

SYNTHESIS OF GOLD, SILVER AND
BIMETALLIC NANOPARTICLES
AND
PREPARATION OF CONDUCTING SILVER NANOSTRUCTURES
AND THEIR APPLICATION IN STRAIN SENSING

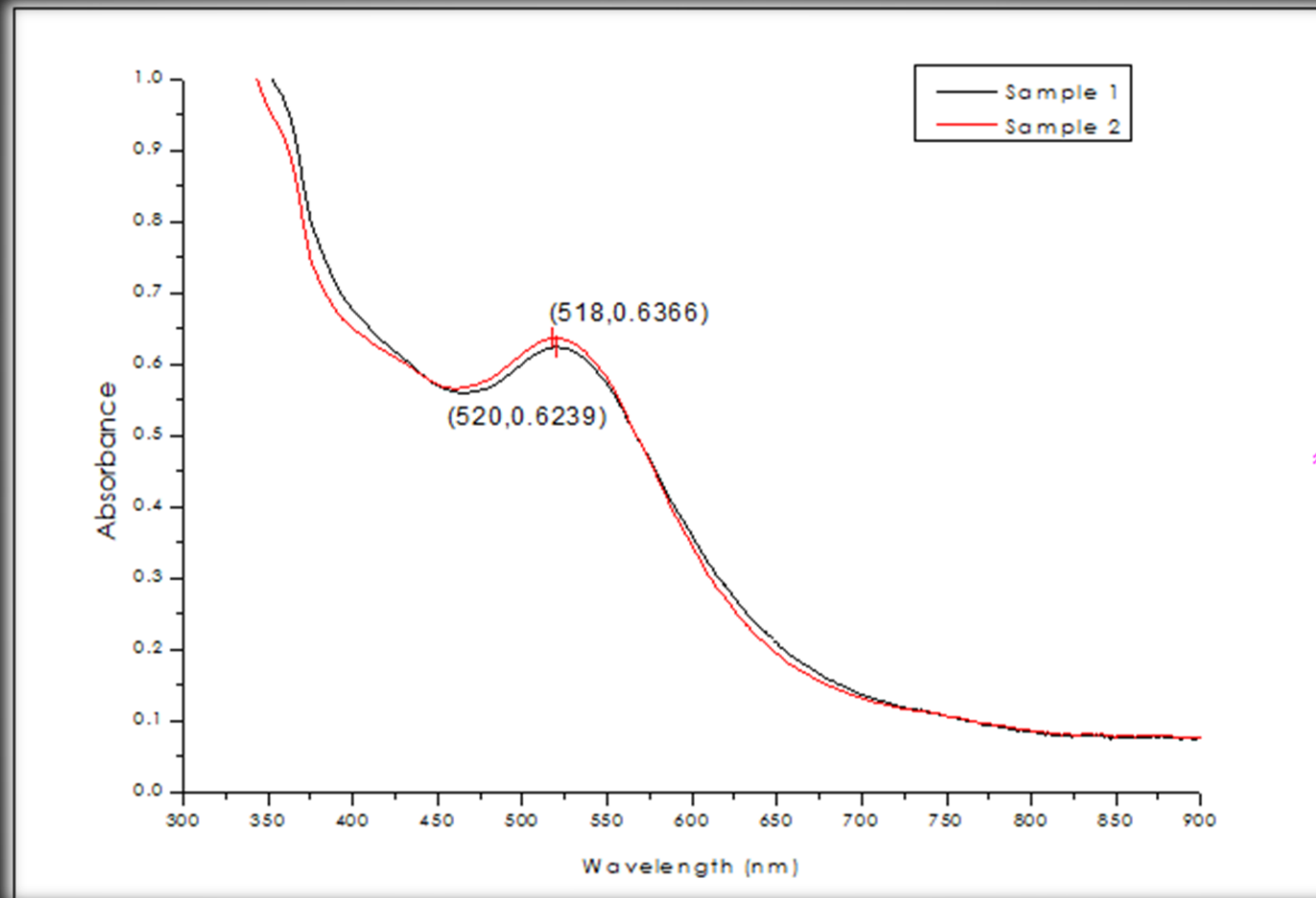
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Summer Intern – 2019
Indian Institute of Science

Synthesis of Gold Nanoparticles

Synthesis of Gold Nanoparticles:

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Chloroauric acid : 0.64 mM, 10 ml added at the rate of 1 ml/min
Tannic acid : 0.04 mM, pH adjusted to 10 using 1 wt.% Potassium Carbonate Solution

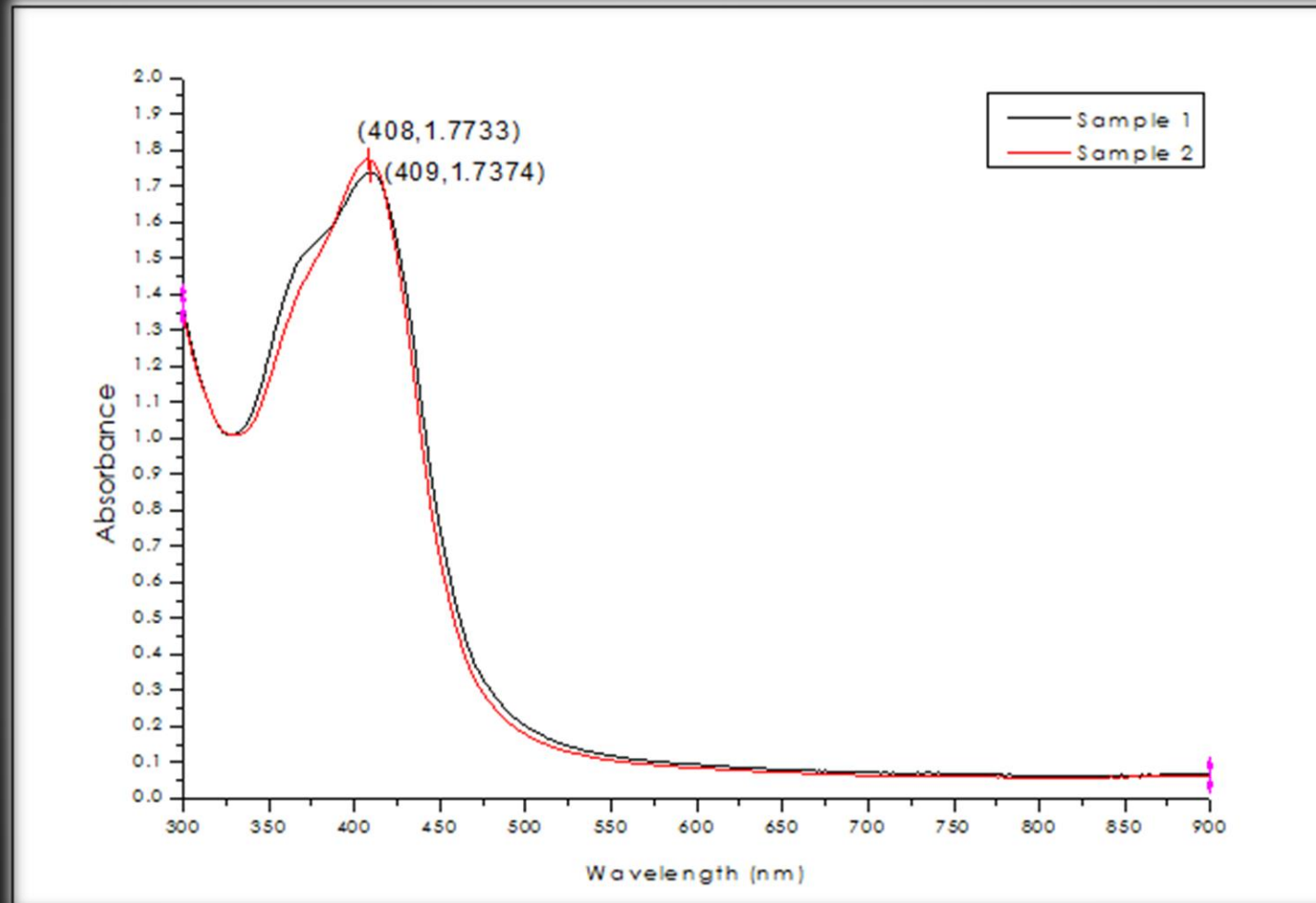


Synthesis of Silver Nanoparticles

Synthesis of Silver Nanoparticles:

Silver Nitrate : 0.64 mM, 10 ml added at the rate of 1 ml/min
Tannic acid : 0.04 mM, pH adjusted to 8 using 1 wt.% Potassium Carbonate Solution

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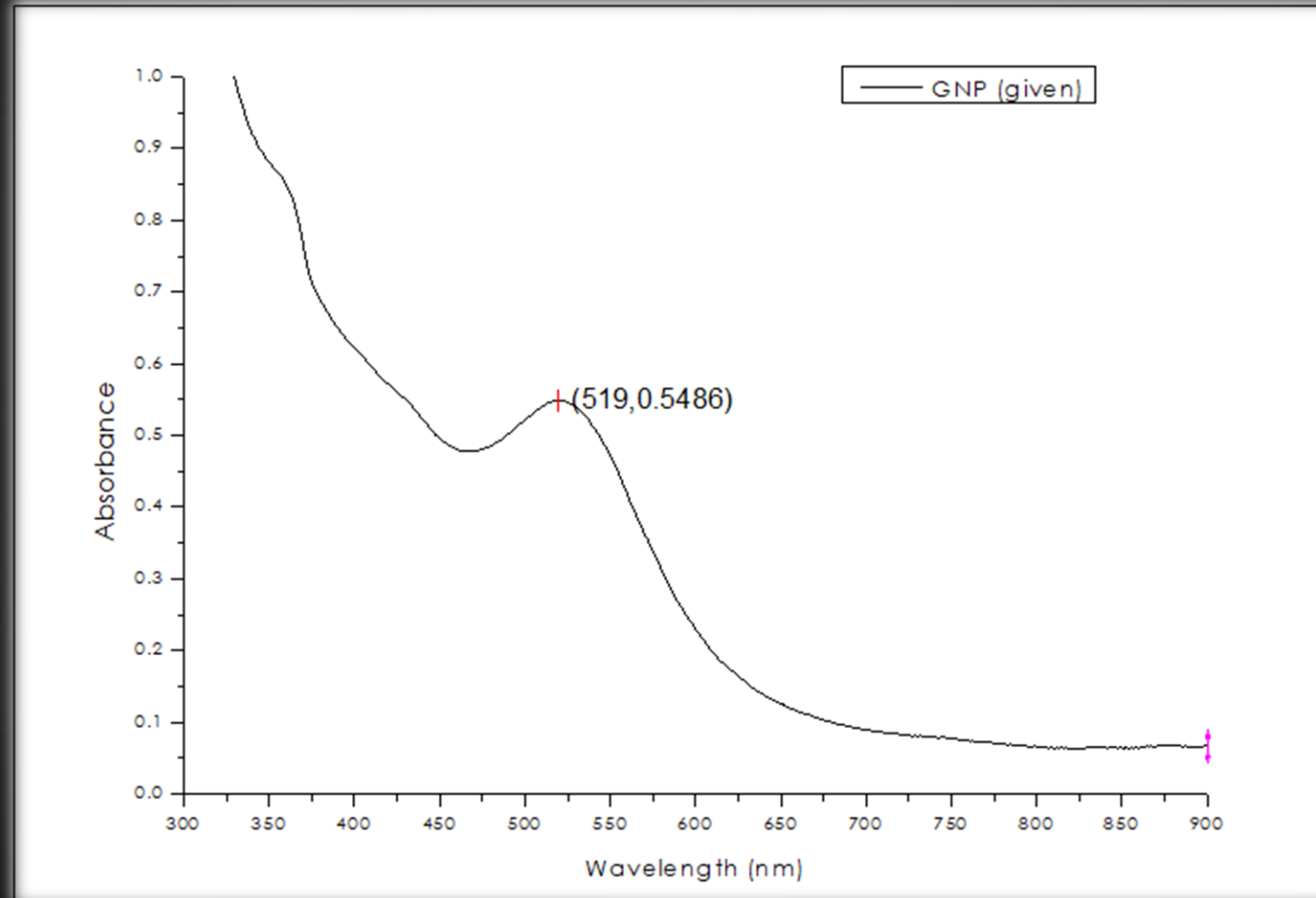
Optimization of Centrifuge Process for maximum output of Gold Nanoparticles

Given Solution:

Chloroauric acid : 0.64 mM, 10 ml added at the rate of 1 ml/min

Tannic acid : 0.04 mM, pH adjusted to 10 using 1 wt.% Potassium Carbonate Solution

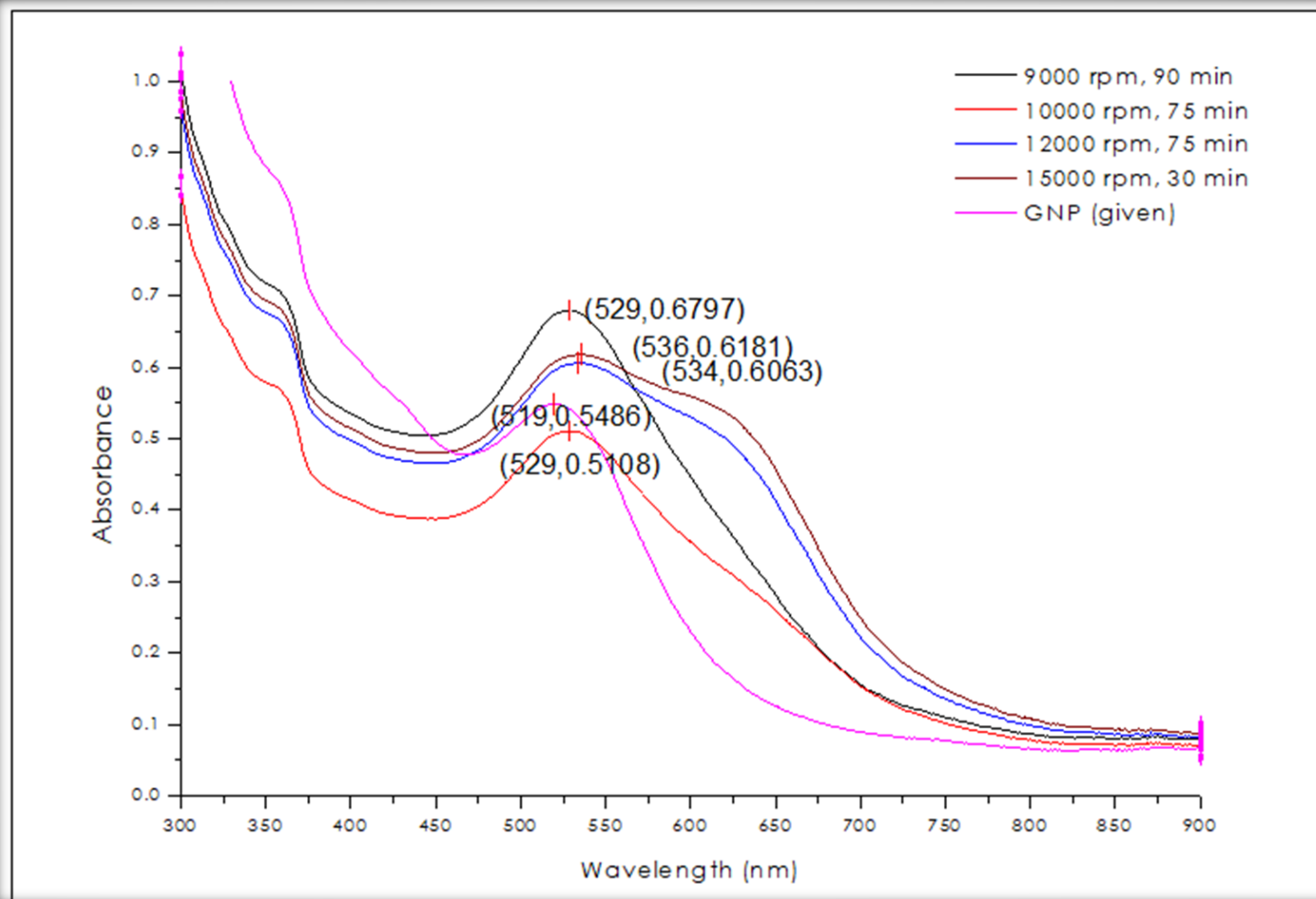
7



Step 1:

Effect of increasing speed, time based on physical observations

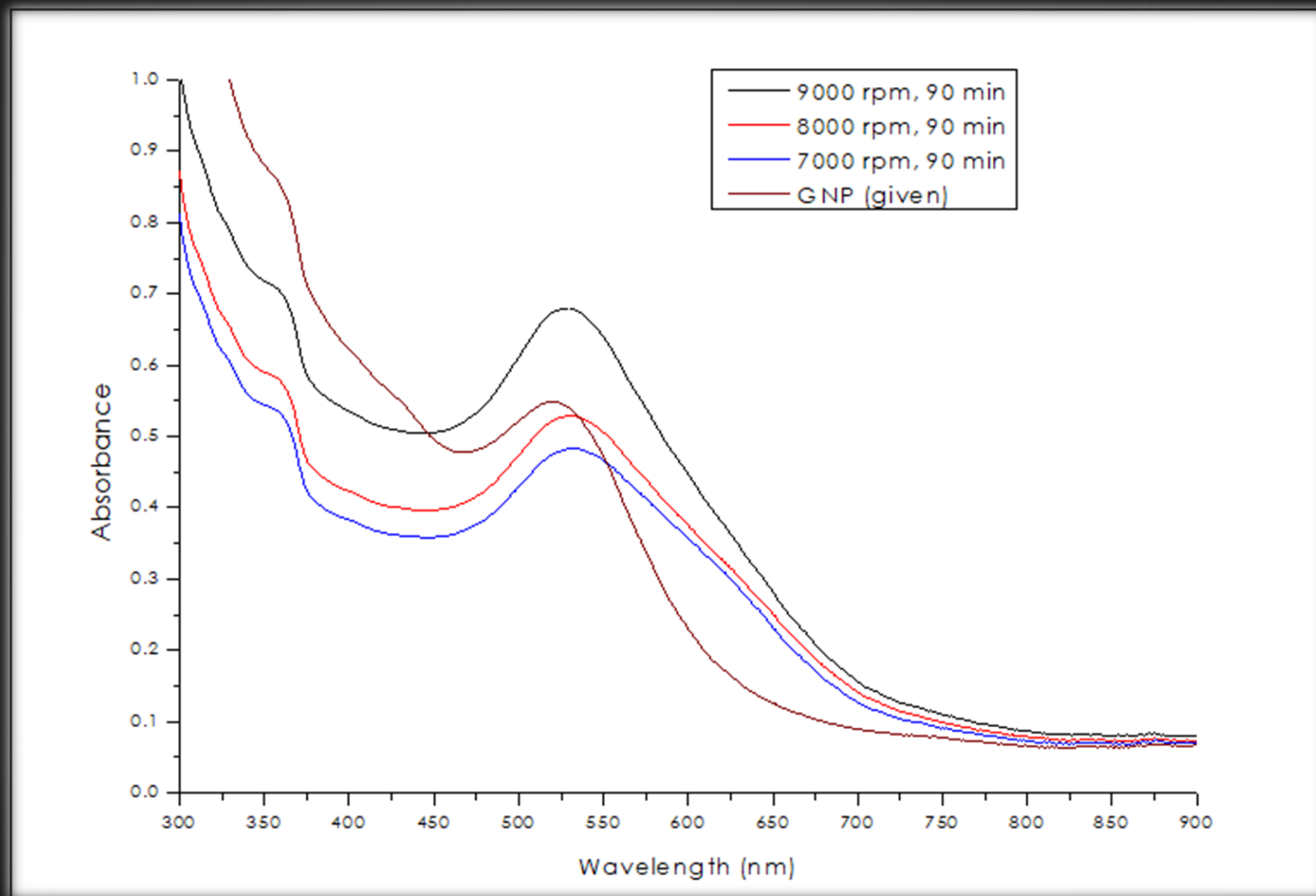
8



Step 2:

Effect of decreasing speed, keeping time constant

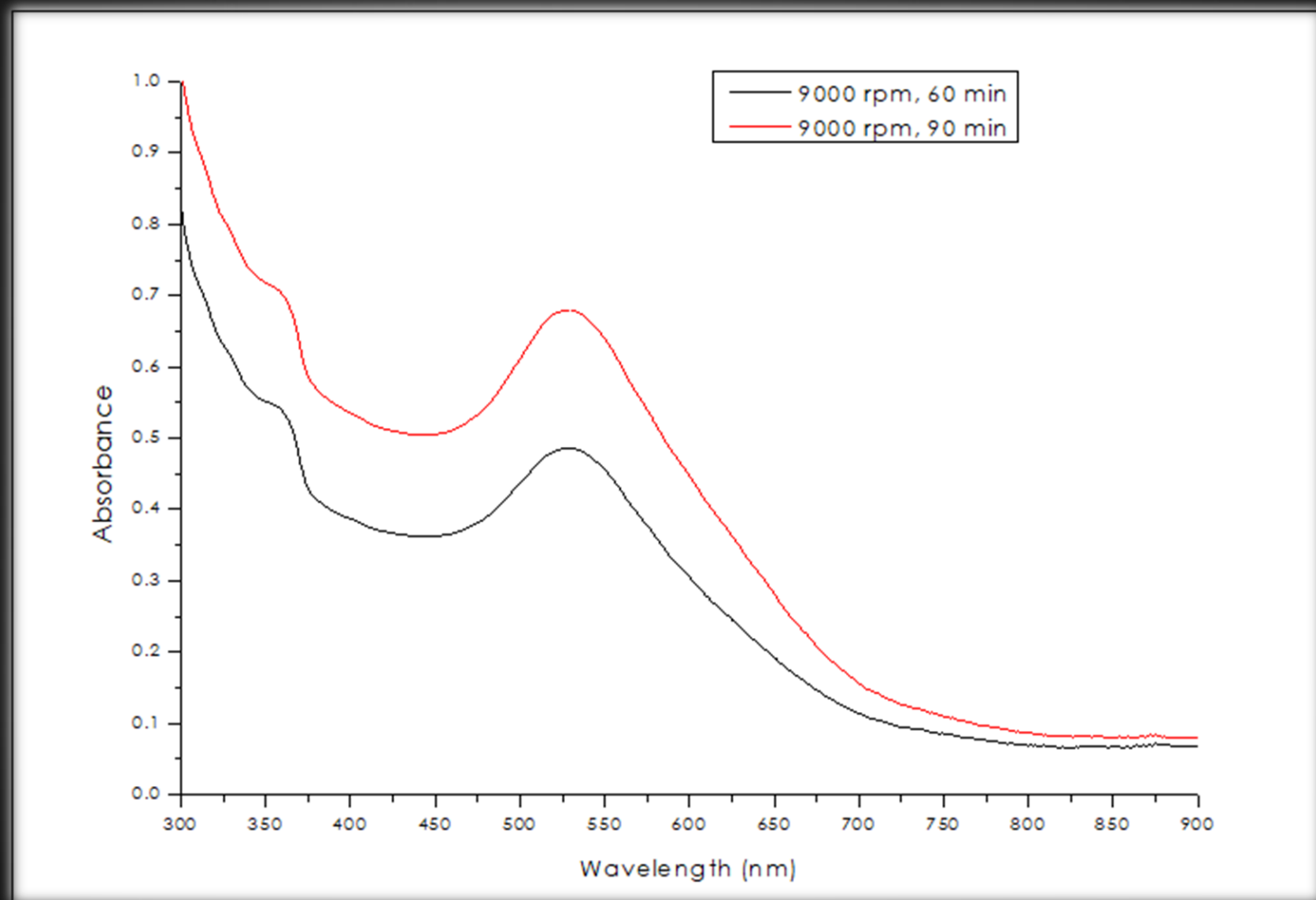
9



Step 2:

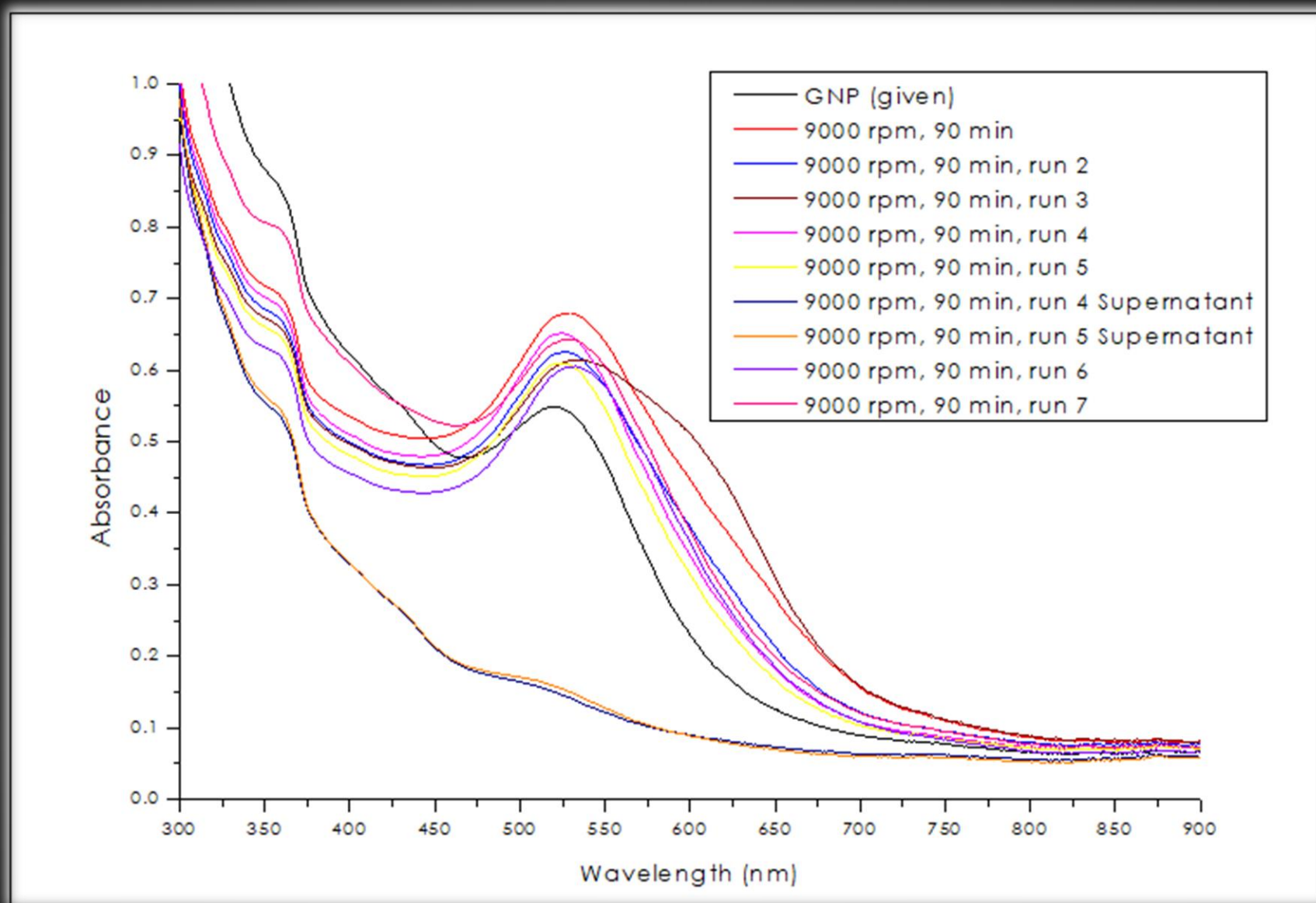
Effect of decreasing time, keeping speed constant

10



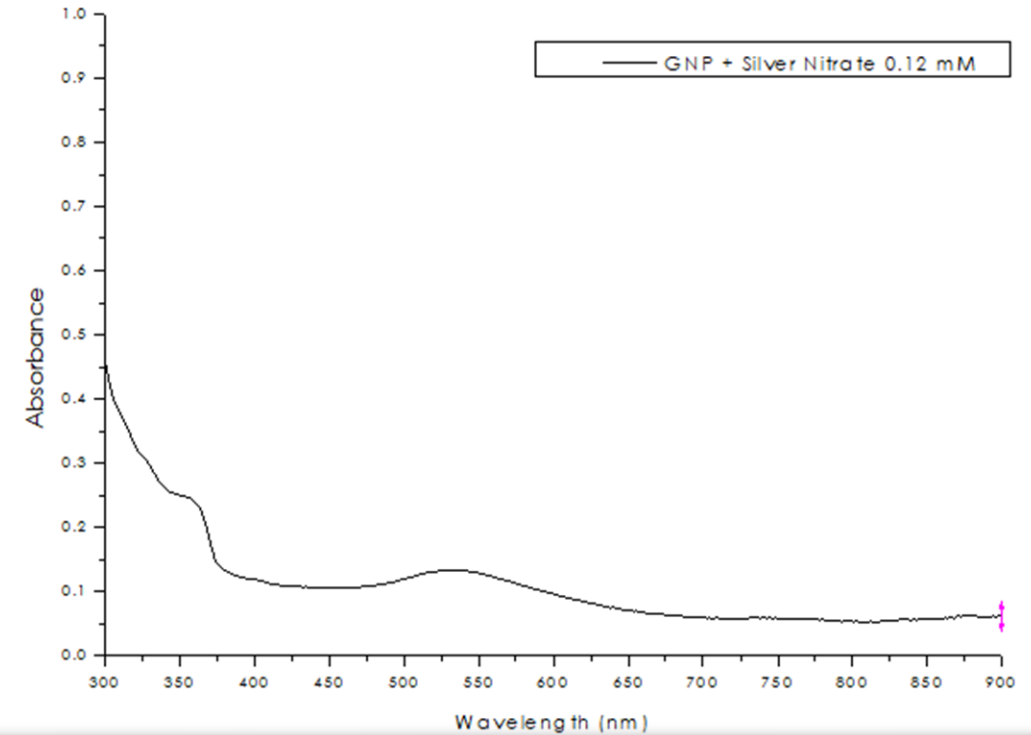
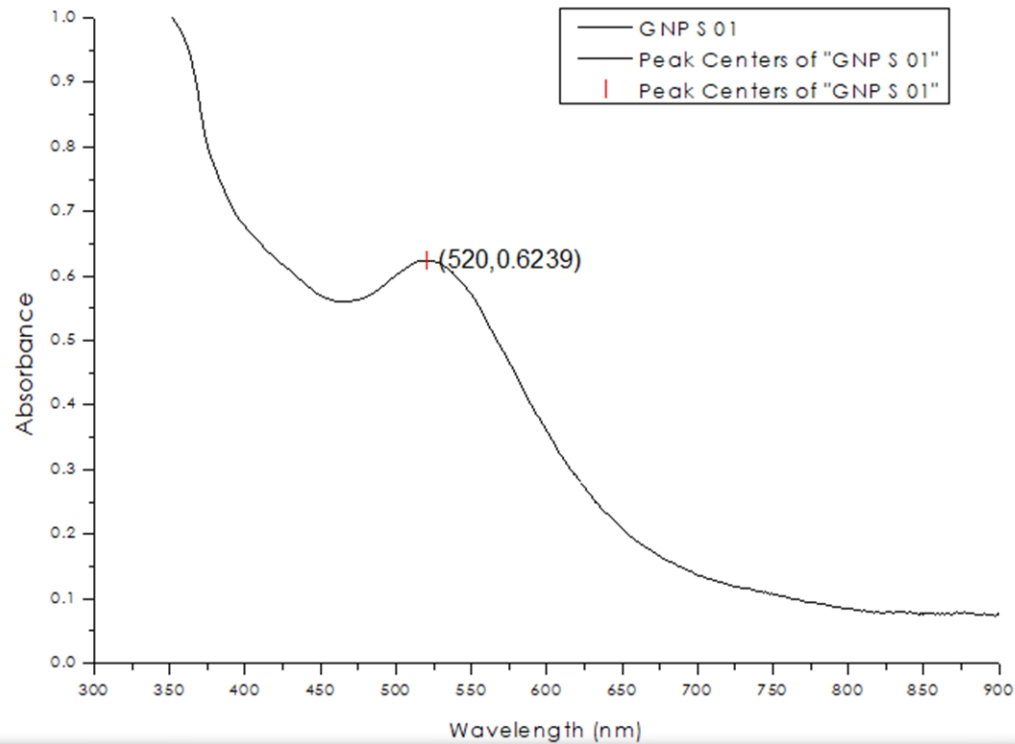
Samples Centrifuged at 9000 rpm, 90 min and their supernatant liquids

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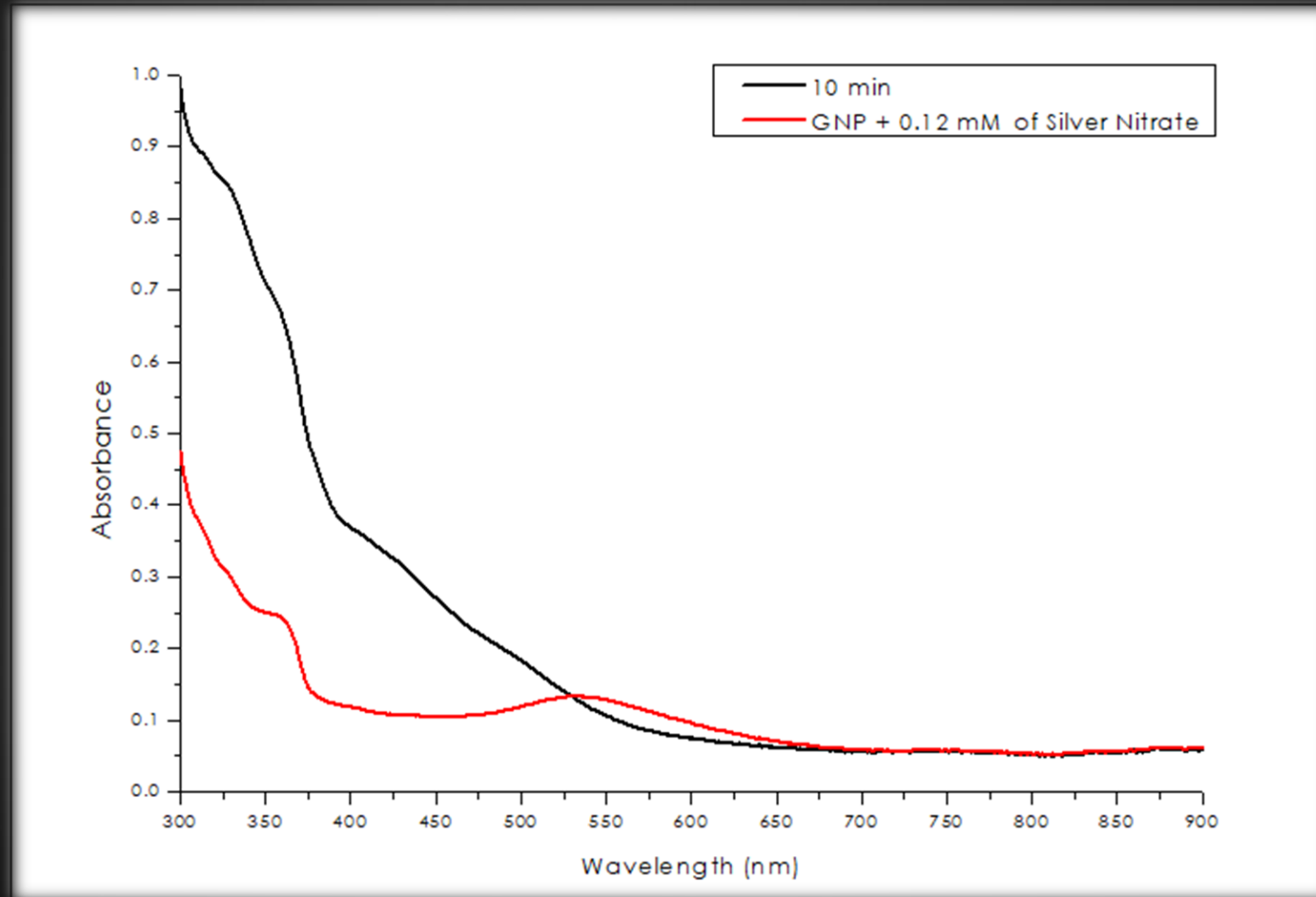
Synthesis of Au-Ag Core-Shell Particles

Centrifuged GNP + 0.12mM Silver Nitrate added in 15 ml of 0.03 mM Tannic acid
at the rate of 1 cc/min for 10 min and 5 min, respectively



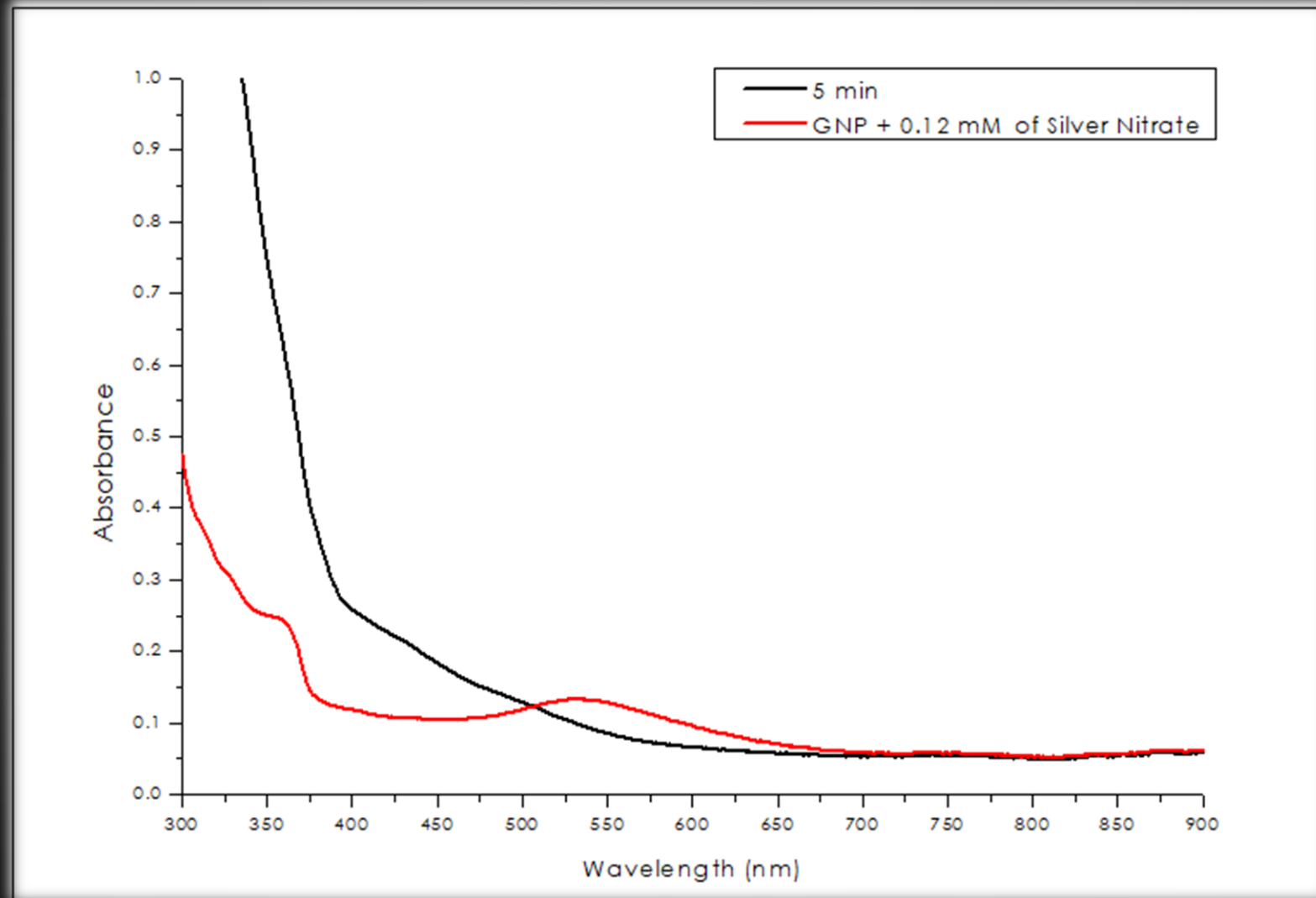
Experiment - I

GNP + 0.12mM Silver Nitrate added in 15 ml of 0.03 mM Tannic acid at the rate of 1 cc/min for 10 min

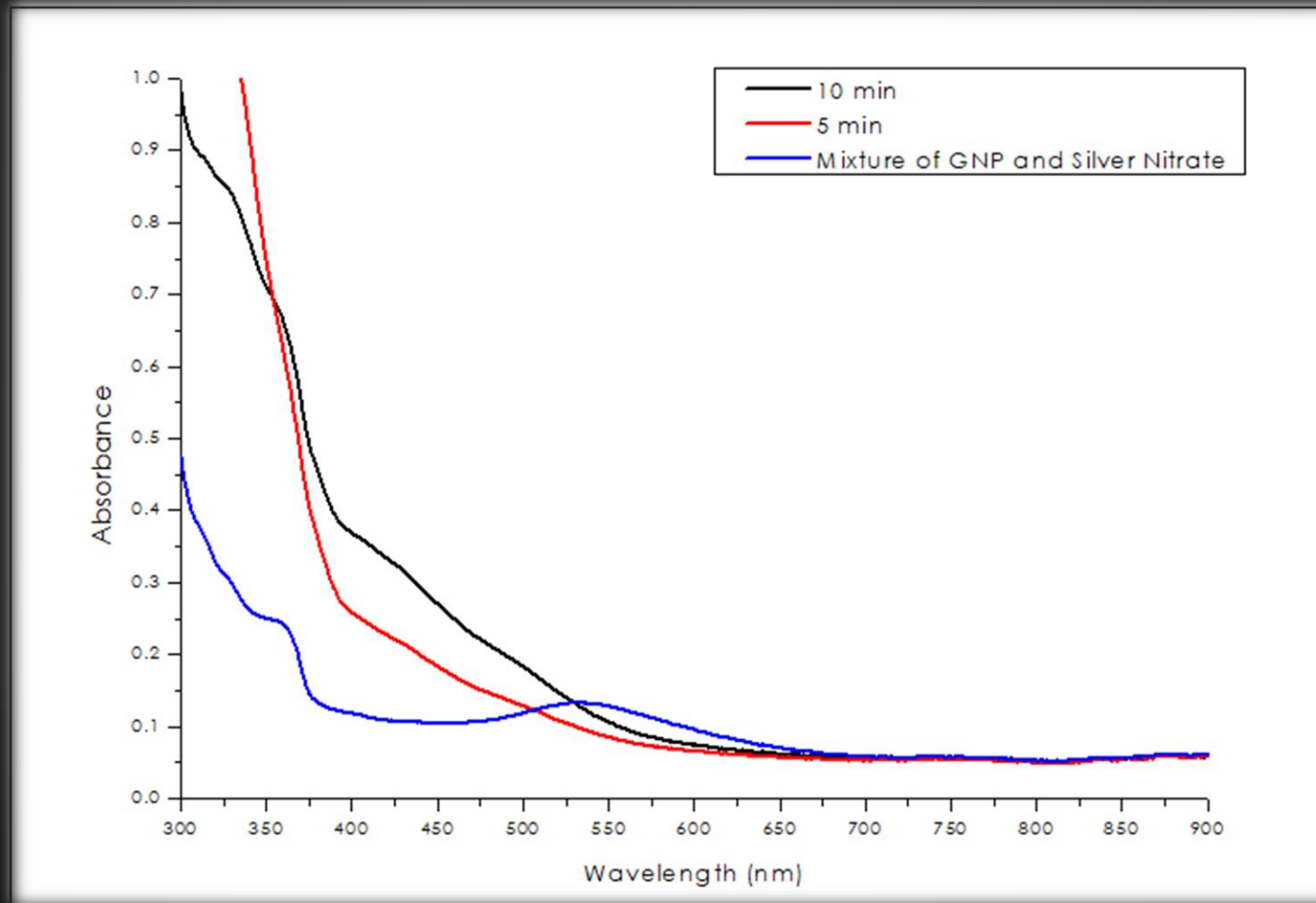


Experiment - II

GNP + 0.12mM Silver Nitrate added in 15 ml of 0.03 mM Tannic acid at the rate of 1 cc/min for 5 min

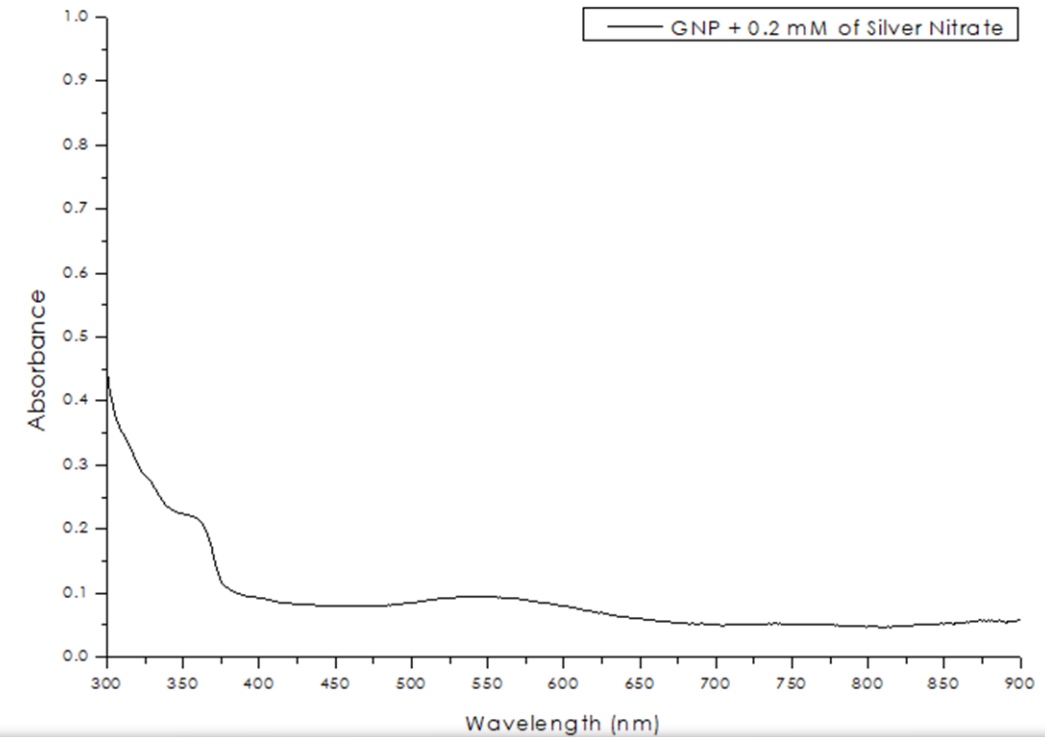
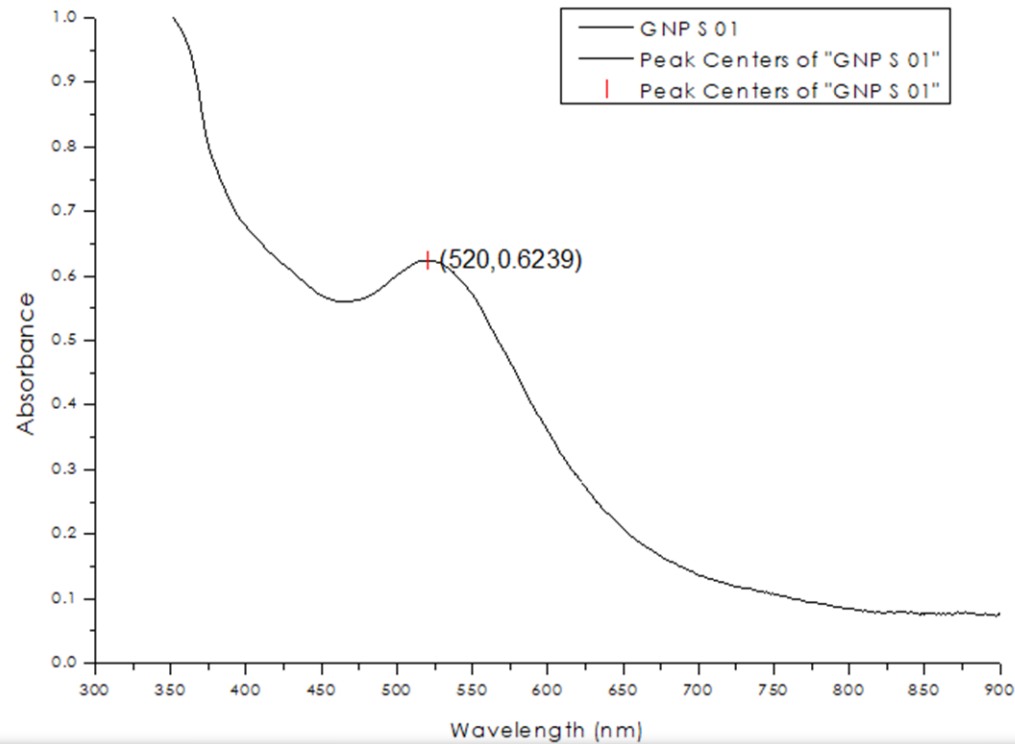


Centrifuged GNP + 0.12mM Silver Nitrate added in 15 ml Tannic acid at the rate of 1 cc/min for 10 min and 5 min, respectively



Experiments III and IV

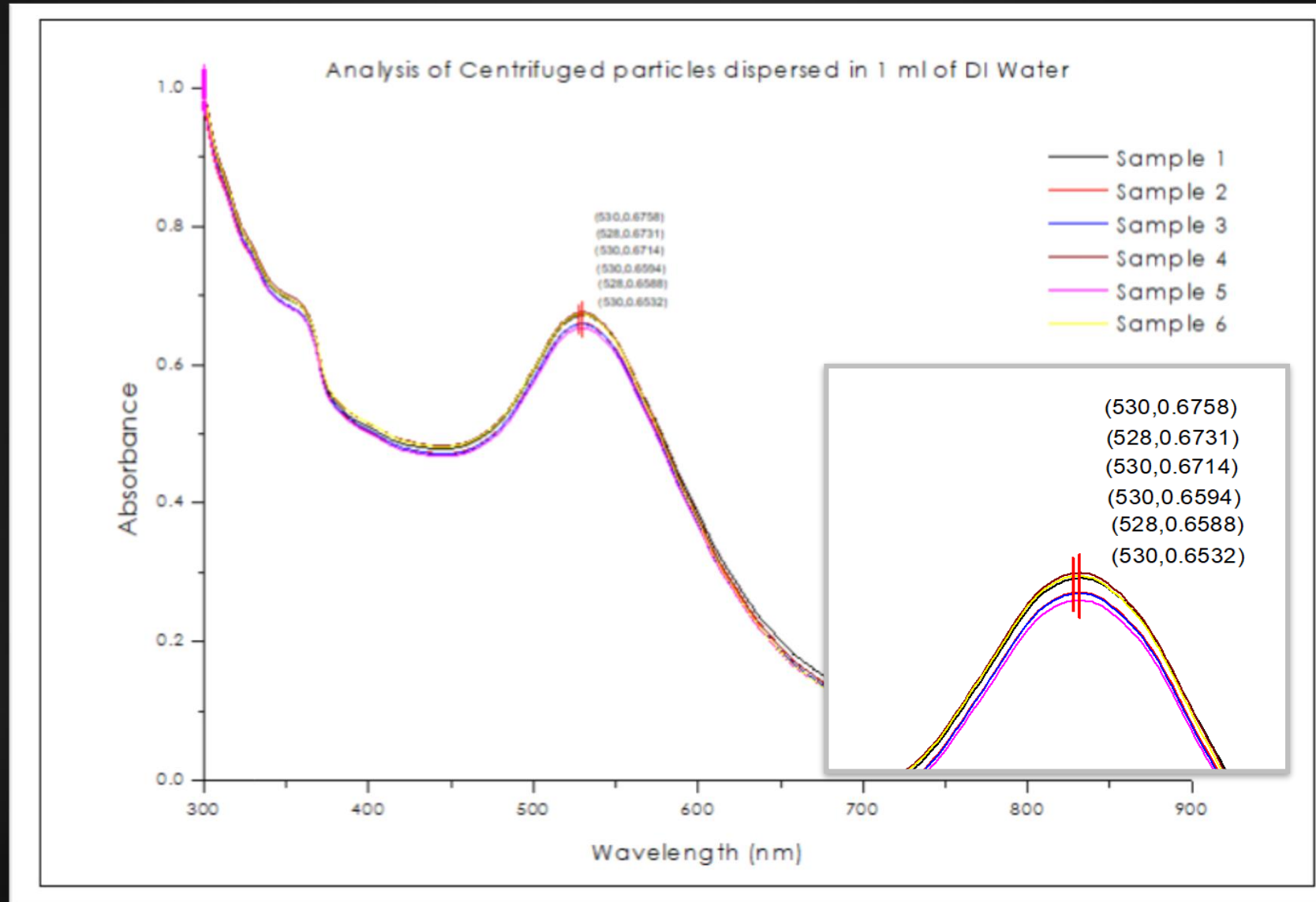
Centrifuged and Dispersed GNP + 0.2 mM Silver Nitrate added in 15 ml of 0.03 mM Tannic acid at the rate of 1 cc/min for 15 min and 20 min, respectively



Experiments III and IV

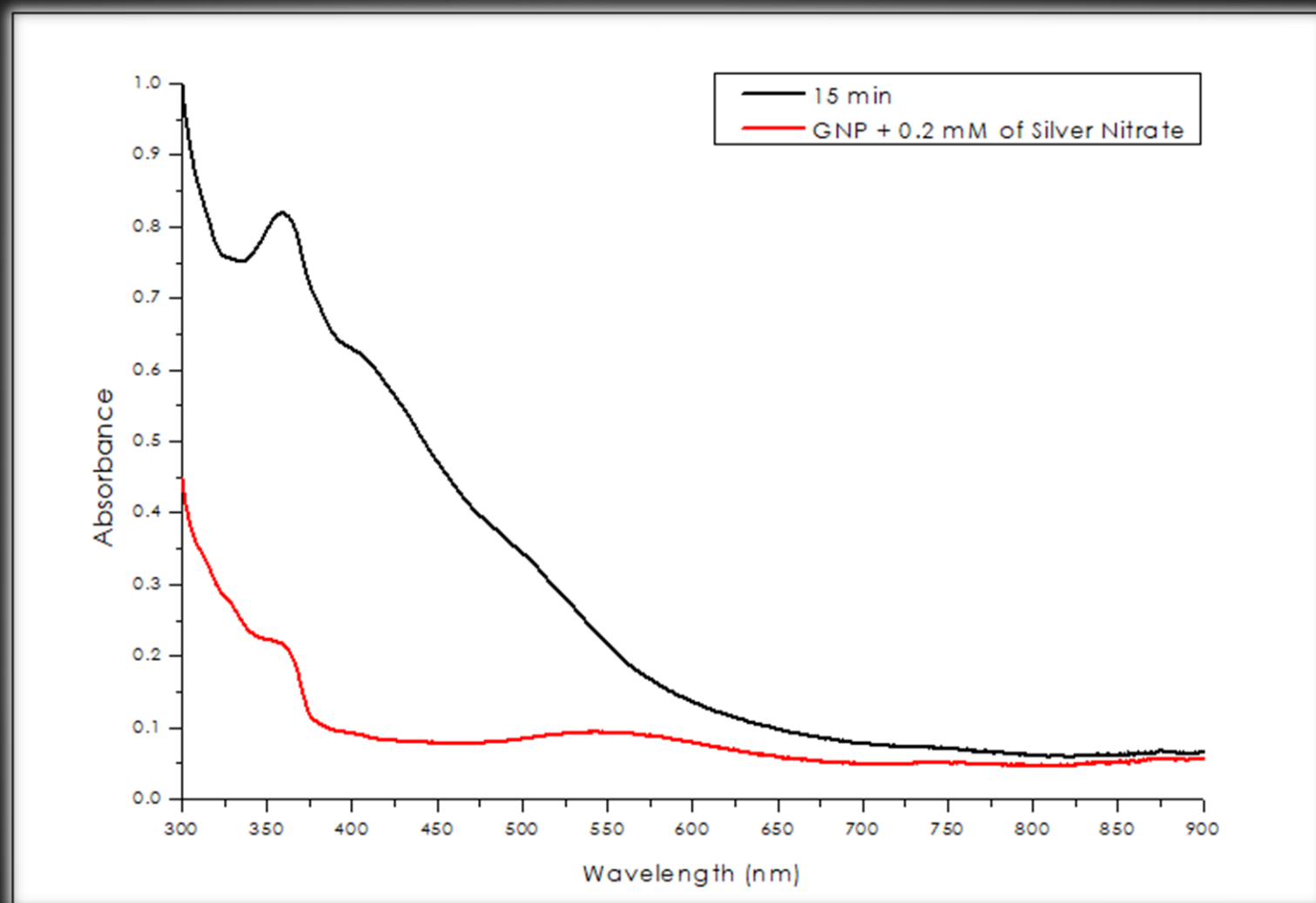
Centrifuged and Dispersed GNP + 0.2 mM Silver Nitrate added in 15 ml of 0.03 mM Tannic acid at the rate of 1 cc/min for 15 min and 20 min, respectively

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Experiment - III

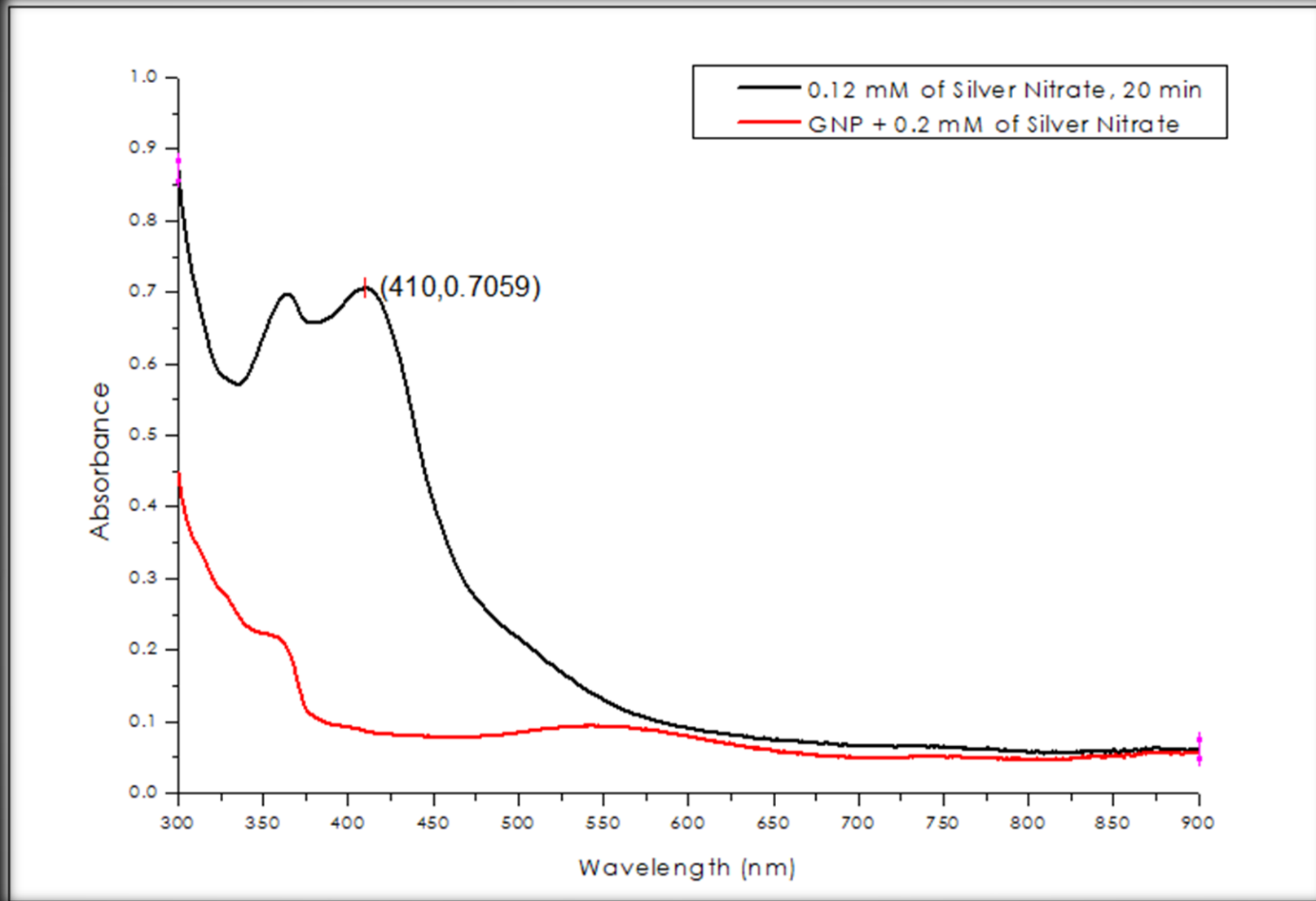
Centrifuged and dispersed GNP + 0.2 mM Silver Nitrate added in 15 ml of 0.03 mM Tannic acid at the rate of 1 cc/min for 15 min



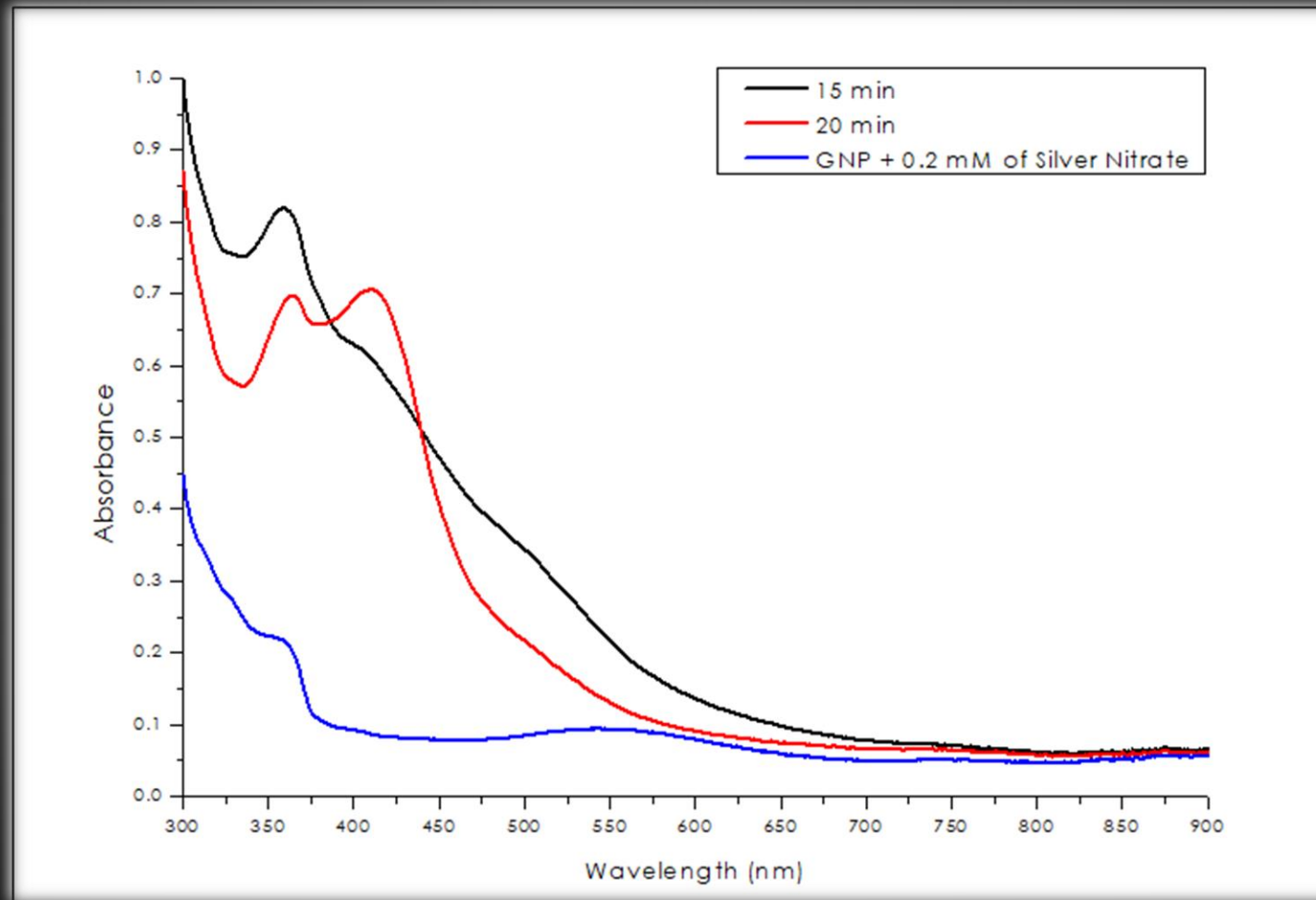
Experiment - IV

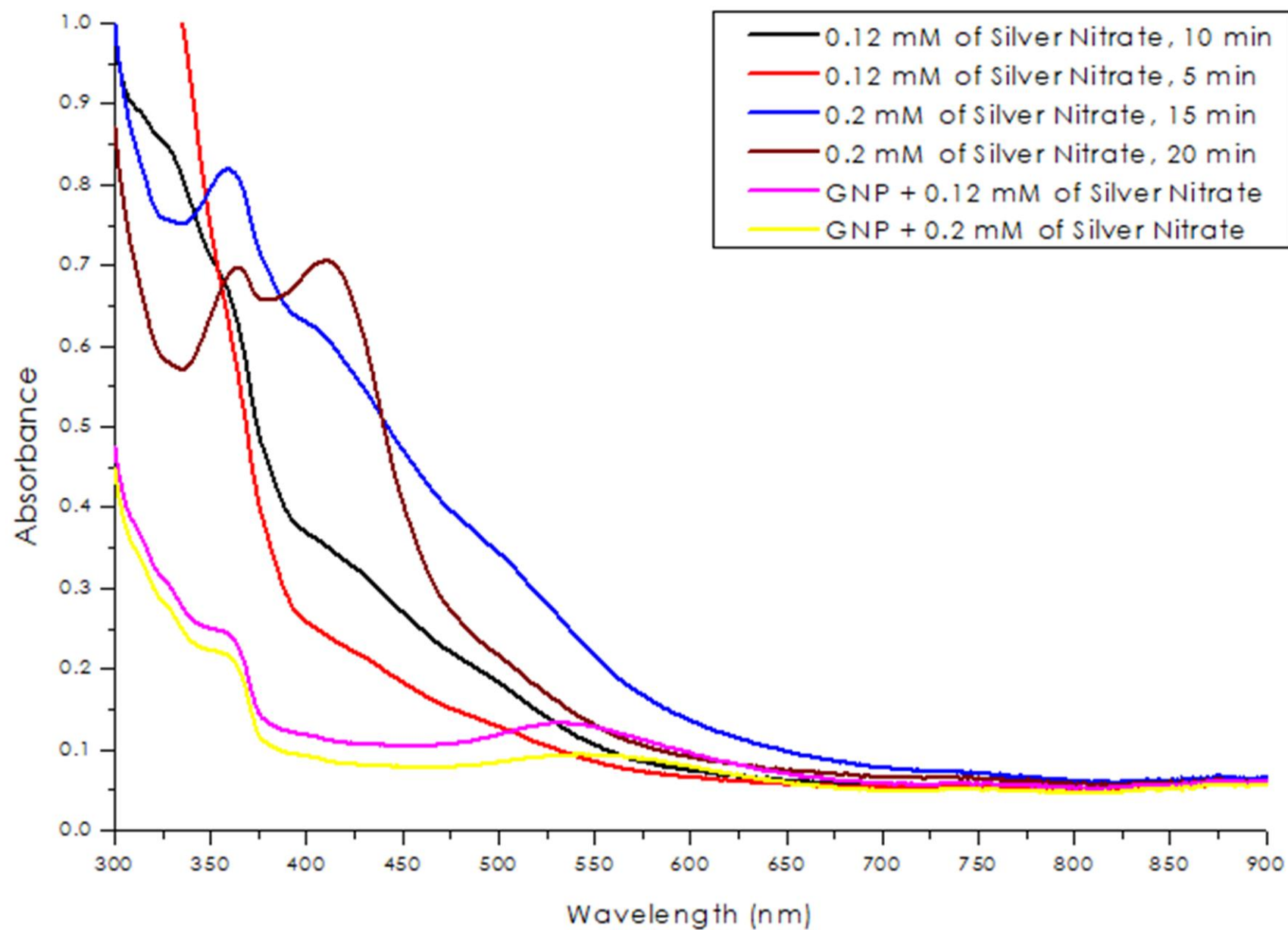
Centrifuged and dispersed GNP + 0.2 mM Silver Nitrate added in 15 ml of 0.03 mM Tannic acid at the rate of 1 cc/min for 20 min

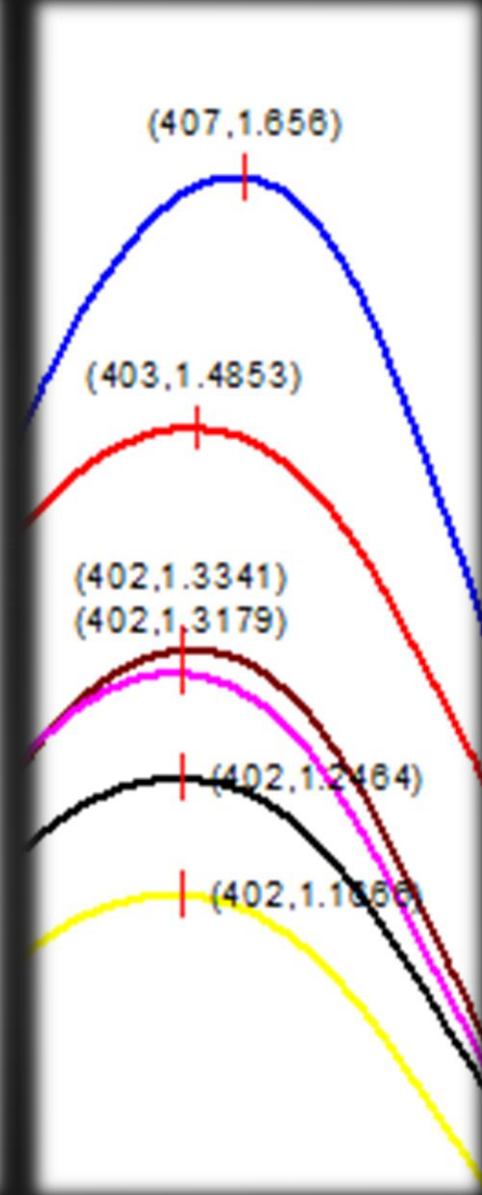
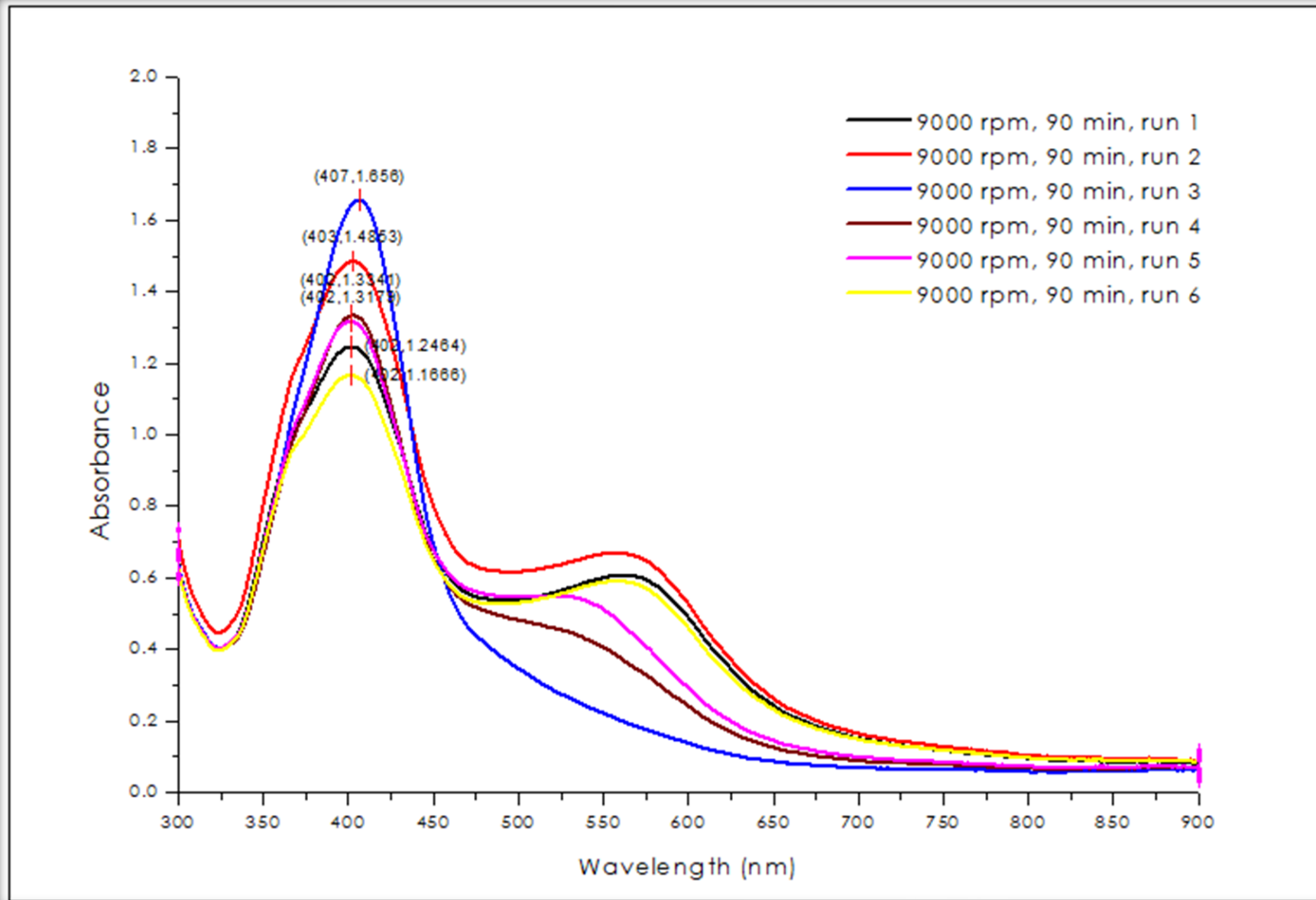
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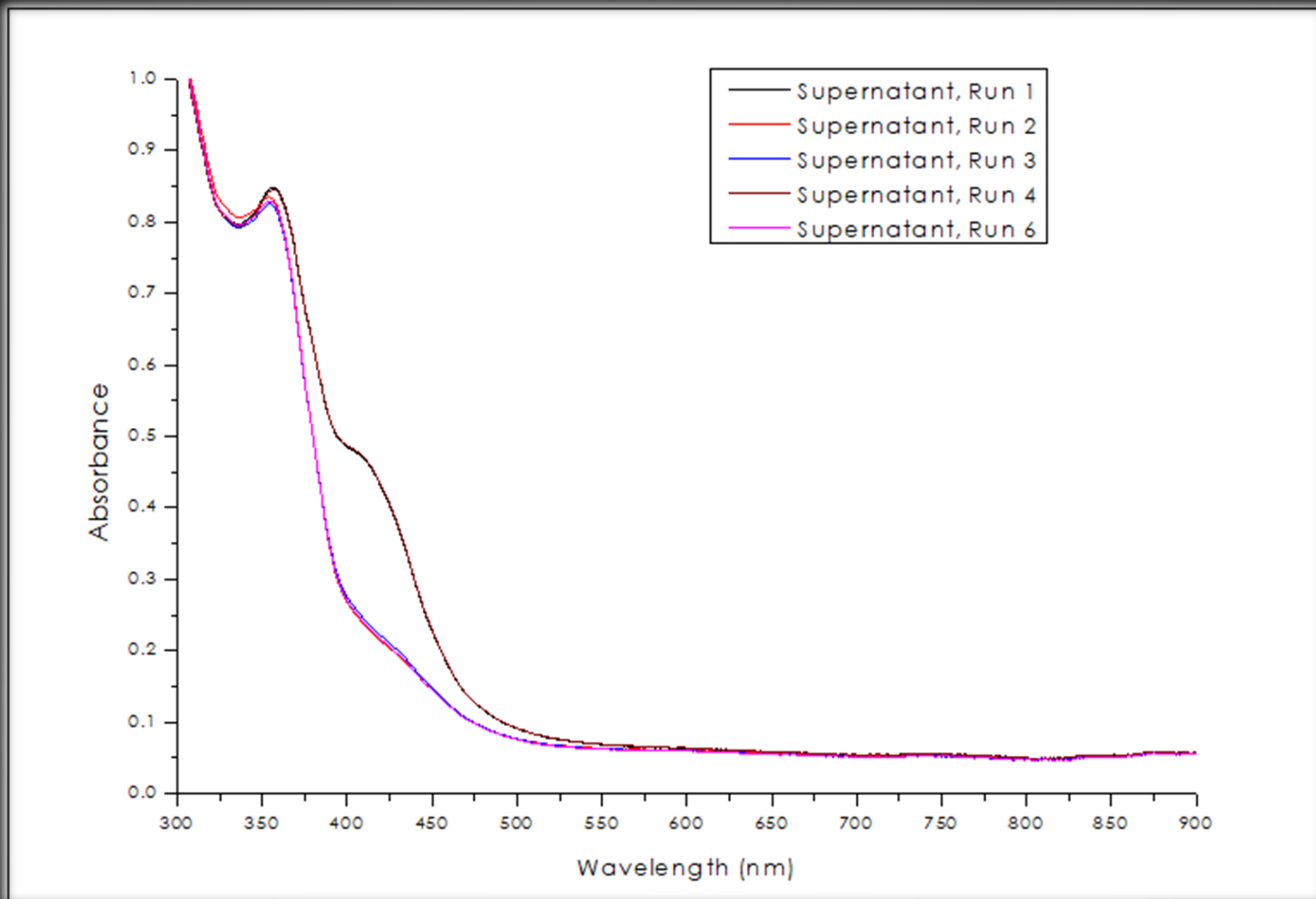
Centrifuged and Dispersed GNP + 0.12mM Silver Nitrate added in 15 ml Tannic acid at the rate of 1 cc/min for 15 min and 20 min, respectively



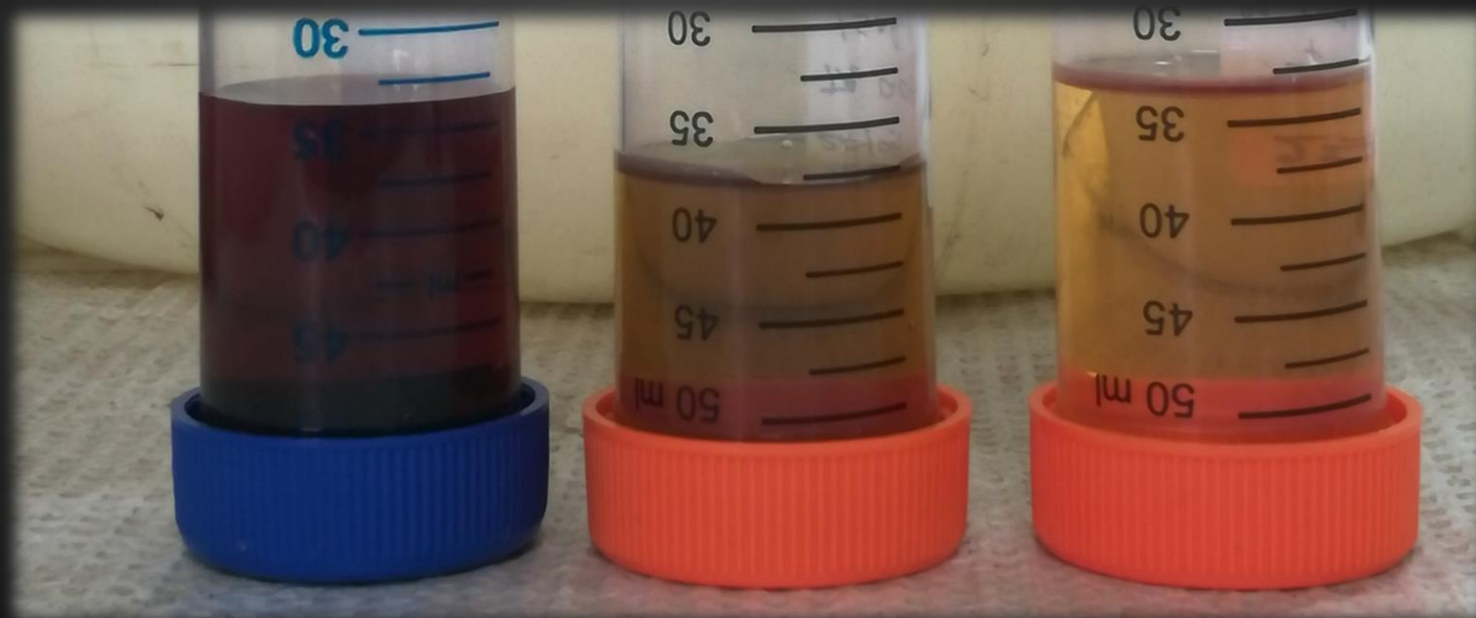
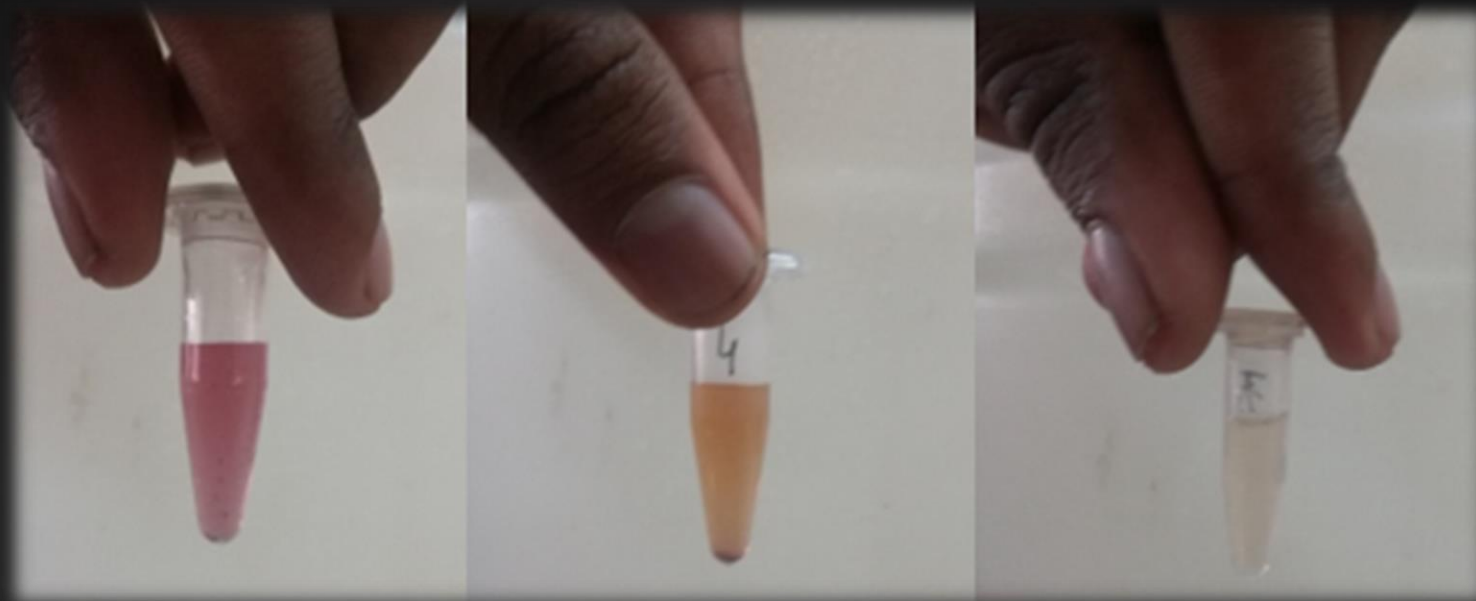




UV-Visible Spectra of Silver Nanoparticle samples centrifuged at 9000 rpm, 90 min. Runs 1,2 and 6 are from sample 1 while the remaining are from sample 2.



UV-Visible Spectra of Supernatant liquids of Silver Nanoparticle solutions



Strain Sensing

- Change in resistance on application of strain.
- Wearable Strain Sensors – used in health monitoring.
- Inkjet Printing – Easiest way to print Silver Nanostructures.
- Wettability of Substrate.

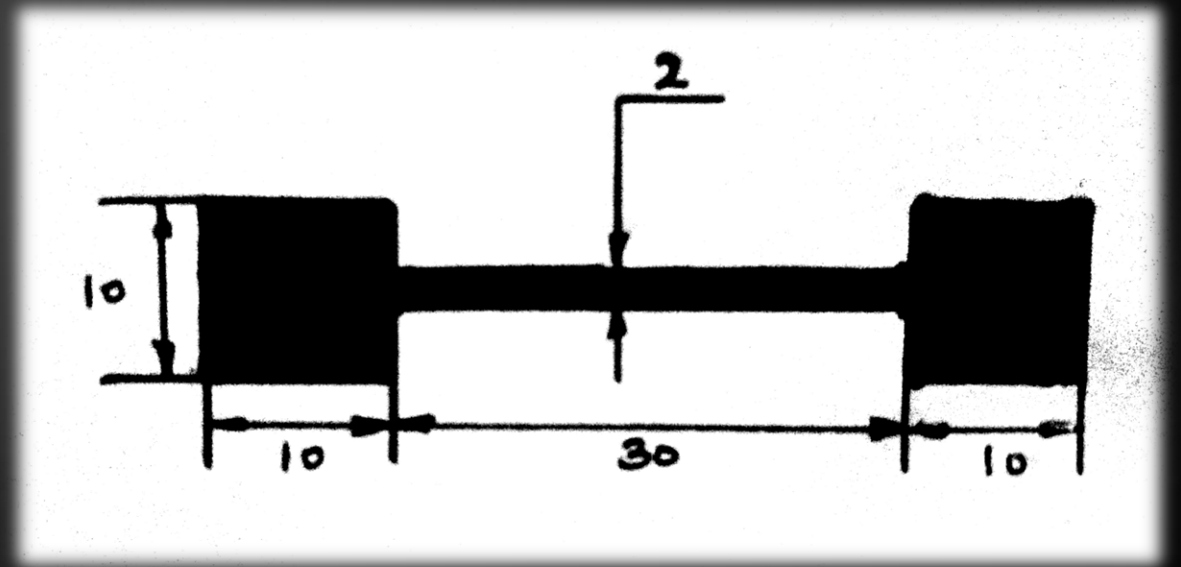
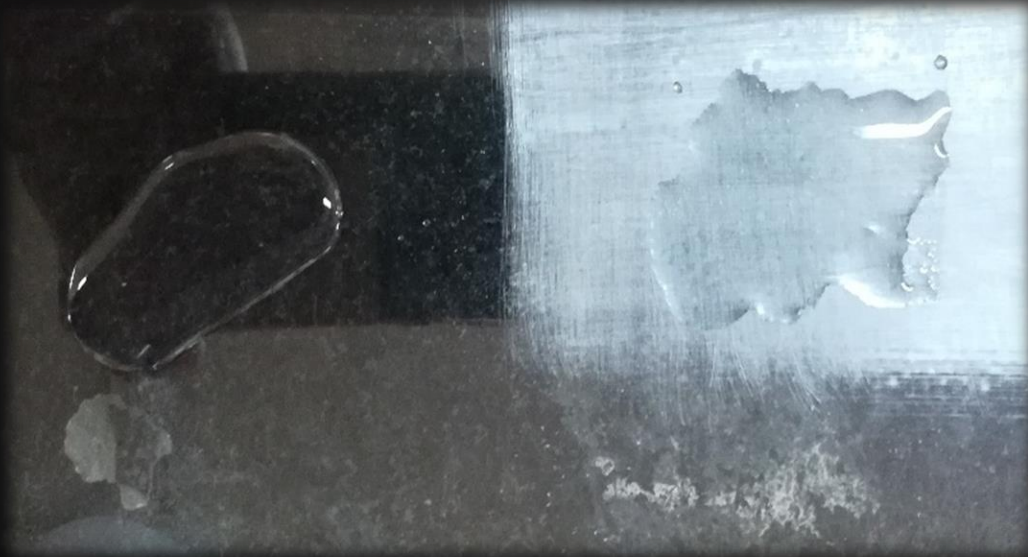
Determination of Loading

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Cartridge No	Run	Initial Weight (g)	Final Weight (g)	Loading (mg/cm ²)
1	1	18.63	18.43	1.6
	2	18.63	18.43	1.6
	3	18.62	18.41	1.68
1.626667				
2	1	18.62	18.41	1.68
	2	18.62	18.4	1.76
	3	18.62	18.4	1.76
1.733333				
3	1	18.62	18.34	2.24
	2	18.62	18.37	2
	3	18.62	18.37	2
2.08				
4 (Wide Reservoir)	1	19.72	19.4	2.56
	2	19.72	19.48	1.92
	3	19.72	19.48	1.92
	4	19.72	19.5	1.76
2.04				



- Materials – Polyethylene Terephthalate(PET), Polyimide tape, Photo paper (Kodak)
- Roughening of PET and Polyimide Surfaces
- Three Coatings each of Potassium Halide and Silver Nitrate (KKKAAA).



Photographic Reduction

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- Exposure to Halogen Light for 10 mins.
- Immersion in ID 78 Photo Developer

ID 78 Photo Developer

Sodium Sulphite – 20 g

Quinol – 2.4 g

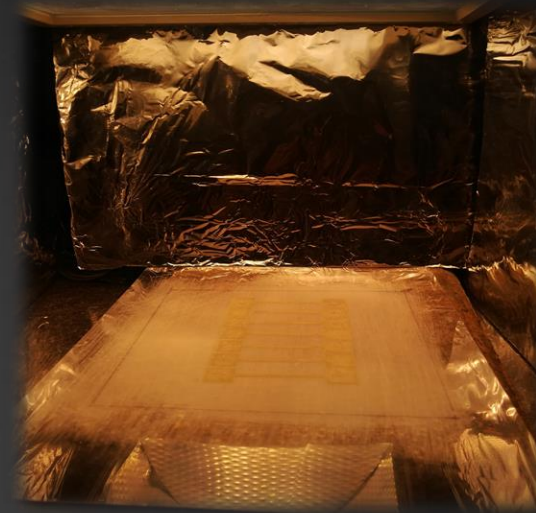
Sodium Carbonate – 12.4 g

Phenidone – 0.5 g

Potassium Bromide – 0.4 g

All dissolved in 200 ml of deionized water

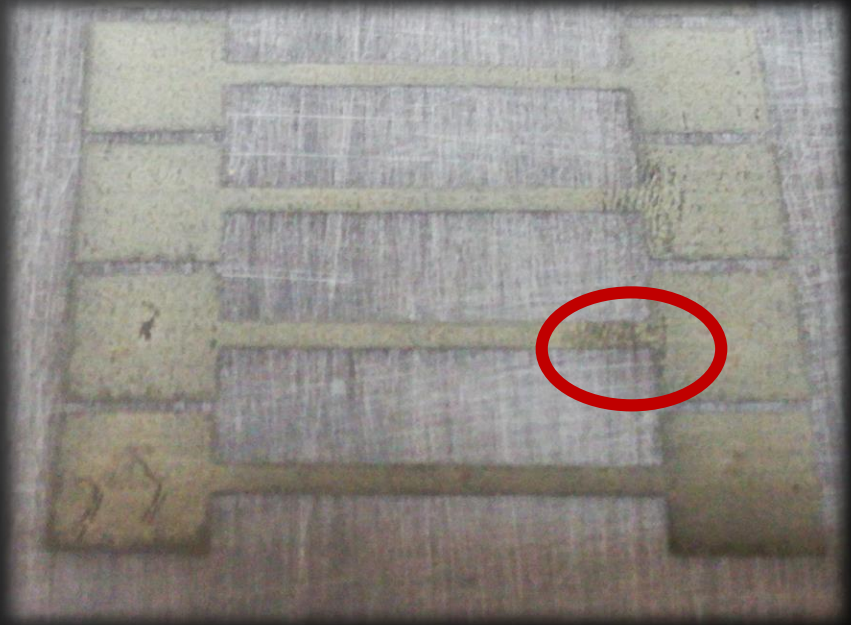
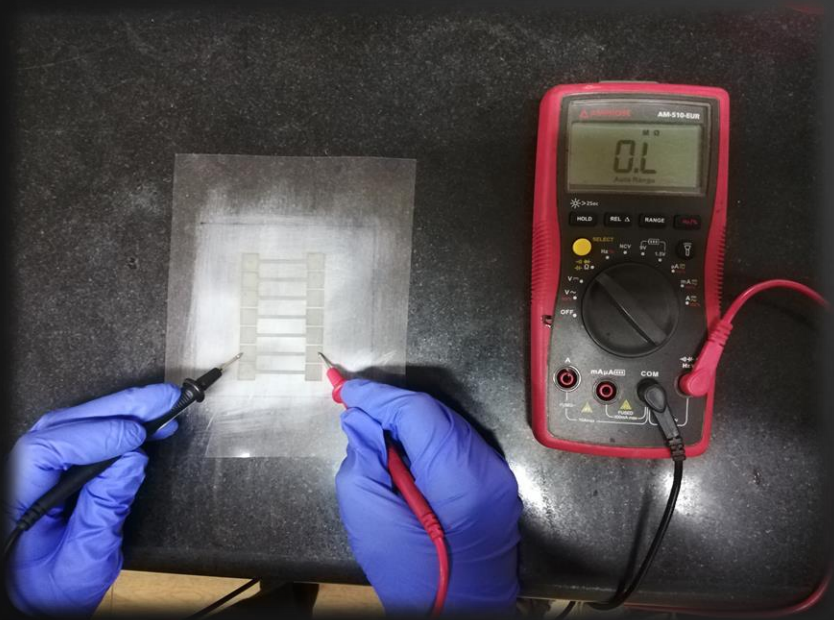
- Immersion for 10 minutes.
- Drying



Measurement of Resistances

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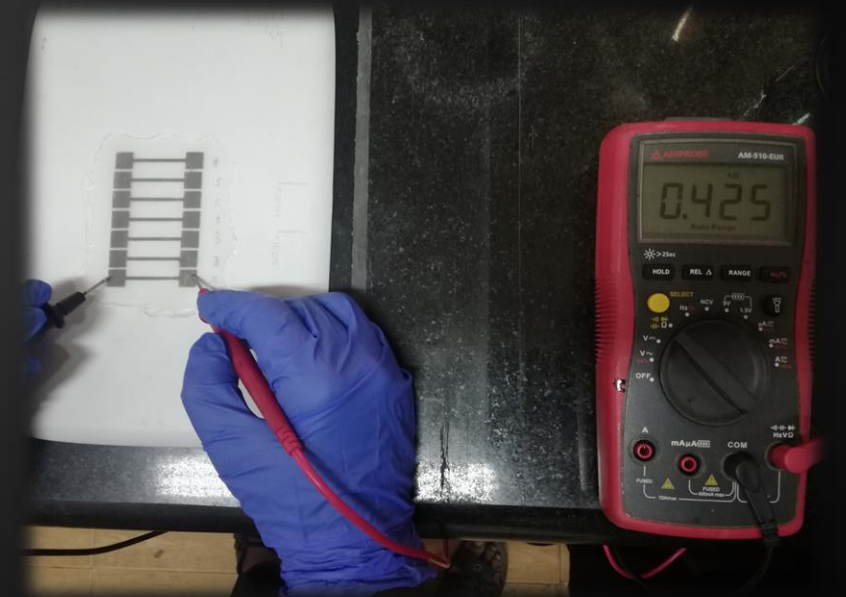
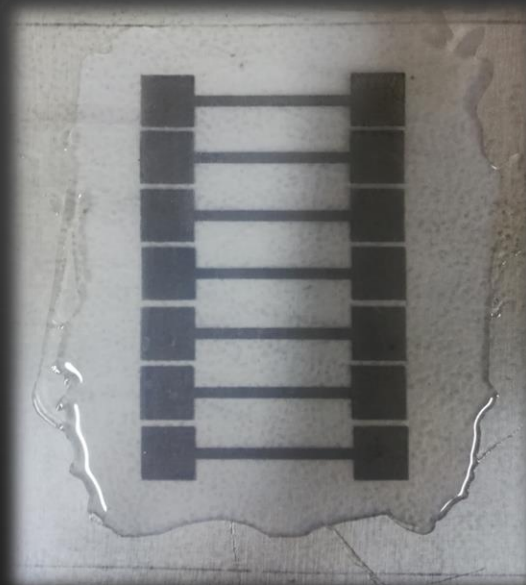
Sample No	PET (Roughened)	Polyimide tape (Roughened)	Photo paper (Kodak)
1	177.1	166.8	9760
2	332.9	0	7560
3	578.0	109.1	14510
4	201.8	242.9	8790
5	386.0	123.1	3970
6	0	182	12850
7	144.1	116.4	4950



Exfoliation of Samples using Dragonskin

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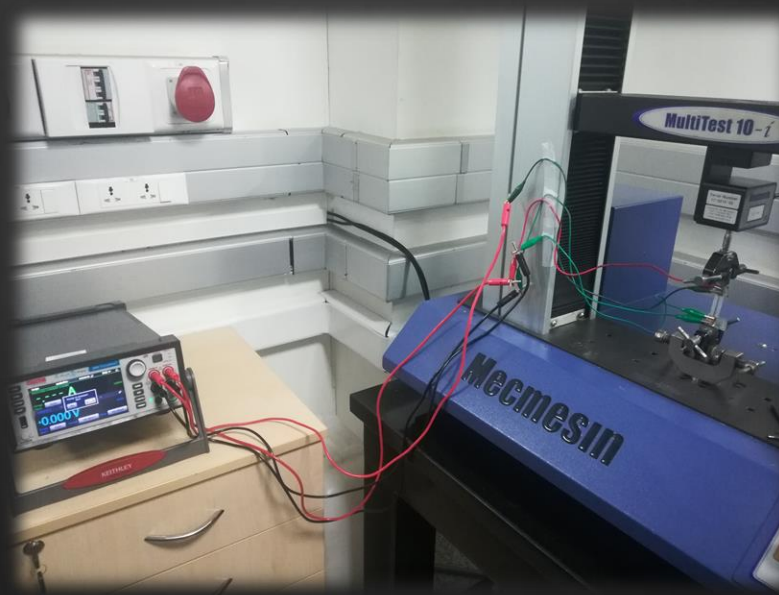
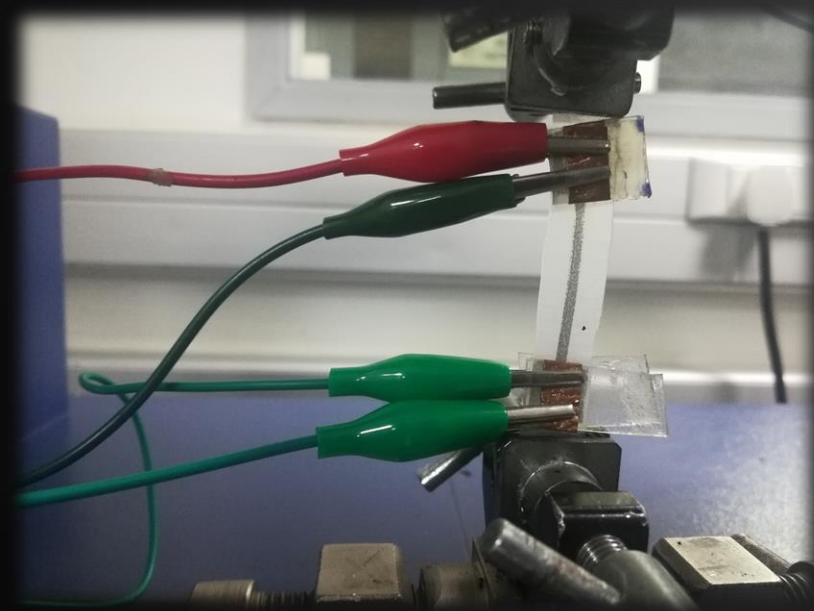
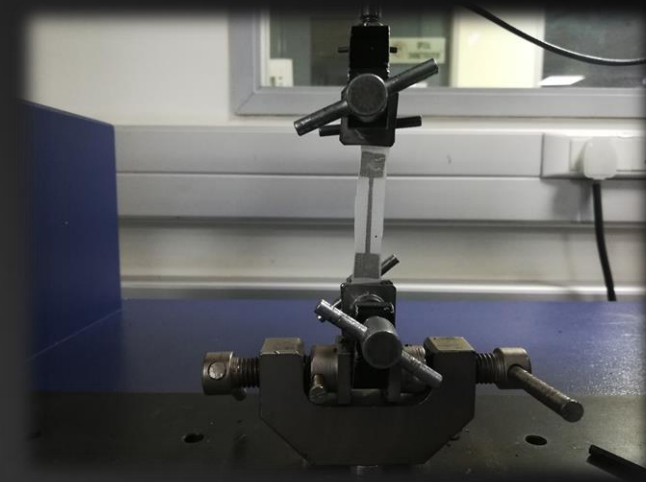
- Dragonskin – Stretchable, Hydrophobic
- Mixing Equal Volumes/Weights of Part A and Part B material
- Applying and Curing



Mechanical Characterization of the Sample

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- Preparing the Sample
- Four-probe testing using Keithley – 2450 Sourcemeter

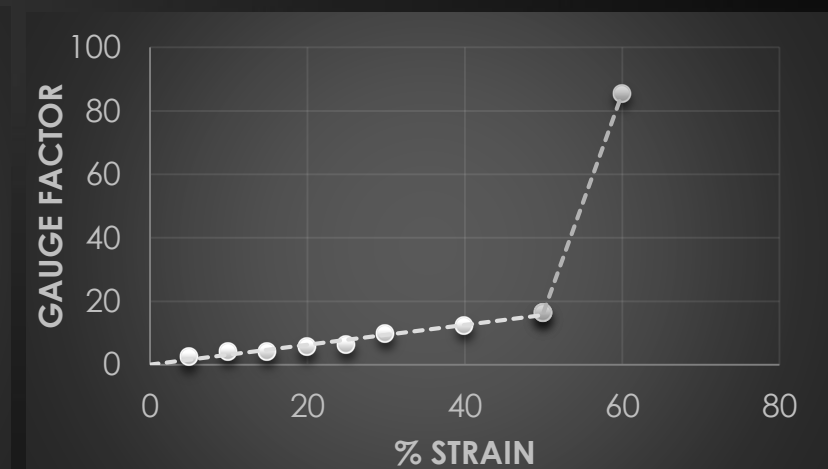
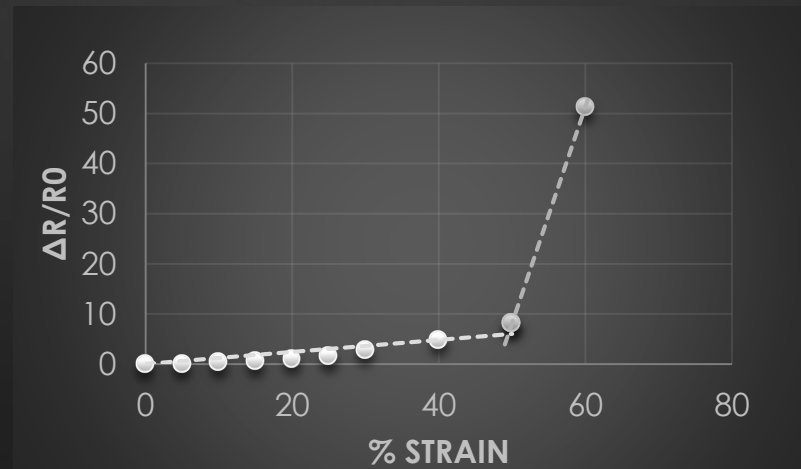
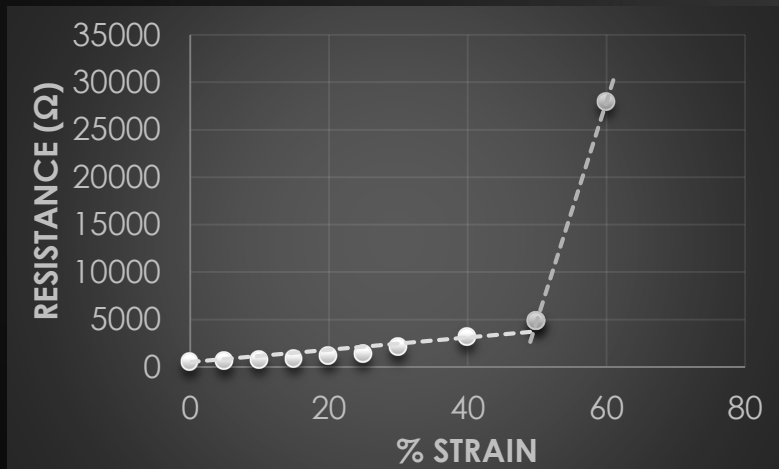


Static Testing

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- Strain vs Resistance

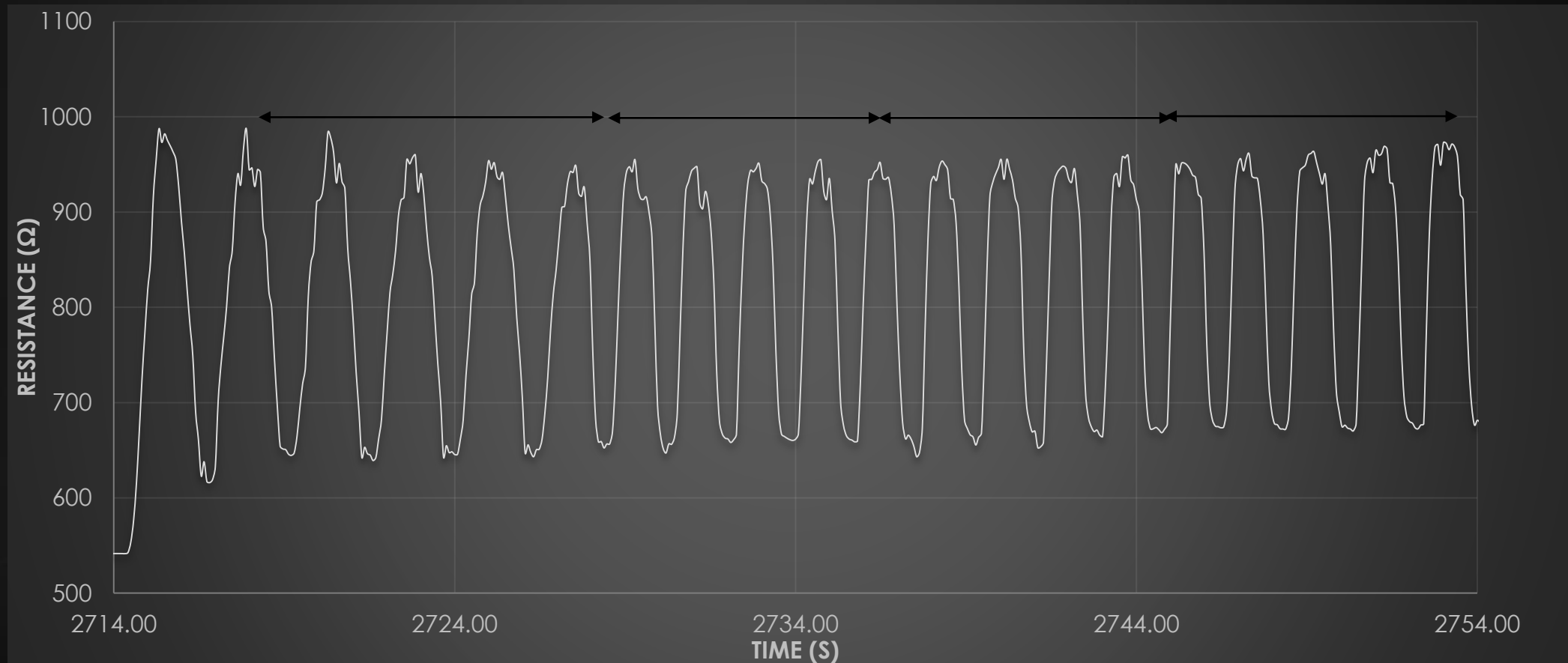
% Strain	Length l (mm)	Resistance (Ω)	$\Delta R/R_0$	Gauge Factor
0	28	535	0	
5	29.4	600	0.121495	2.429907
10	30.8	762	0.424299	4.242991
15	32.2	863	0.613084	4.087227
20	33.6	1129	1.11028	5.551402
25	35	1384	1.586916	6.347664
30	36.4	2096	2.917757	9.725857
40	39.2	3168	4.921495	12.30374
50	42	4936	8.226168	16.45234
60	44.8	27973	51.28598	85.47664



Dynamic Testing

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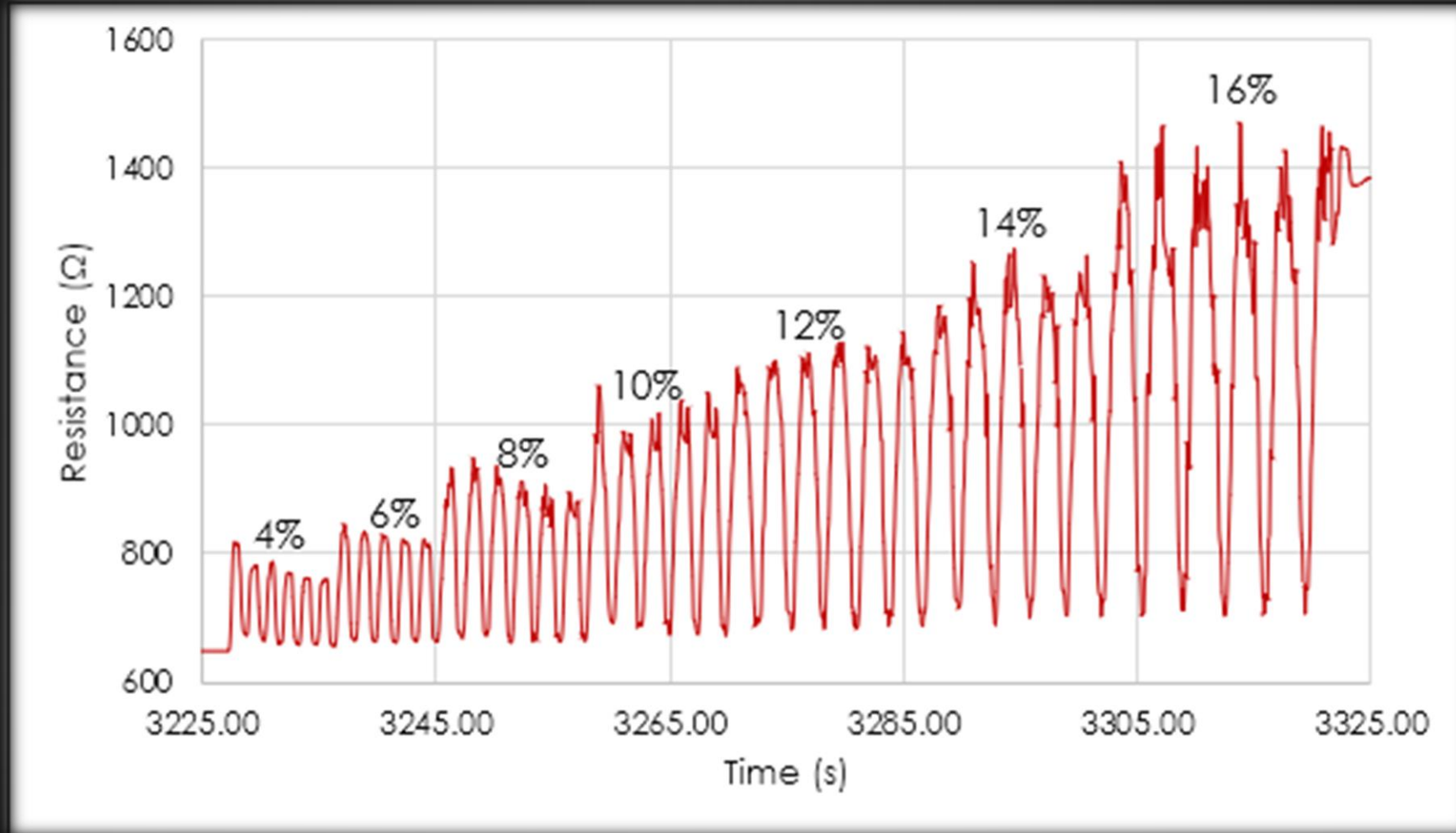
- Effect of Frequency (Displacement Rate)
- 200 mm/min to 800 mm/min in steps of 200 mm/min, 10% strain, 5 Cycles.



Dynamic Testing

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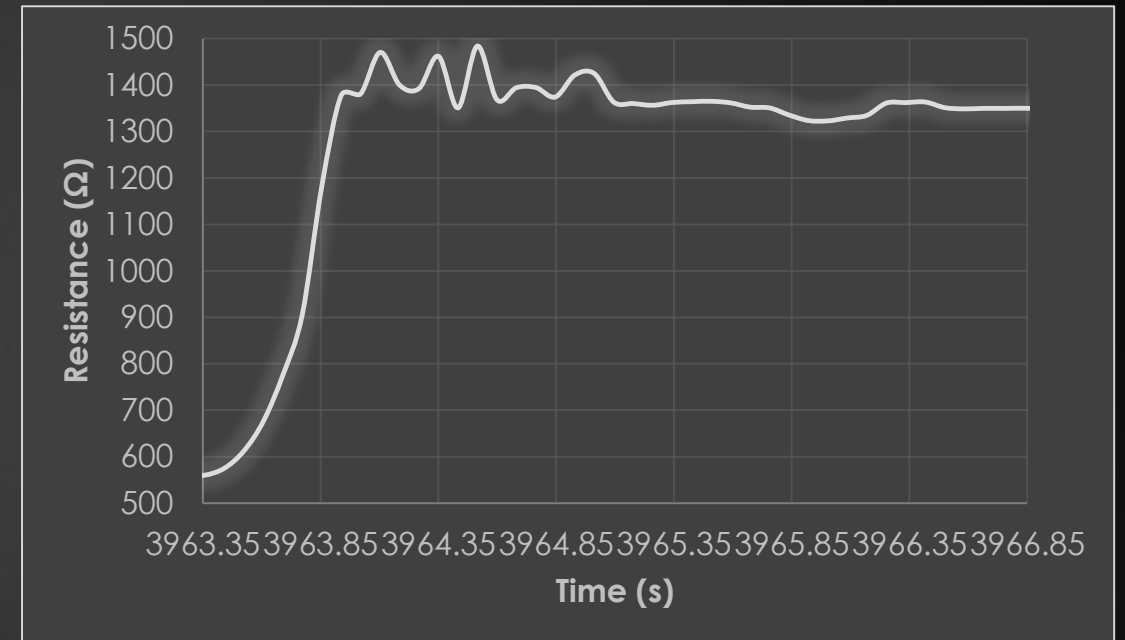
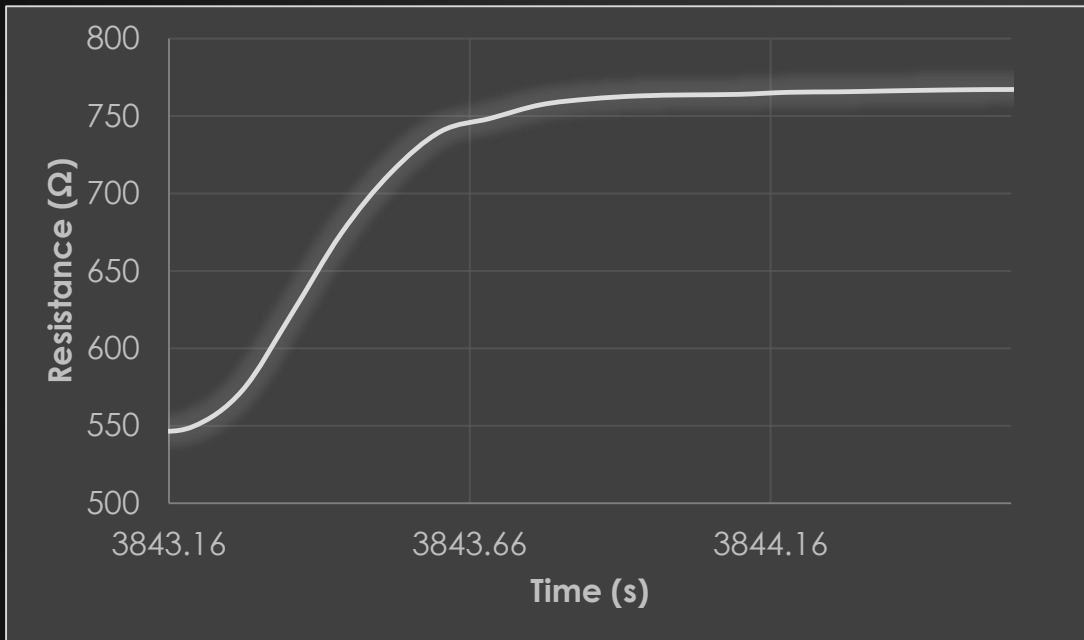
- Effect of Strain
- 4% to 16% in steps of 2%, 200 mm/min, 5 Cycles.



Dynamic Testing

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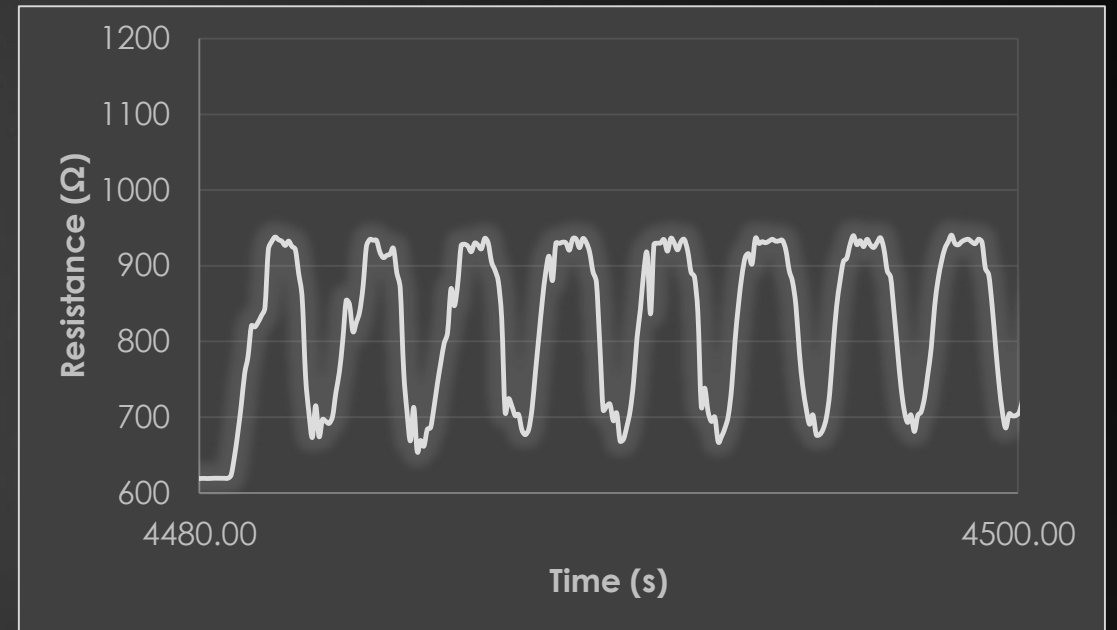
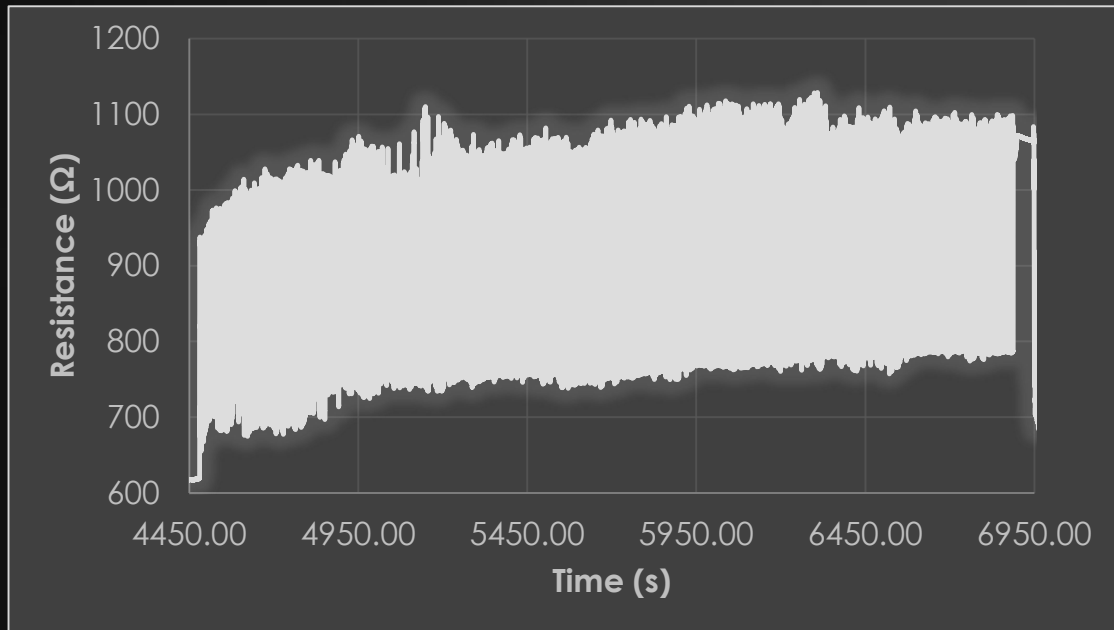
- Response time
- 5% and 10% strain, 1000 mm/min



Dynamic Testing

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- Fatigue Testing for 1000 Cycles
- 10% strain, 200 mm/min



Thank you!