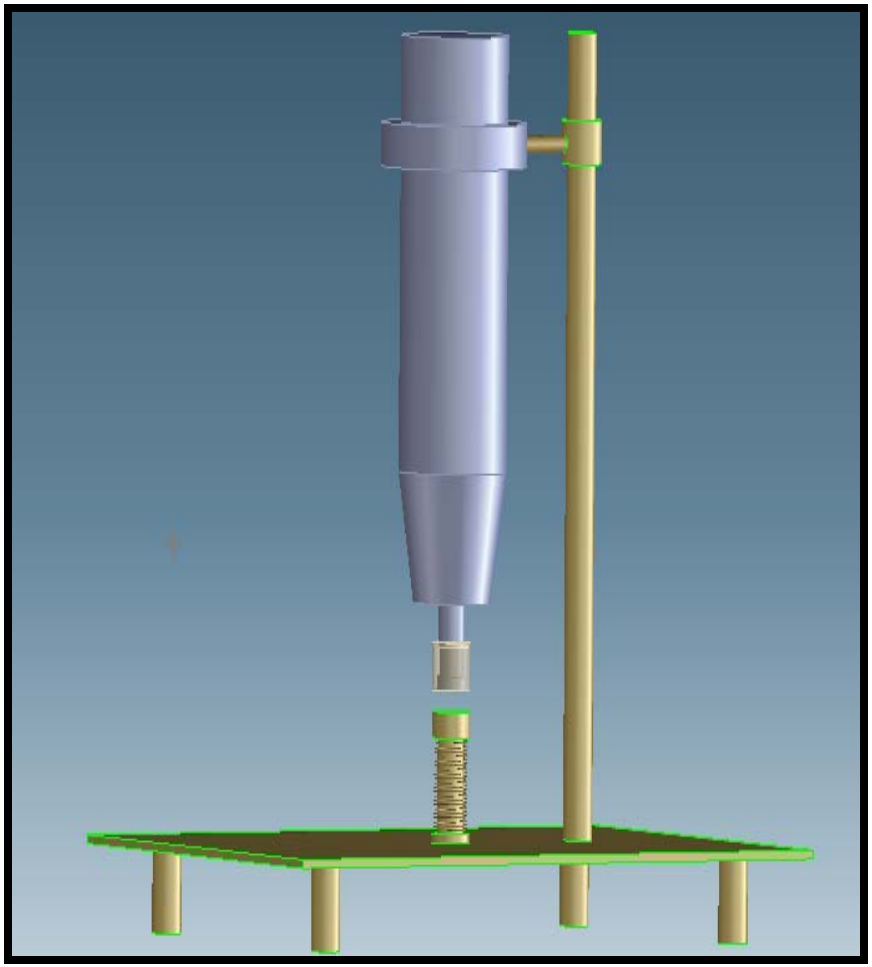


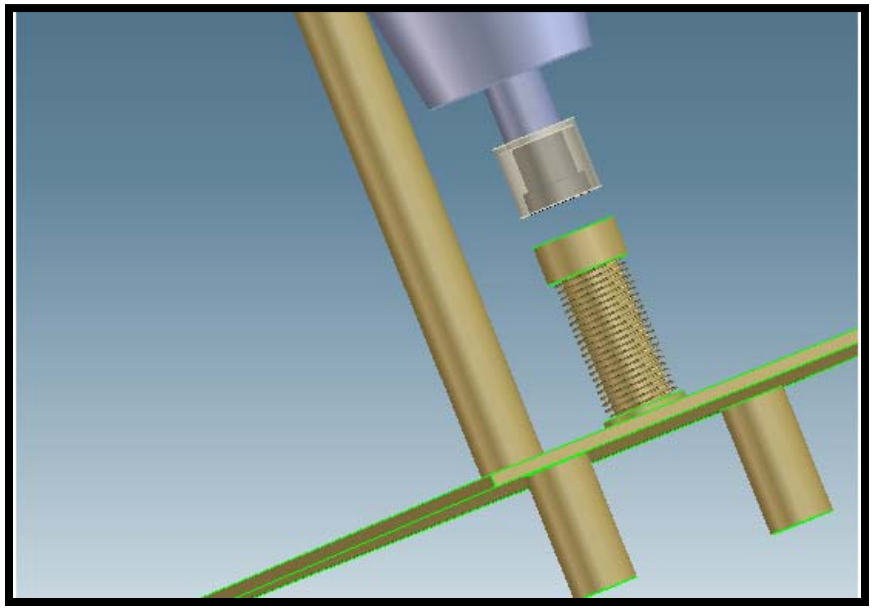
Schematic of Experimental Setup for Dielectric Measurements



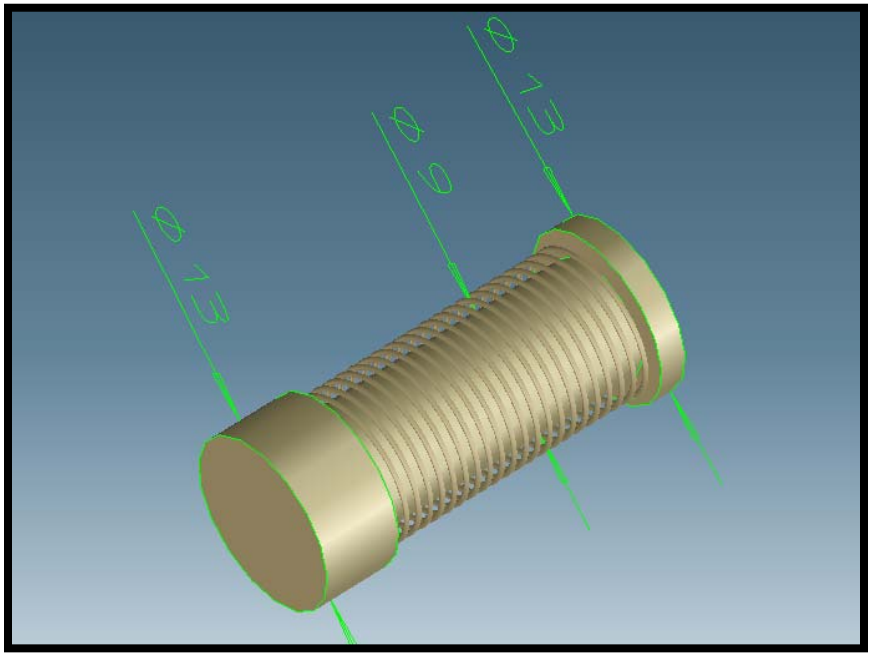
Note: Temperature dependant Dielectric Measurements can be taken only up to 300 degree C through this experimental arrangement . For much higher temperature (up to almost 800 degree C) we are manufacturing another arrangement.

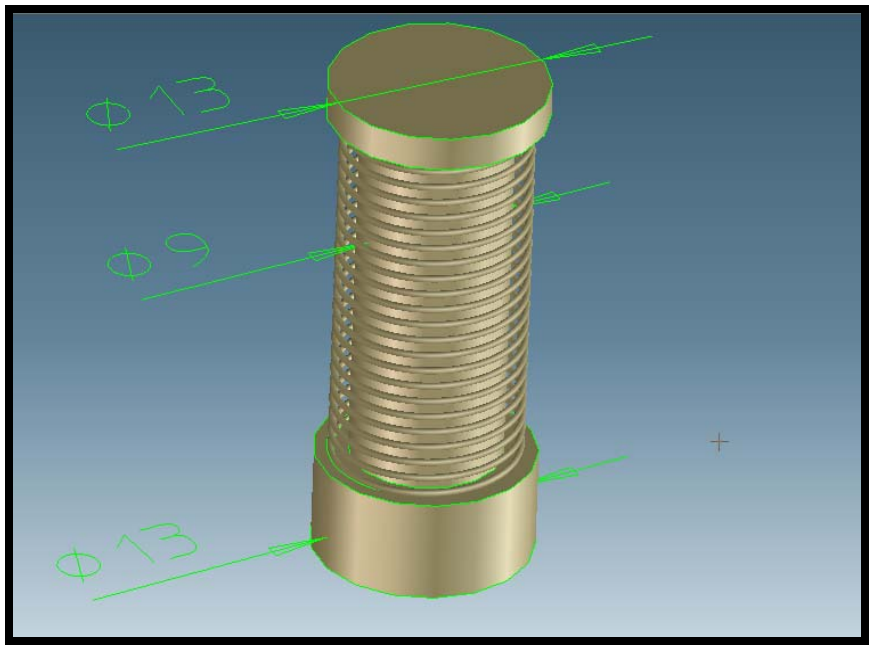
CAD 3D Model of Dielectric Cell Final Design



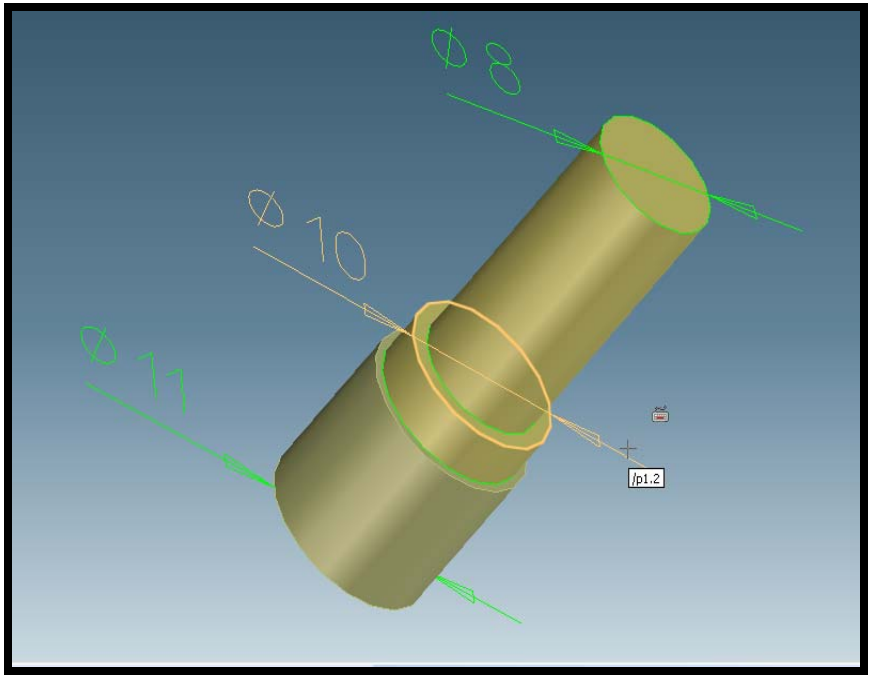


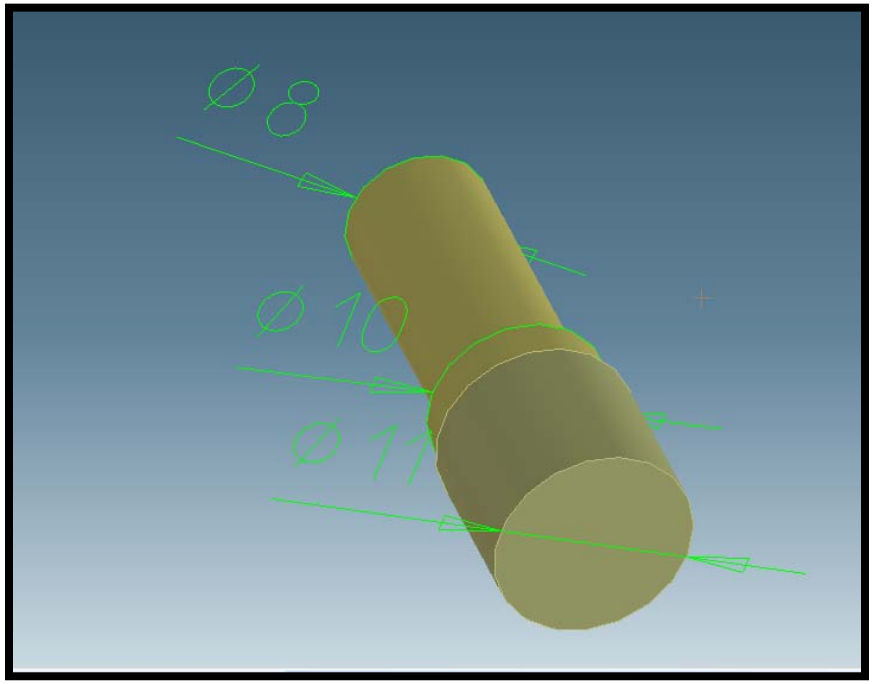
CAD 3D Model of Dielectric Cell (Cont…)
Final Design
Lower Electrode



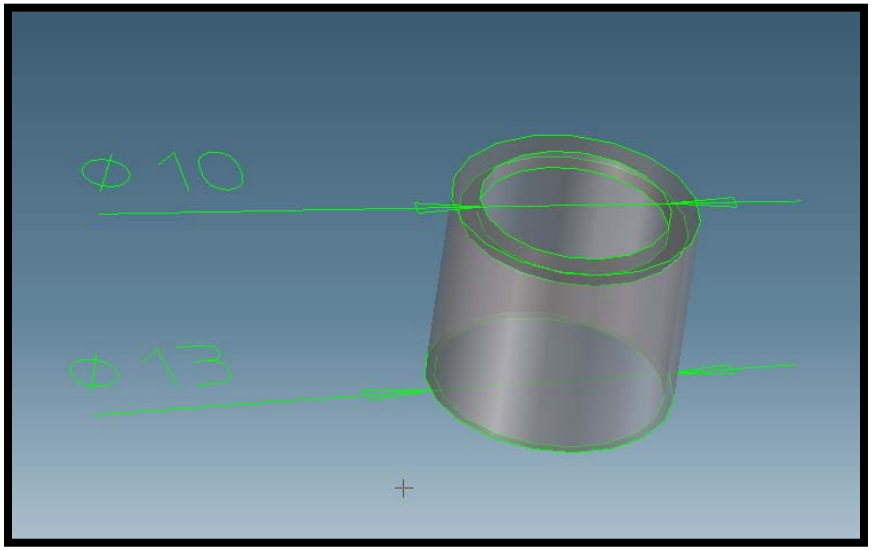


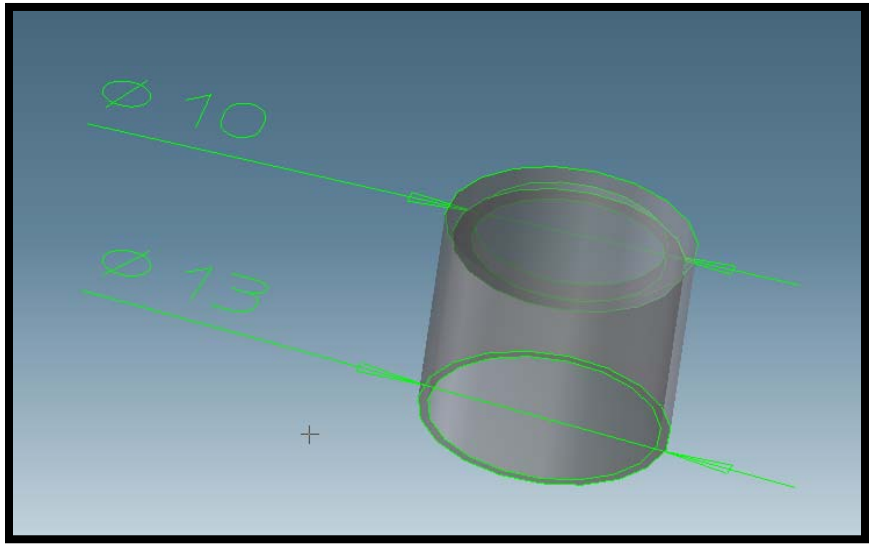
CAD 3D Model of Dielectric Cell (Cont…)
Final Design
Upper Electrode



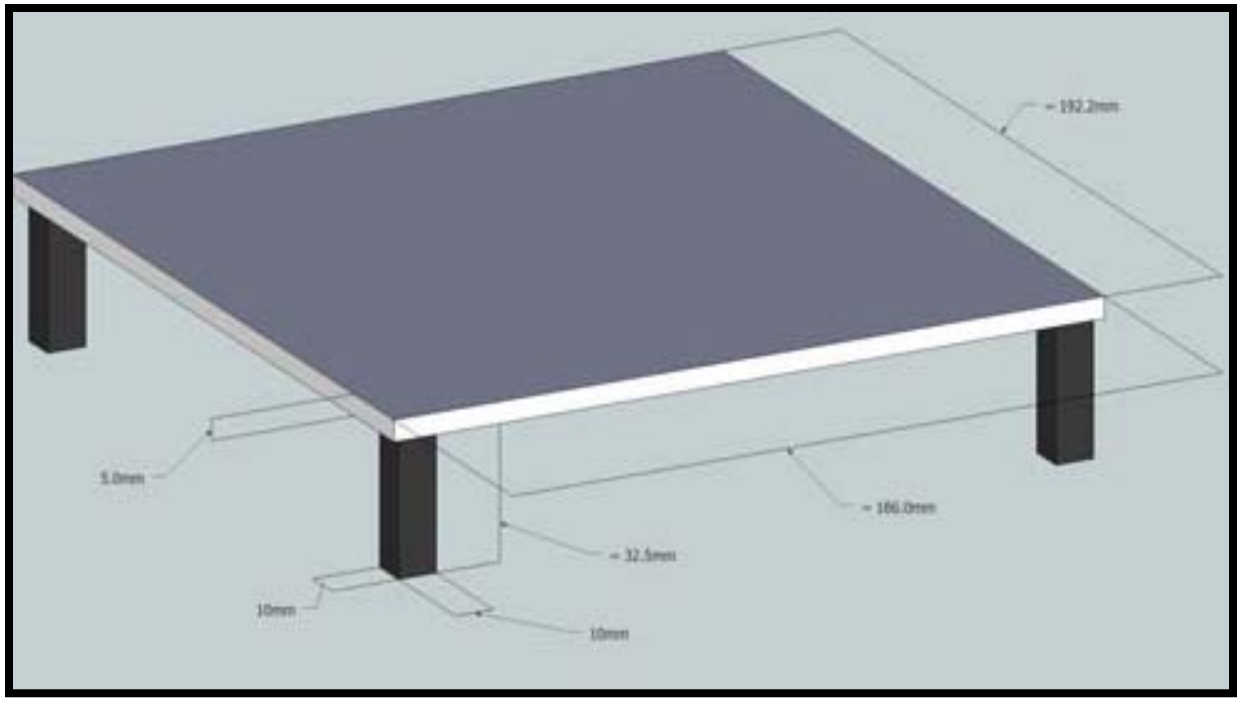


CAD 3D Model of Dielectric Cell (Cont…)
Final Design
Guard Ring

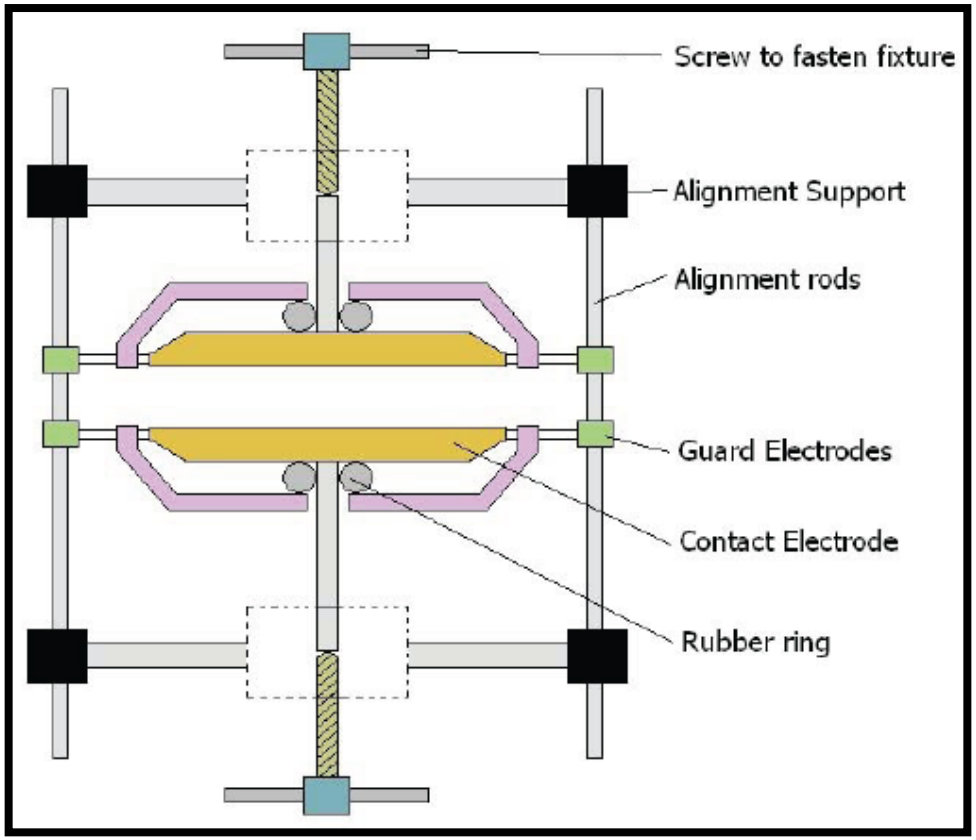




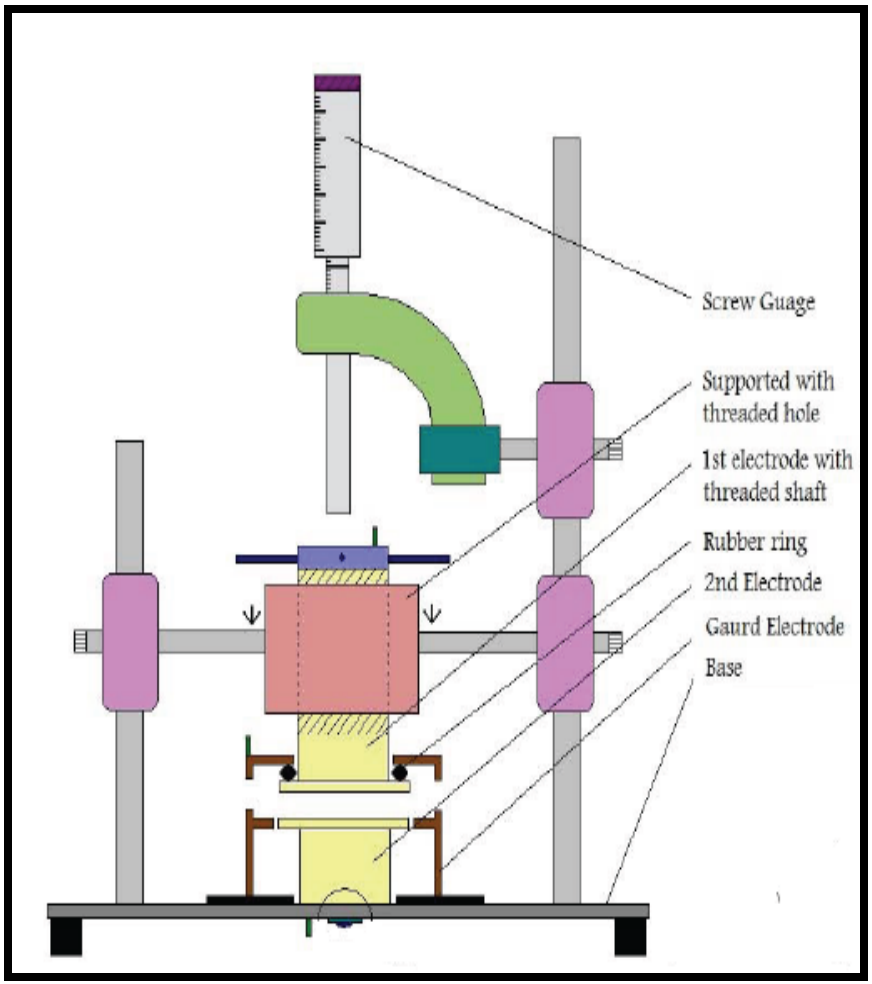
CAD 3D Model of Dielectric Cell (Cont…)
Final Design
Base Plate

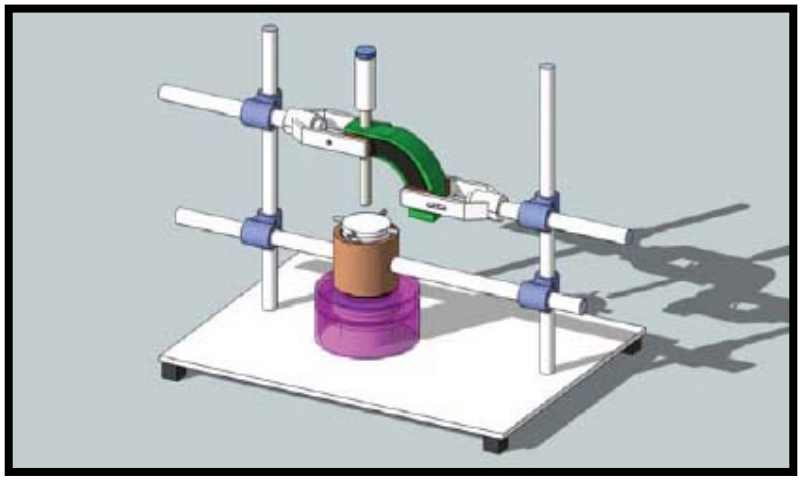


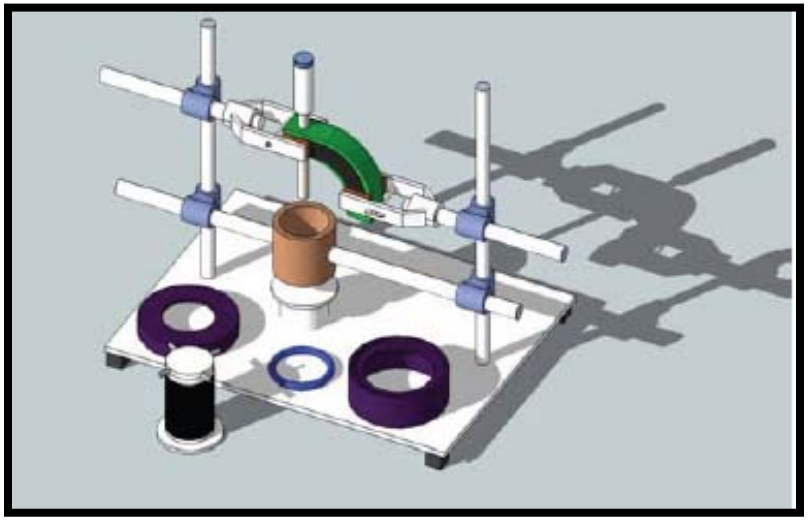
Initial Dielectric Cell Designs
First Design



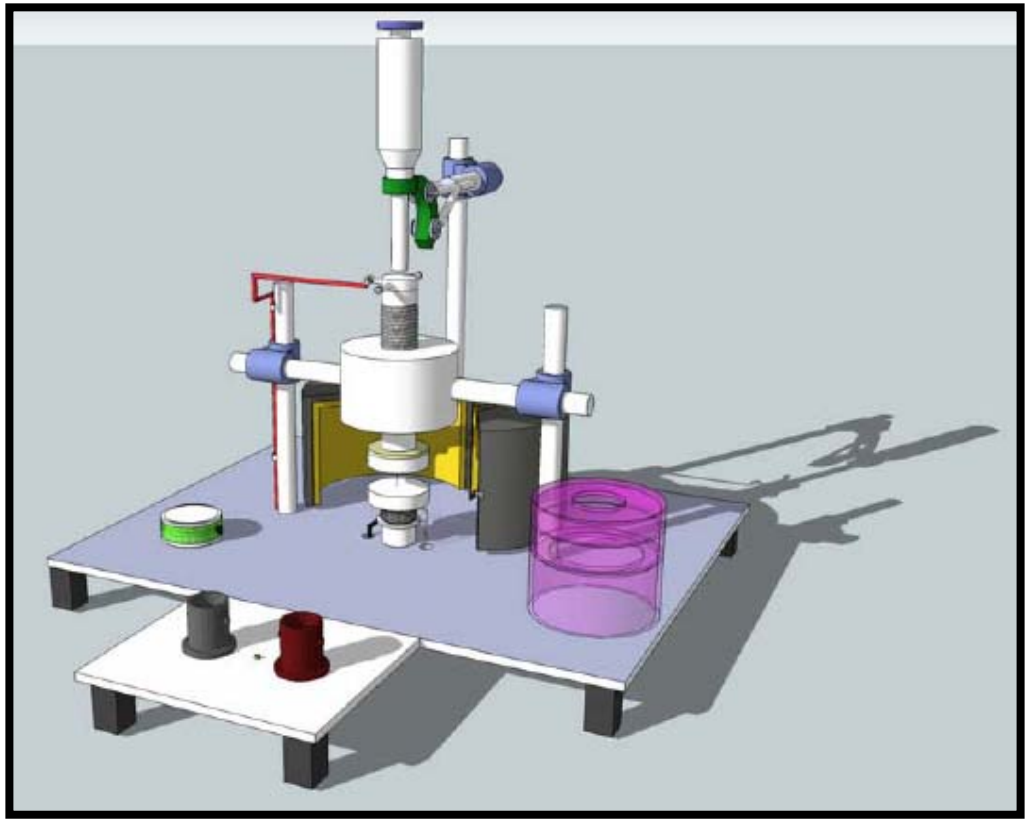
Initial Dielectric Cell Designs (Cont…)
Second Design



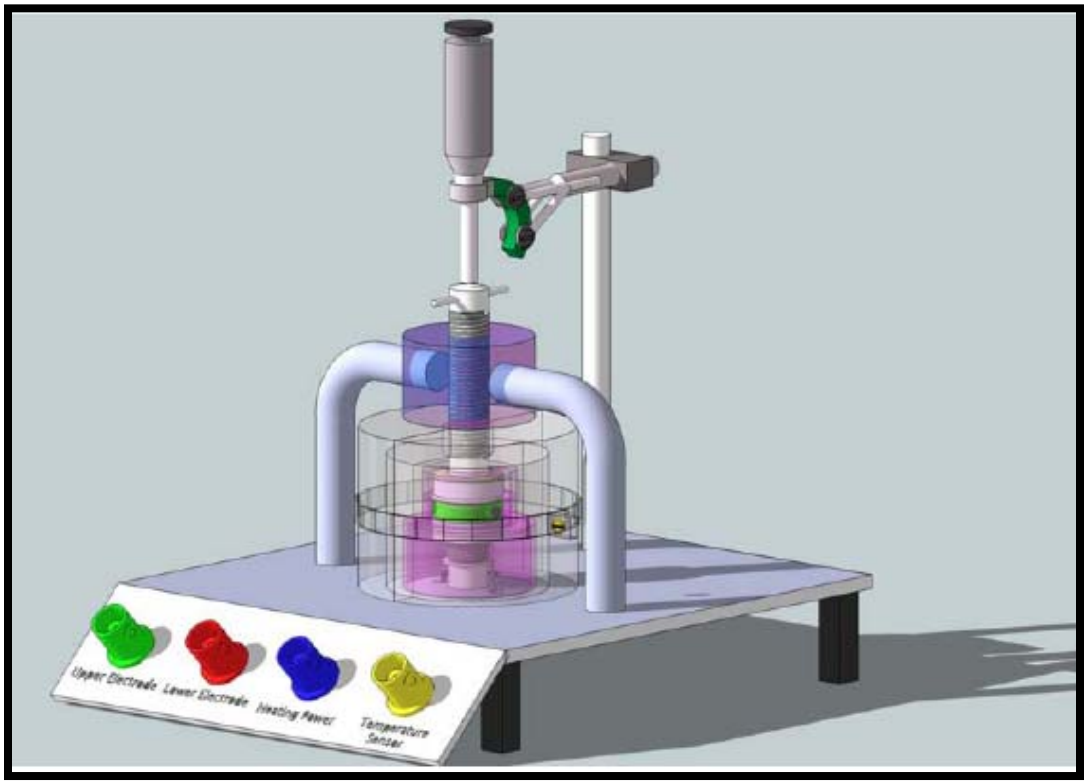




Initial Dielectric Cell Designs (Cont…)
Third Design



Initial Dielectric Cell Designs (Cont…)
Fourth Design



Selection of Design

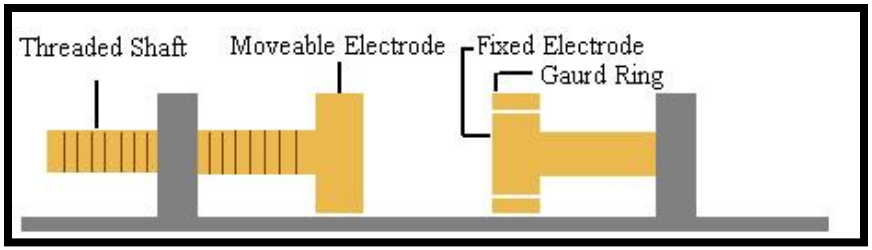
Factors for selection of design:

- Complexity
- Manufacturability
- Electrical connections
- Material required
- Cost
- Thickness Measurement
- Contact stability

Manufacturing of Dielectric Cell

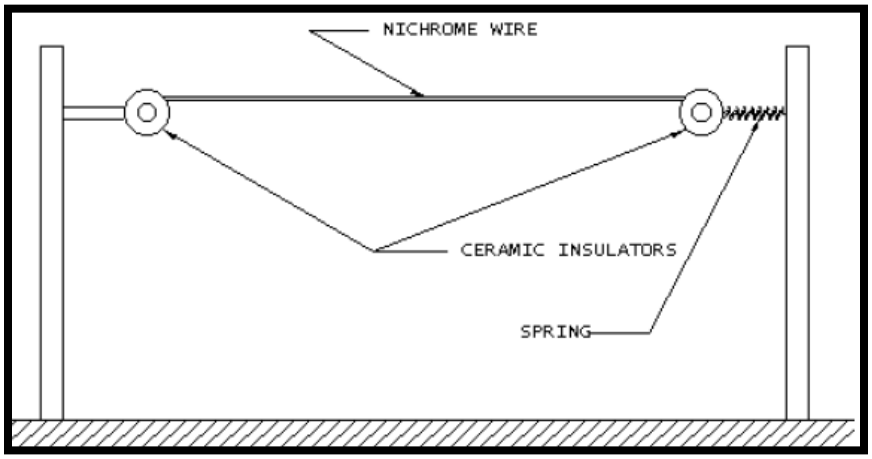
Manufacturing of Dielectric Cell (Cont…)

Horizontal Dielectric Cell



- This Dielectric Cell is designed in such way that it can be placed in vacuum tube furnace which have a capacity to rise up to 1100 degree C.
- For electrical connections we also have stainless steel vacuum flange contain 6 through brass screw threads fixed on one side of Alumina tube..
- Internal/external electrical probing can be done via high temperature insulated wires.

Designing a Heater for Dielectric Cell Test Phase



- Tests were also performed on coiled NiChrome wire in air and coiled NiChrome wire on Alumina tube.
- Data got from these tests helped us in designing heater for Dielectric Cell.

NiChrome Wire Data

Approximate Amperes to Heat NiChrome Wire											
Gauge Wire	Diameter (mm)	°F °C	400 205	600 316	800 427	1000 538	1200 649	1400 760	1600 871	1800 982	2000 1093
10	2.591		16.2	23.3	29.7	37.5	46.0	56.0	68.0	80.0	92.0
11	2.311		13.8	19.2	24.8	31.5	39.0	48.0	57.0	67.0	78.0
12	2.057		11.6	16.1	20.8	26.5	33.5	40.8	48.0	56.0	65.0
13	1.829		9.80	13.6	17.6	22.5	28.2	34.2	41.0	48.0	55.0
14	1.626		8.40	11.6	15.0	18.8	23.5	29.0	34.6	40.5	46.0
15	1.448		7.20	10.0	12.8	16.1	20.0	24.5	29.4	34.3	39.2
16	1.295		6.40	8.70	10.9	13.7	17.0	20.9	25.1	29.4	33.6
17	1.143		5.50	7.50	9.50	11.7	14.5	17.6	21.1	24.6	28.1
18	1.016		4.80	6.50	8.20	10.1	12.2	14.8	17.7	20.7	23.7
19	0.914		4.30	5.80	7.20	8.70	10.6	12.7	15.2	17.8	20.5
20	0.813		3.80	5.10	6.30	7.60	9.10	11.0	13.0	15.2	17.5
21	0.7239		3.30	4.30	5.30	6.50	7.80	9.40	11.0	12.9	14.8
22	0.6426		2.90	3.70	4.50	5.60	6.80	8.20	9.60	11.0	12.5
23	0.5740		2.58	3.30	4.00	4.90	5.90	7.00	8.30	9.60	11.0
24	0.5105		2.21	2.90	3.40	4.20	5.10	6.00	7.10	8.20	9.40
25	0.4547		1.92	2.52	3.00	3.60	4.30	5.20	6.10	7.10	8.00
26	0.4039		1.67	2.14	2.60	3.20	3.80	4.50	5.30	6.10	6.90
27	0.3607		1.44	1.84	2.25	2.73	3.30	3.90	4.60	5.30	6.00
28	0.3200		1.24	1.61	1.95	2.38	2.85	3.40	3.90	4.50	5.10
29	0.2870		1.08	1.41	1.73	2.10	2.51	2.95	3.40	3.90	4.40
30	0.2540		0.92	1.19	1.47	1.78	2.14	2.52	2.90	3.30	3.70
31	0.2261		0.77	1.03	1.28	1.54	1.84	2.17	2.52	2.85	3.2
32	0.2032		0.68	0.90	1.13	1.36	1.62	1.89	2.18	2.46	2.76
33	0.1803		0.59	0.79	0.97	1.17	1.40	1.62	1.86	2.12	2.35
34	0.1600		0.50	0.68	0.83	1.00	1.20	1.41	1.60	1.80	1.99
35	0.1422		0.43	0.57	0.72	0.87	1.03	1.21	1.38	1.54	1.71
36	0.1270		0.38	0.52	0.63	0.77	0.89	1.04	1.19	1.33	1.48
37	0.1143		0.35	0.46	0.57	0.68	0.78	0.9	1.03	1.16	1.29
38	0.1016		0.30	0.41	0.50	0.59	0.68	0.78	0.88	0.98	1.09
39	0.0889		0.27	0.36	0.42	0.49	0.58	0.66	0.75	0.84	0.92
40	0.0787		0.24	0.31	0.36	0.43	0.50	0.57	0.64	0.72	0.79

Ohms/ft at Room Temperature			
Gauge Wire	Diameter (mm)	NiCr A	NiCr C
10	2.591	0.06248	0.06488
11	2.311	0.07849	0.08151
12	2.057	0.09907	0.10290
13	1.829	0.12540	0.13020
14	1.626	0.15870	0.16480
15	1.448	0.20010	0.20780
16	1.295	0.24990	0.25950
17	1.143	0.32100	0.33330
18	1.016	0.40630	0.42190
19	0.914	0.50150	0.52080
20	0.813	0.63480	0.65920
21	0.7239	0.80020	0.83100
22	0.6426	1.01500	1.05500
23	0.5740	1.27300	1.32200
24	0.5105	1.60900	1.67100
25	0.4547	2.02900	2.10700
26	0.4039	2.571	2.670
27	0.3607	3.224	3.348
28	0.3200	4.094	4.252
29	0.2870	5.090	5.286
30	0.2540	6.500	6.750
31	0.2261	8.206	8.522
32	0.2032	10.160	10.550
33	0.1803	12.890	13.390
34	0.1600	16.380	17.010
35	0.1422	20.730	21.520
36	0.1270	26.000	27.000
37	0.1143	32.100	33.330
38	0.1016	40.630	42.190
39	0.0889	53.060	55.100
40	0.0787	67.640	70.240

Outcomes to design a NiChrome wire heater

To design and create our own NiChrome wire heater using tables and figures above, we need to play with these parameters.

- **DIAMETER -** The smaller the wire, the higher the resistance per foot
- **LENGTH -** The longer the wire, the higher the over all resistance
- **HEAT -** The more heat a wire generates, the more resistance it will create

Calculations of Designing heater for Dielectric Cell

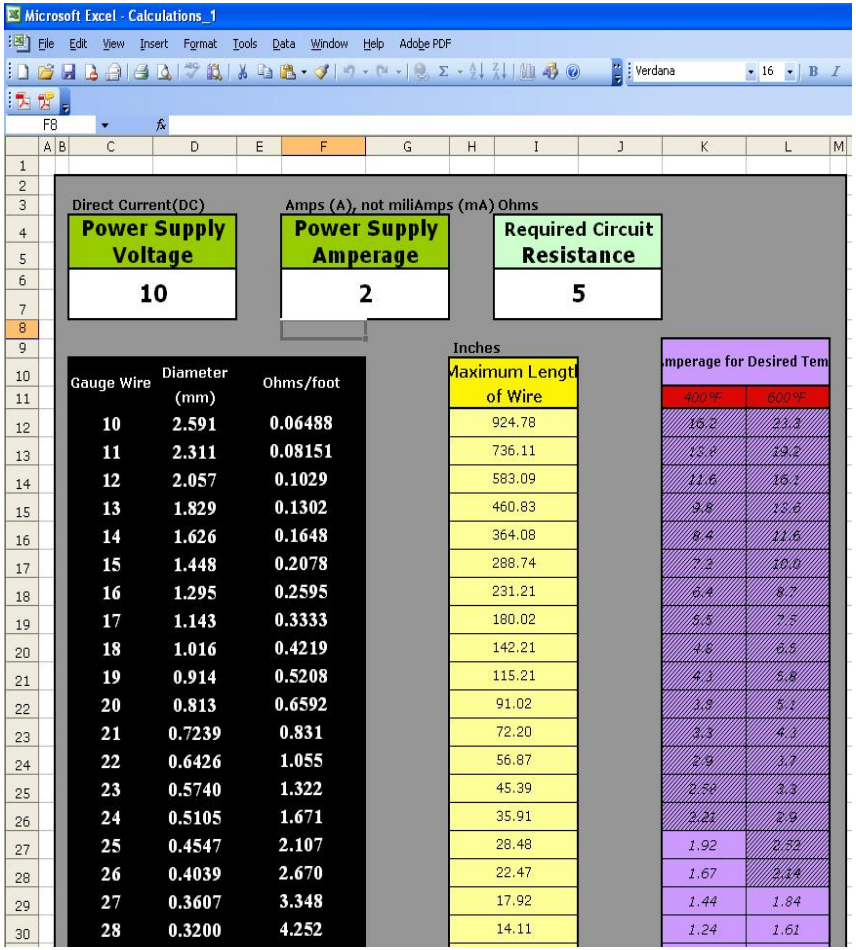
- Available Nichrome wire: 37 AWG
  Dia .1143 resistance 108 ohm/ meter
- Maximum achievable Temp of NiChrome wire = 1100 degee C (NiChrome Wire Data Tables)
- Max current under safety: 0.65 A

We want to make 35 Wattage heater

- P=VI
  V=35/.65
  Max Voltage = 53 V
- V=IR
  R=53/.65
  Req. circuit resistance = 81 ohms
- Length of wire = .75 meters

- 37 Gauge Nichrome Wire C – 108.2 ohms per meter resistance
- 0.7 meter of length (constraint: Design Space) = *75.6 Ohms resistance*
- 0.65 Amps (Temperature desired 1100 degree centigrade***)***
- V=IR
  V = .65 * 75.6
  Max Voltage = 50 V
- P=VI
  P = 50* .65
  Wattage = 32 Watts

Excel Sheet for NiChrome wire heater calculations

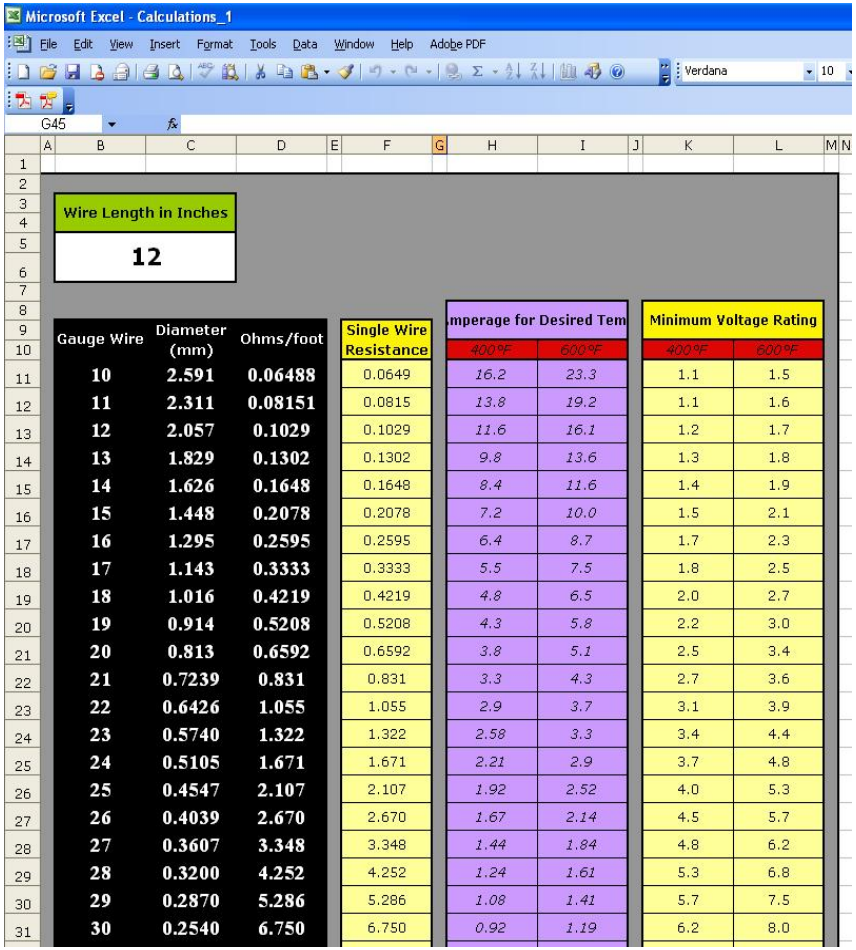


Microsoft Excel - Calculations_1

Direct Current(DC) | Amps (A), not miliAmps (mA) | Ohms

Power Supply Voltage	Power Supply Amperage	Required Circuit Resistance
10	2	5

Gauge Wire	Diameter (mm)	Ohms/foot	Maximum Length of Wire (Inches)	Amperage for Desired Temp 400°F	Amperage for Desired Temp 600°F
10	2.591	0.06488	924.78	16.2	23.3
11	2.311	0.08151	736.11	13.8	19.2
12	2.057	0.1029	583.09	11.6	16.1
13	1.829	0.1302	460.83	9.8	13.6
14	1.626	0.1648	364.08	8.4	11.6
15	1.448	0.2078	288.74	7.2	10.0
16	1.295	0.2595	231.21	6.4	8.7
17	1.143	0.3333	180.02	5.5	7.5
18	1.016	0.4219	142.21	4.8	6.5
19	0.914	0.5208	115.21	4.3	5.8
20	0.813	0.6592	91.02	3.8	5.1
21	0.7239	0.831	72.20	3.3	4.3
22	0.6426	1.055	56.87	2.9	3.7
23	0.5740	1.322	45.39	2.58	3.3
24	0.5105	1.671	35.91	2.21	2.9
25	0.4547	2.107	28.48	1.92	2.52
26	0.4039	2.670	22.47	1.67	2.14
27	0.3607	3.348	17.92	1.44	1.84
28	0.3200	4.252	14.11	1.24	1.61



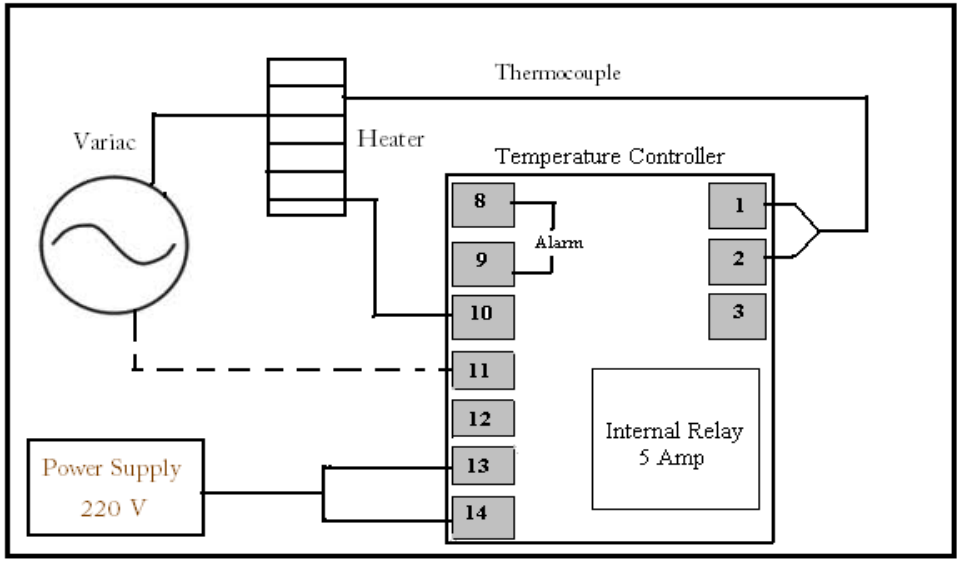
Microsoft Excel - Calculations_1

Wire Length in Inches: 12

Gauge Wire	Diameter (mm)	Ohms/foot	Single Wire Resistance	Amperage for Desired Temp 400°F	Amperage for Desired Temp 600°F	Minimum Voltage Rating 400°F	Minimum Voltage Rating 600°F
10	2.591	0.06488	0.0649	16.2	23.3	1.1	1.5
11	2.311	0.08151	0.0815	13.8	19.2	1.1	1.6
12	2.057	0.1029	0.1029	11.6	16.1	1.2	1.7
13	1.829	0.1302	0.1302	9.8	13.6	1.3	1.8
14	1.626	0.1648	0.1648	8.4	11.6	1.4	1.9
15	1.448	0.2078	0.2078	7.2	10.0	1.5	2.1
16	1.295	0.2595	0.2595	6.4	8.7	1.7	2.3
17	1.143	0.3333	0.3333	5.5	7.5	1.8	2.5
18	1.016	0.4219	0.4219	4.8	6.5	2.0	2.7
19	0.914	0.5208	0.5208	4.3	5.8	2.2	3.0
20	0.813	0.6592	0.6592	3.8	5.1	2.5	3.4
21	0.7239	0.831	0.831	3.3	4.3	2.7	3.6
22	0.6426	1.055	1.055	2.9	3.7	3.1	3.9
23	0.5740	1.322	1.322	2.58	3.3	3.4	4.4
24	0.5105	1.671	1.671	2.21	2.9	3.7	4.8
25	0.4547	2.107	2.107	1.92	2.52	4.0	5.3
26	0.4039	2.670	2.670	1.67	2.14	4.5	5.7
27	0.3607	3.348	3.348	1.44	1.84	4.8	6.2
28	0.3200	4.252	4.252	1.24	1.61	5.3	6.8
29	0.2870	5.286	5.286	1.08	1.41	5.7	7.5
30	0.2540	6.750	6.750	0.92	1.19	6.2	8.0

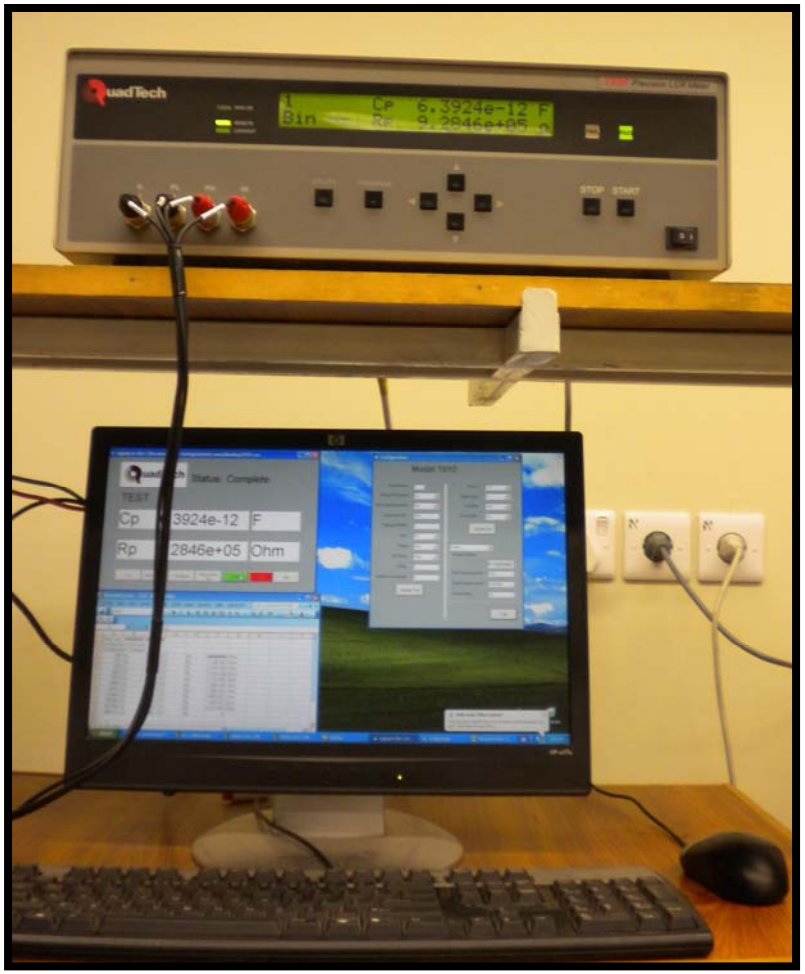
Setting up Temperature Controller with Dielectric measurement system

Front Panel of Temperature Controller

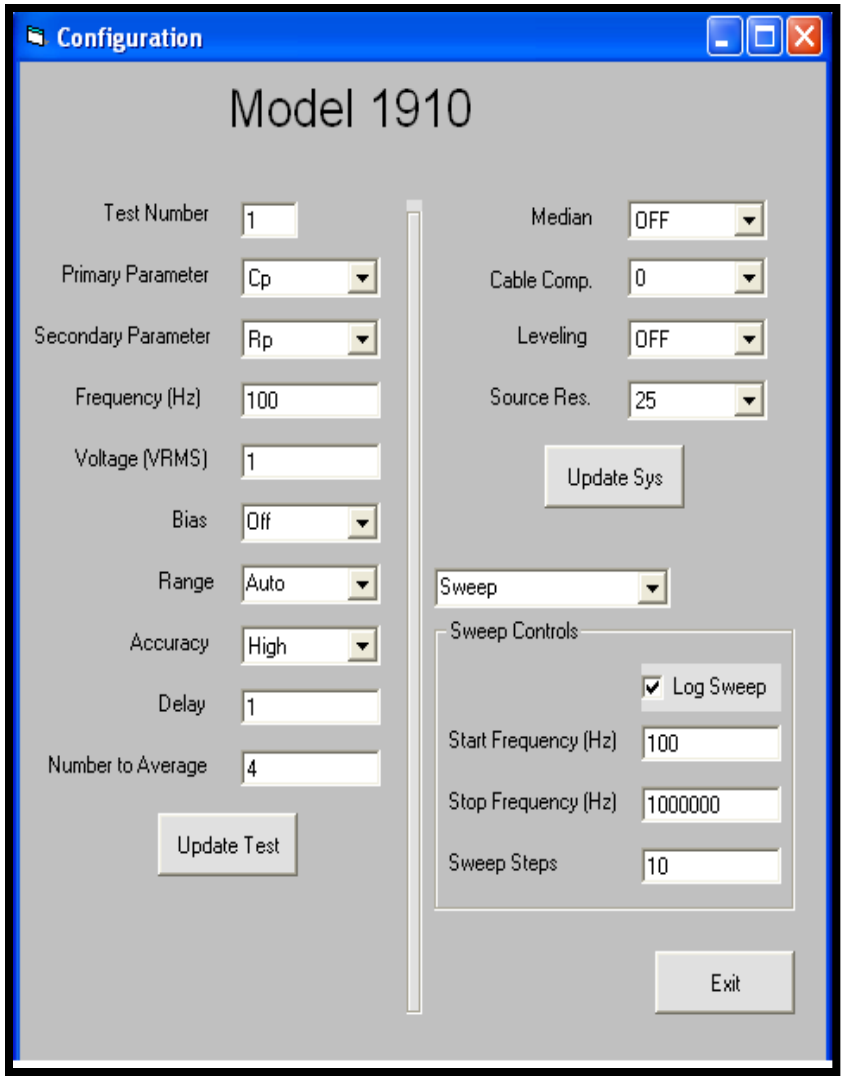


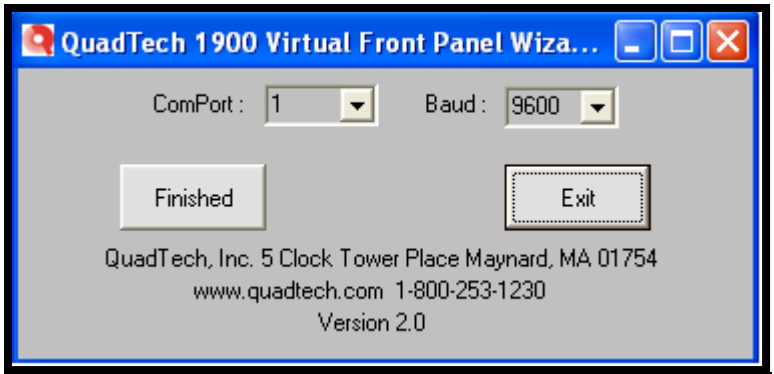
Circuitry for Temperature Control setup

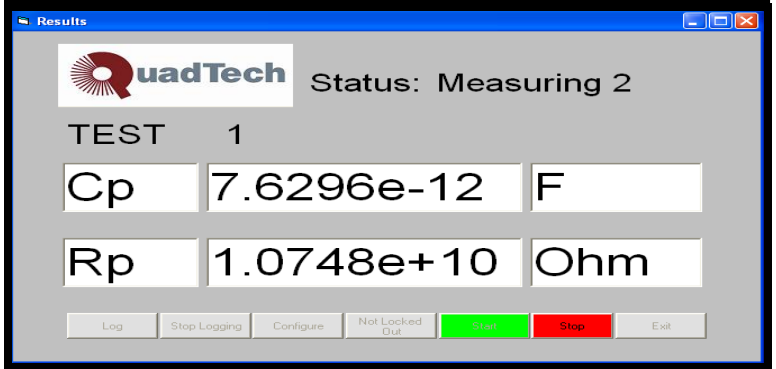
LCR meter/Computer Interface

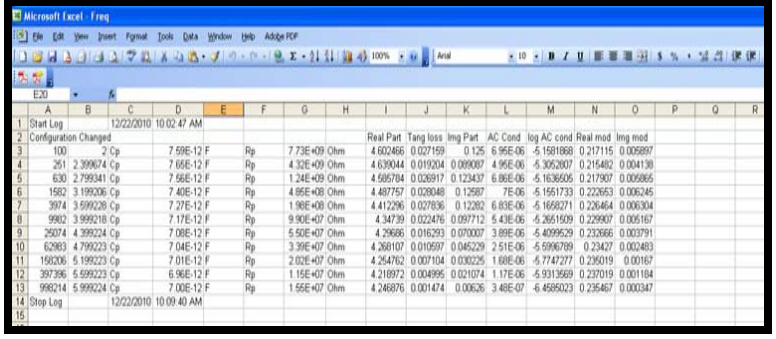


LCR meter/Computer Interface (Cont…)

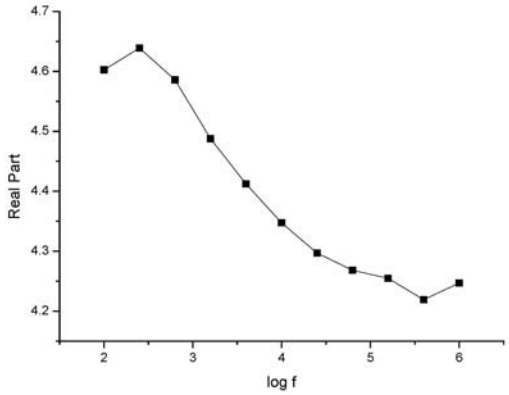


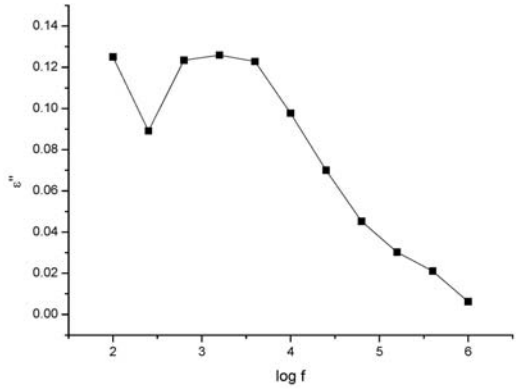


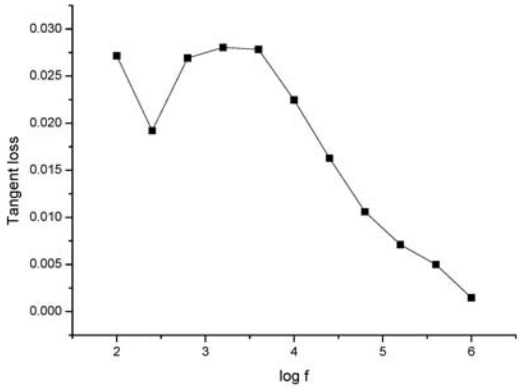


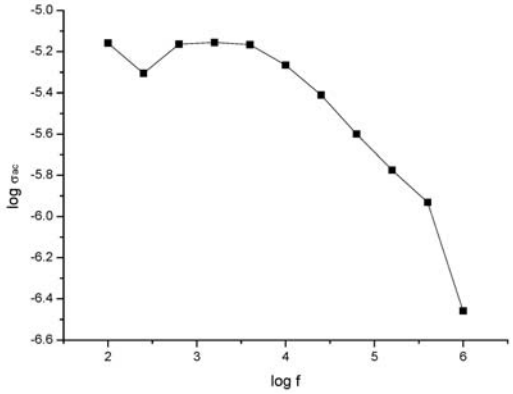


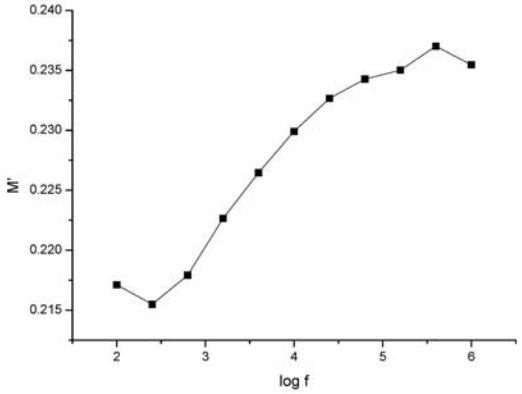
Measurement of Dielectric Properties Mica (frequency dependant)

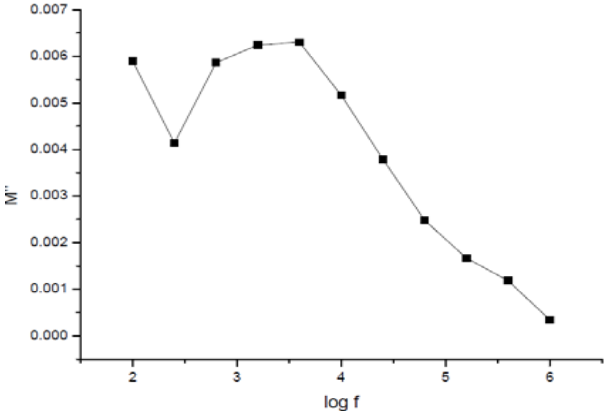




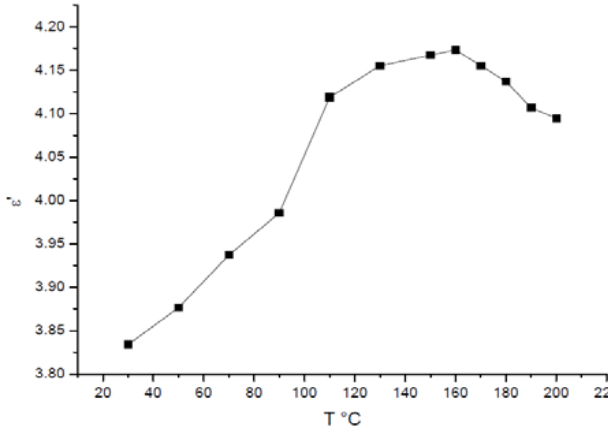


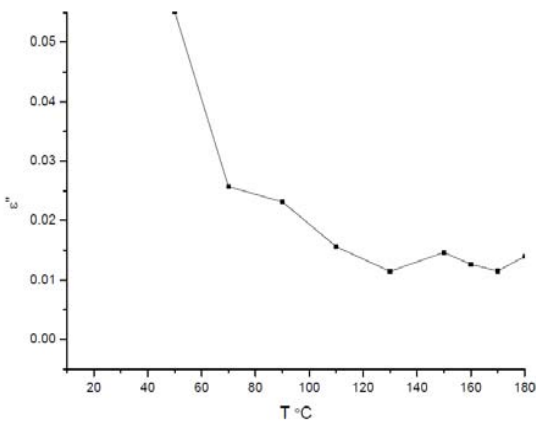


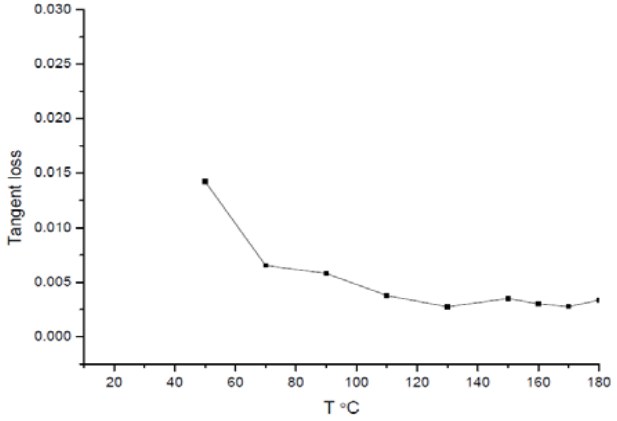


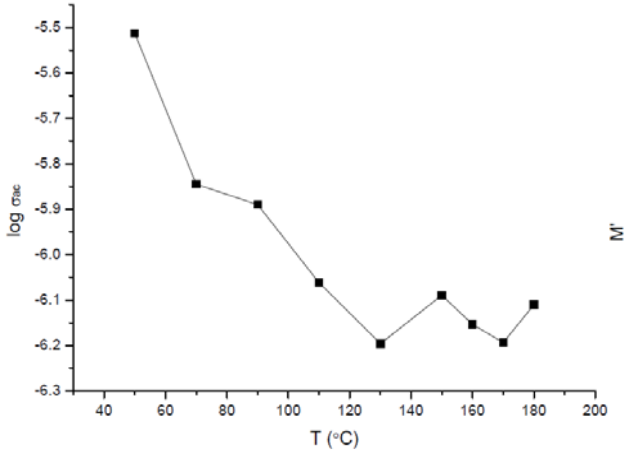


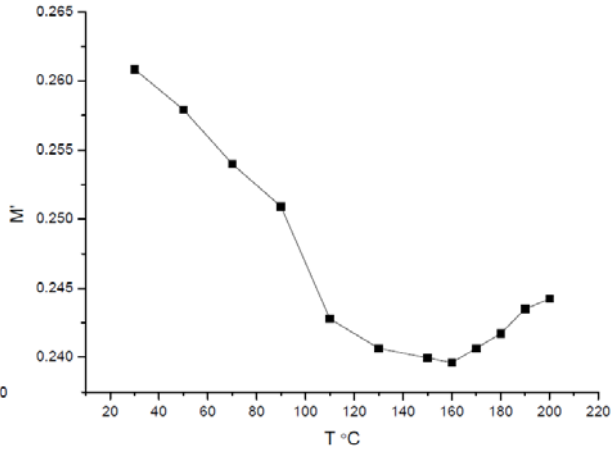
Measurement of Dielectric Properties (Cont…)
Mica (temperature dependant)

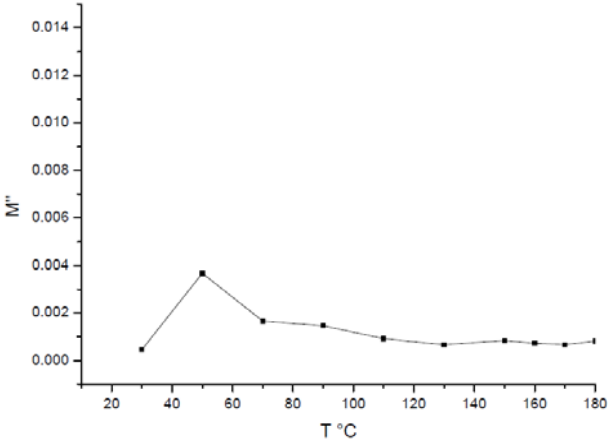




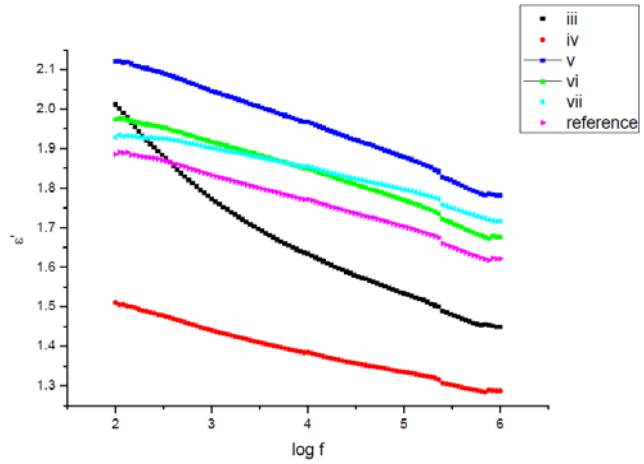


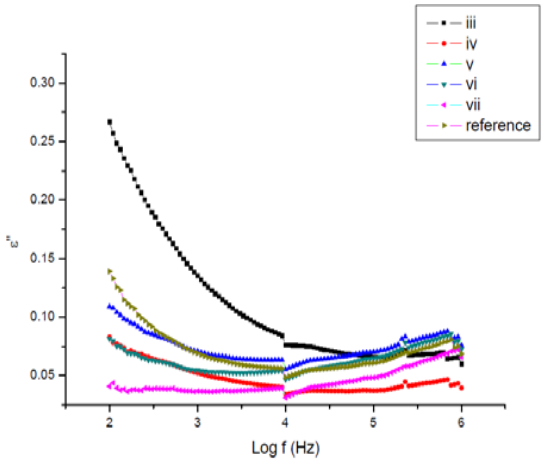


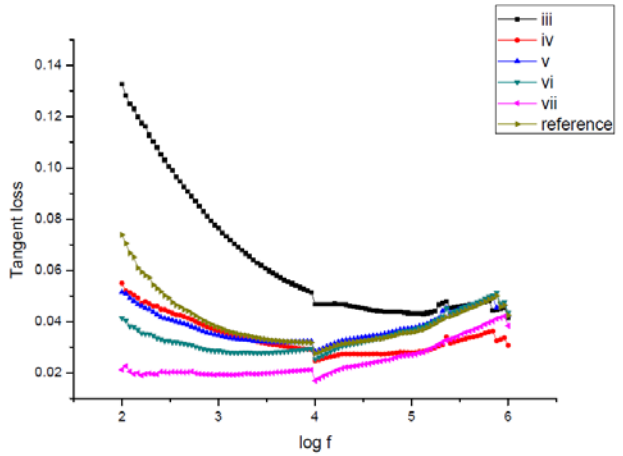


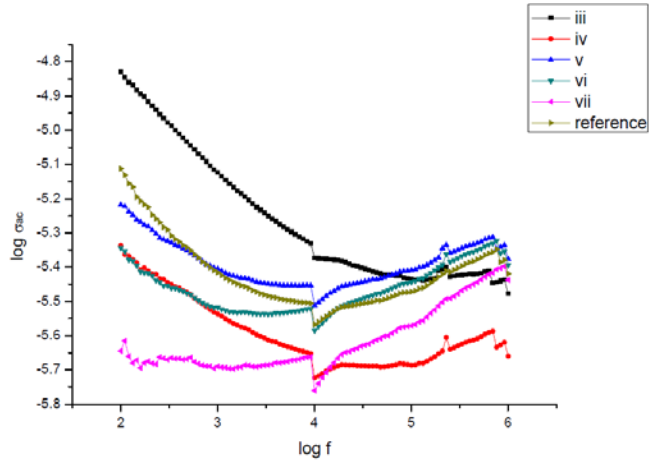


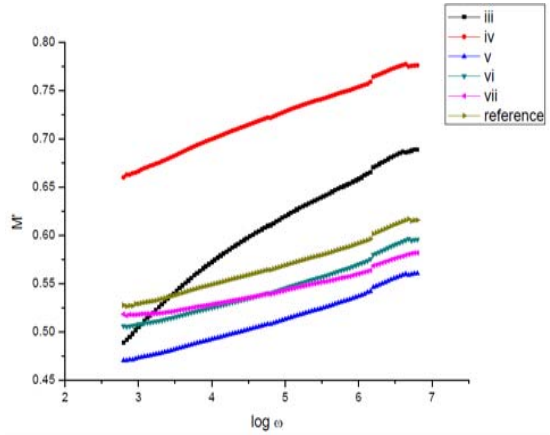
Measurement of Dielectric Properties (Cont...)
MNPs/Polymer (frequency dependant)

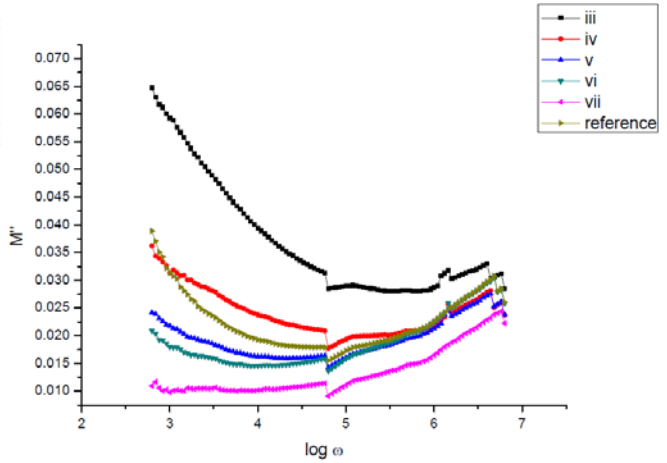




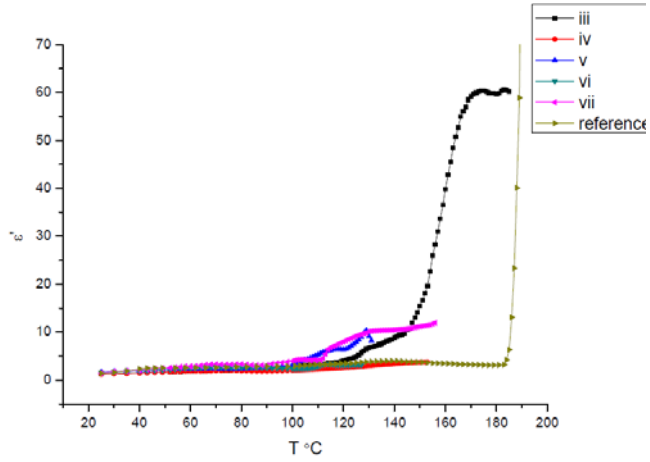


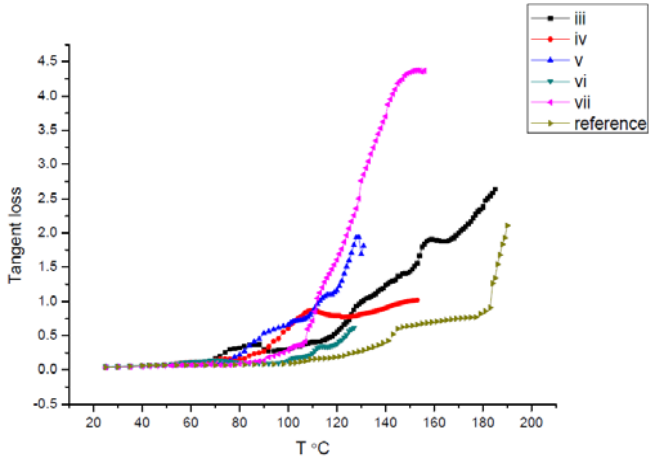


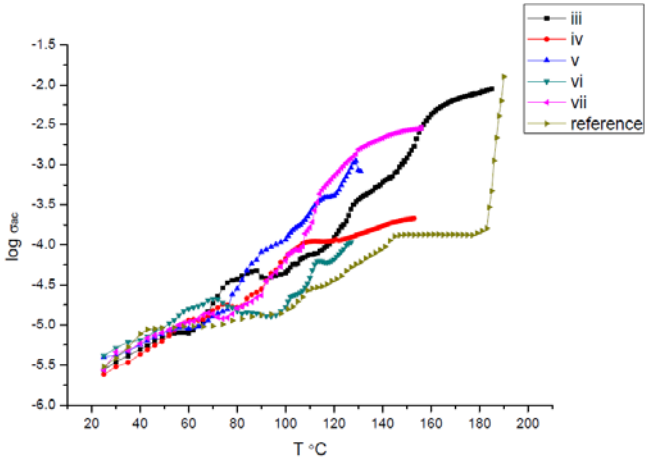


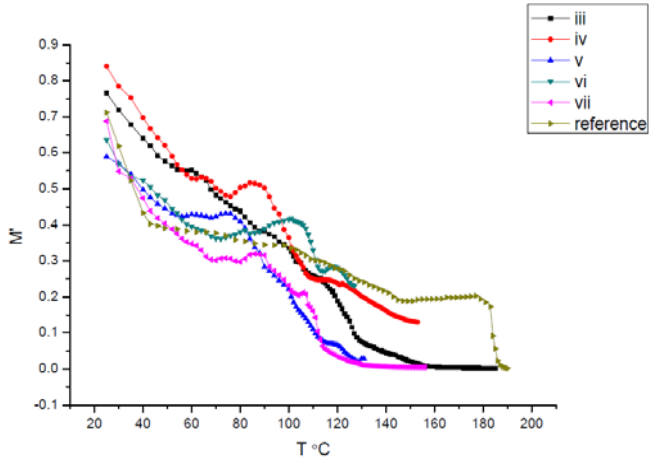


Measurement of Dielectric Properties (Cont...) MNPs/Polymer (temperature dependant)









Measurement of Dielectric Properties (Cont...) $PbTiO_3$ (frequency dependant)