CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Introduction:

In this chapter, the gained results are being reviewed and analyzed.

4.2. Effect of an Applying voltage and Electrode position on the amplitude of deflection:

4.2.1.Electrical Potential and Amplitude of deflection under applied voltage (32 mV) when 100% of cantilever covered with electrode pad: Figure (4.1)

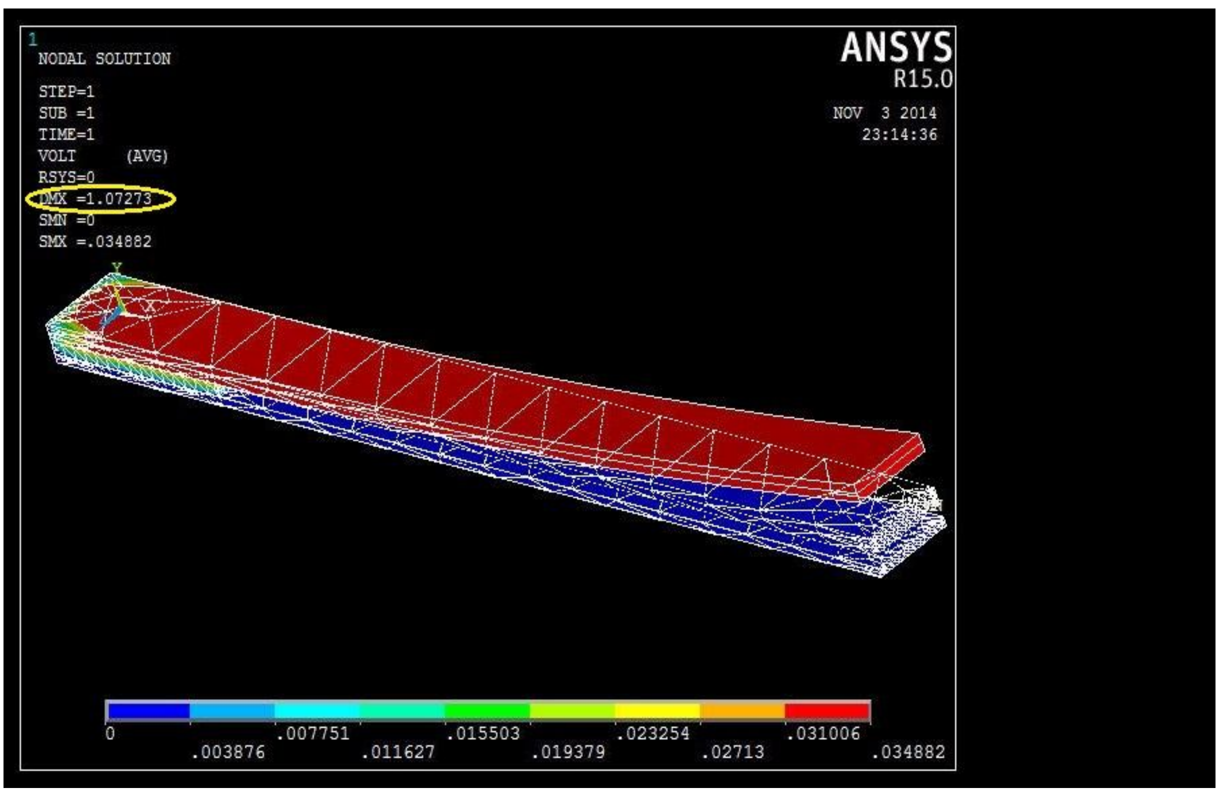


Figure (4.1): Electrical Potential and Amplitude of deflection under Applied voltage (32 mV) for 100% covered

It is noticed that the maximum voltage potential concentrated in the pad layer which has the highest electrical conductivity (copper), however the amount of electricity reduced gradually in the actuator layer and isolator layer which made of semi-conductor (silicon) and SIO2 respectively until zero in base layer.

The above figure shows amplitude at the end of actuator layer due to electrostatic force which resulted from voltage difference. This amplitudeincreased gradually until it reaches the maximum value at the end of actuator because it is free end cantilever.

The DMX value that show in the above figure is the Maximum displacement (Amplitude of deflection) due to applied pull- in voltage (32 mV), as you know this applied voltage caused the amplitude of deflection exceed the one-third of the total gap which reach to the critical point, because the DMX=1.07273µm as shown above, as well as the one-third(1µm) of total gap (3µm) of cantilever is (1µm), So the 10% of cantilever covered with electrode pad reach to critical point of deflection when we applied (32 mV).

4.2.2 Electrical Potential andAmplitude of deflection under applied voltage (33 mV) when 90% of cantilever covered with electrode pad (starting from fixed part, and leaving the tip of the cantilever without electrode): Figure (4.2)

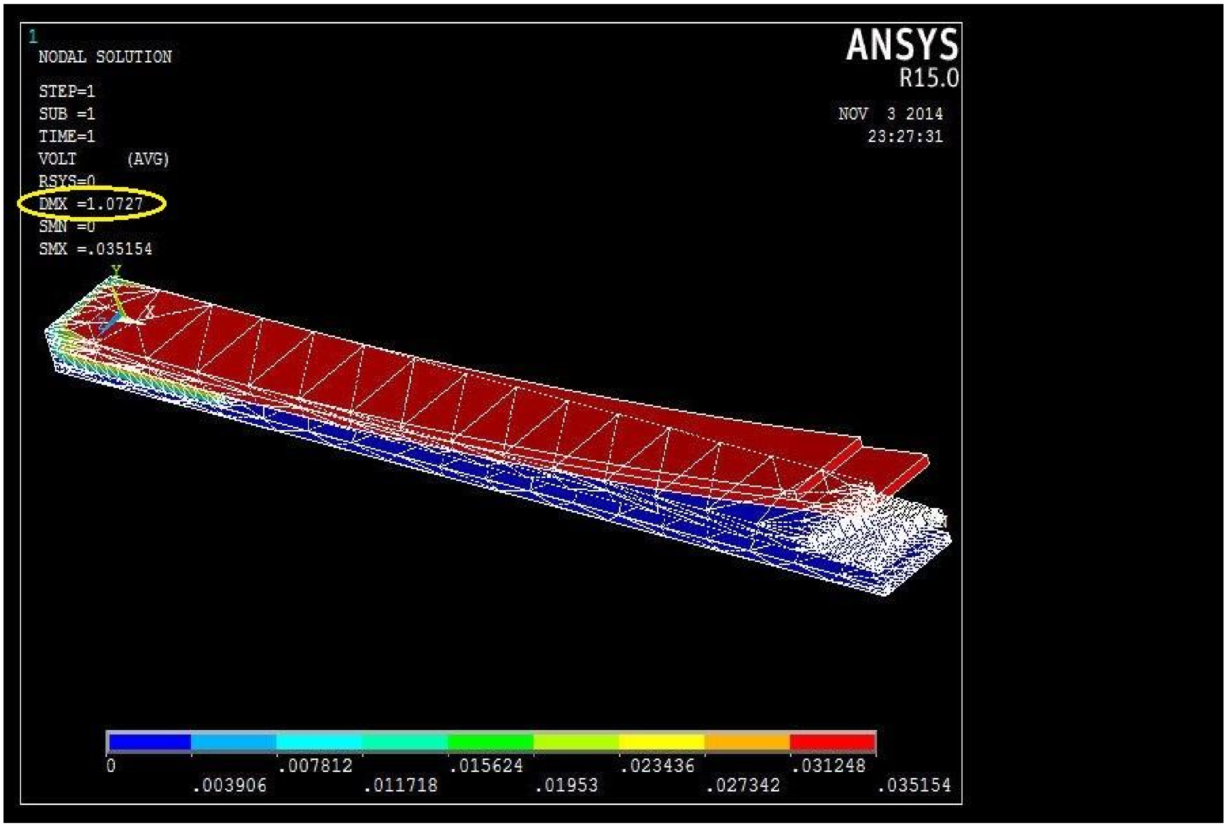


Figure (4.2): Electrical Potential and Amplitude of deflection under applied voltage (33 mV) for 90% covered

The DMX value that show in the above figure is the Maximum displacement (Amplitude of deflection) due to applied pull- in voltage (33 mV), as you know this applied voltage caused the amplitude of deflection exceed the one-third of the total gap which reach to the critical point, because the DMX=1.0727µm as shown above, as well as the one-third(1µm) of total gap (3µm) of cantilever is (1µm), So the 10% of cantilever covered with electrode pad reach to critical point of deflection when we applied (33 mV).

4.2.3. Electrical Potential andAmplitude of deflection under applied voltage (35 mV) when (L=160μm)Figure (4.3)

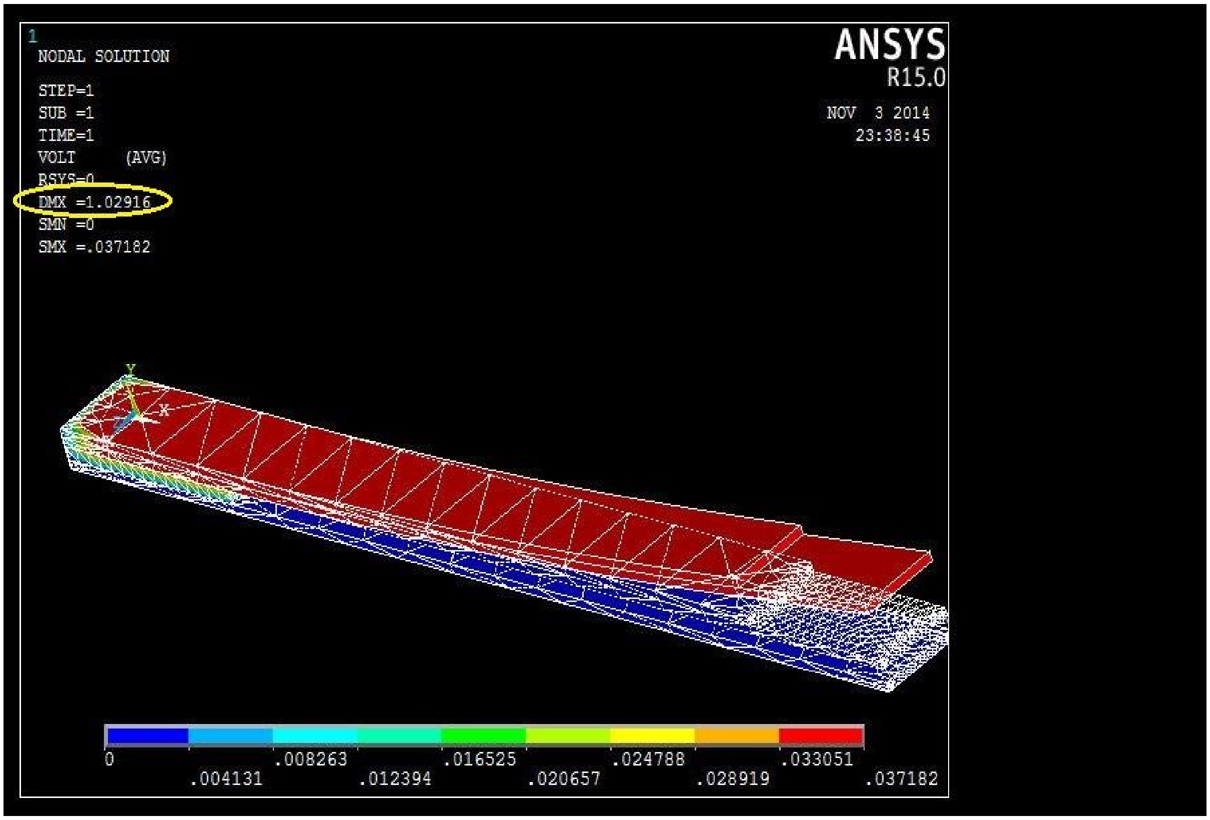


Figure (4.3): Electrical Potential and Amplitude of deflection under applied voltage (35 mV) for 80% covered

The DMX value that show in the above figure is the Maximum displacement (Amplitude of deflection) due to applied pull- in voltage (35 mV), as you know this applied voltage caused the amplitude of deflection exceed the one-third of the total gap which reach to the critical point, because the DMX=1.02916μm as shown above, as well as the one-third(1μm) of total gap (3μm) of cantilever is (1μm), So the 10% of cantilever covered with electrode pad reach to critical point of deflection when we applied (35 mV).

4.2.4. Electrical Potential andAmplitude of deflection under applied voltage (38 mV) when (L=140µm)Figure (4.4)

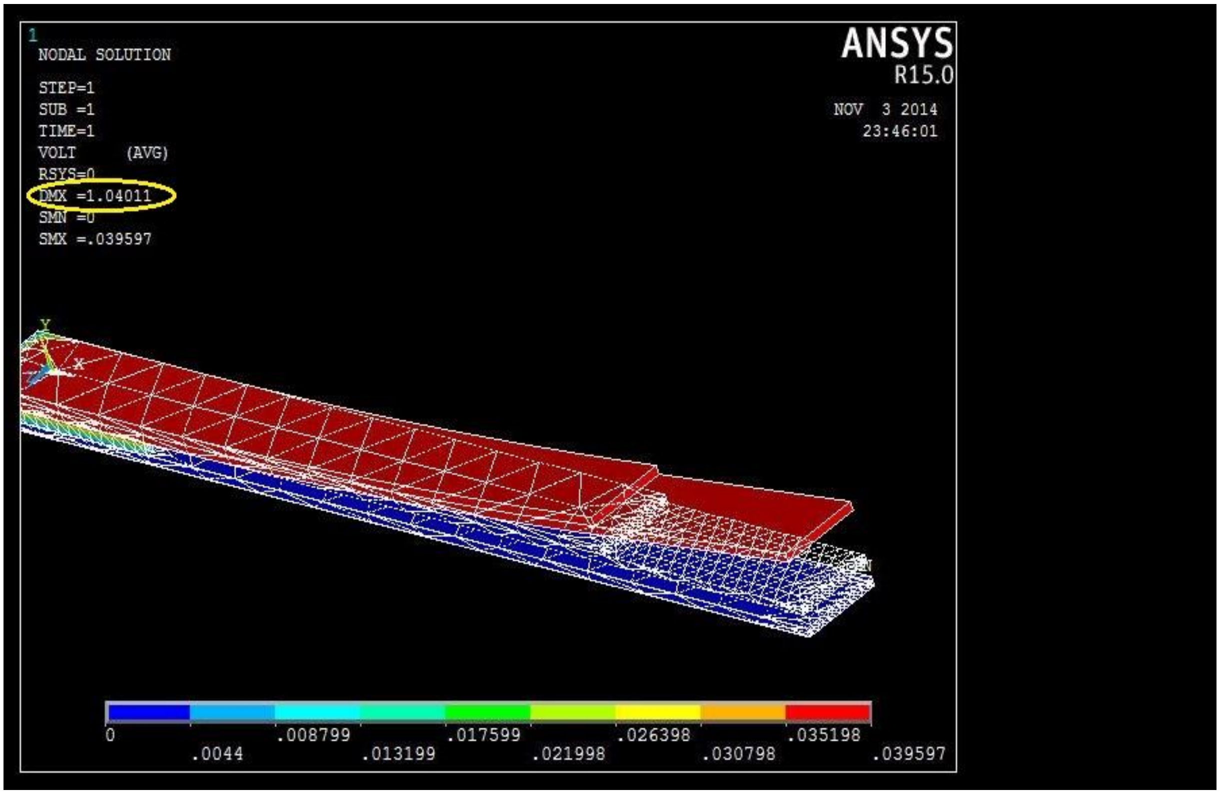


Figure (4.4): Electrical Potential and Amplitude of deflection under applied voltage (38 mV) for 70% covered

The DMX value that show in the above figure is the Maximum displacement (Amplitude of deflection) due to applied pull- in voltage (38 mV), as you know this applied voltage caused the amplitude of deflection exceed the one-third of the total gap which reach to the critical point, because the DMX=1.04011µm as shown above, as well as the one-third(1µm) of total gap (3µm) of cantilever is (1µm), So the 10% of cantilever covered with electrode pad reach to critical point of deflection when we applied (38 mV).

4.2.5. Electrical Potential andAmplitude of deflection under applied voltage (40 mV) when (L=120µm)Figure (4.5)

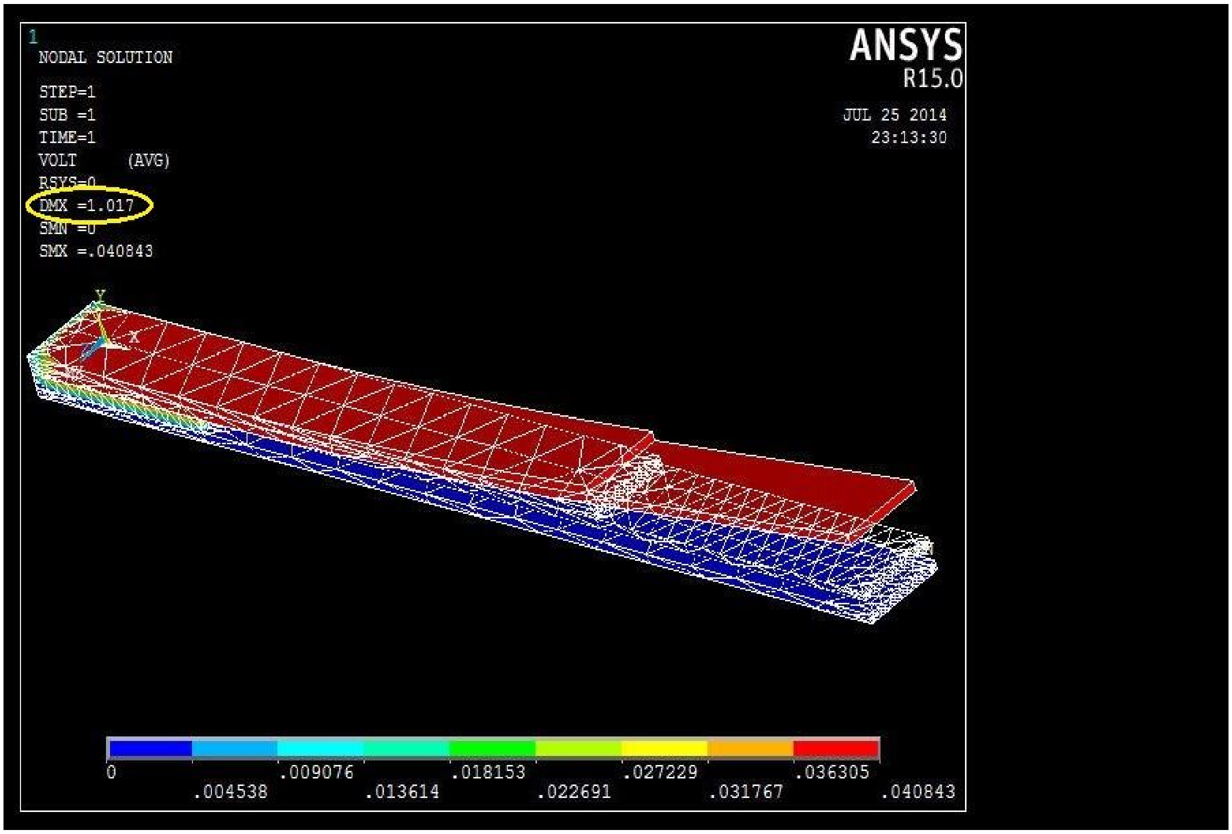


Figure (4.5): Electrical Potential and Amplitude of deflection under applied voltage (40 mV) for 60% covered

The DMX value that show in the above figure is the Maximum displacement (Amplitude of deflection) due to applied pull- in voltage (40 mV), as you know this applied voltage caused the amplitude of deflection exceed the one-third of the total gap which reach to the critical point, because the DMX=1.0170µm as shown above, as well as the one-third(1µm) of total gap (3µm) of cantilever is (1µm), So the 10% of cantilever covered with electrode pad reach to critical point of deflection when we applied (40 mV).

4.2.6. Electrical Potential andAmplitude of deflection under applied voltage (43 mV) (L=100µm)Figure (4.6)

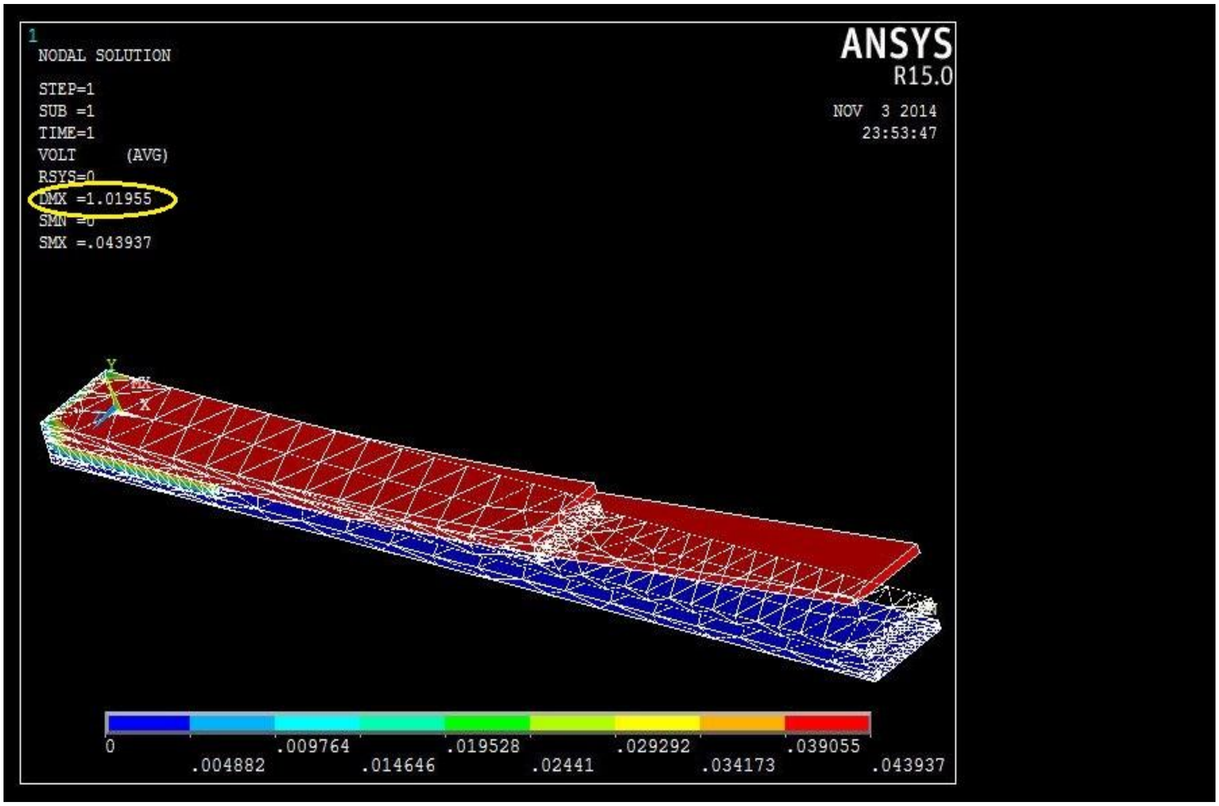


Figure (4.6): Electrical Potential and Amplitude of deflection under applied voltage (43 mV) for 50% covered

The DMX value that show in the above figure is the Maximum displacement (Amplitude of deflection) due to applied pull- in voltage (43 mV), as you know this applied voltage caused the amplitude of deflection exceed the one-third of the total gap which reach to the critical point, because the DMX=1.01955µm as shown above, as well as the one-third(1µm) of total gap (3µm) of cantilever is (1µm), So the 10% of cantilever covered with electrode pad reach to critical point of deflection when we applied (43 mV).

4.2.7 Electrical Potential andAmplitude of deflection under applied voltage (47 mV) when (L=80µm)Figure (4.7)

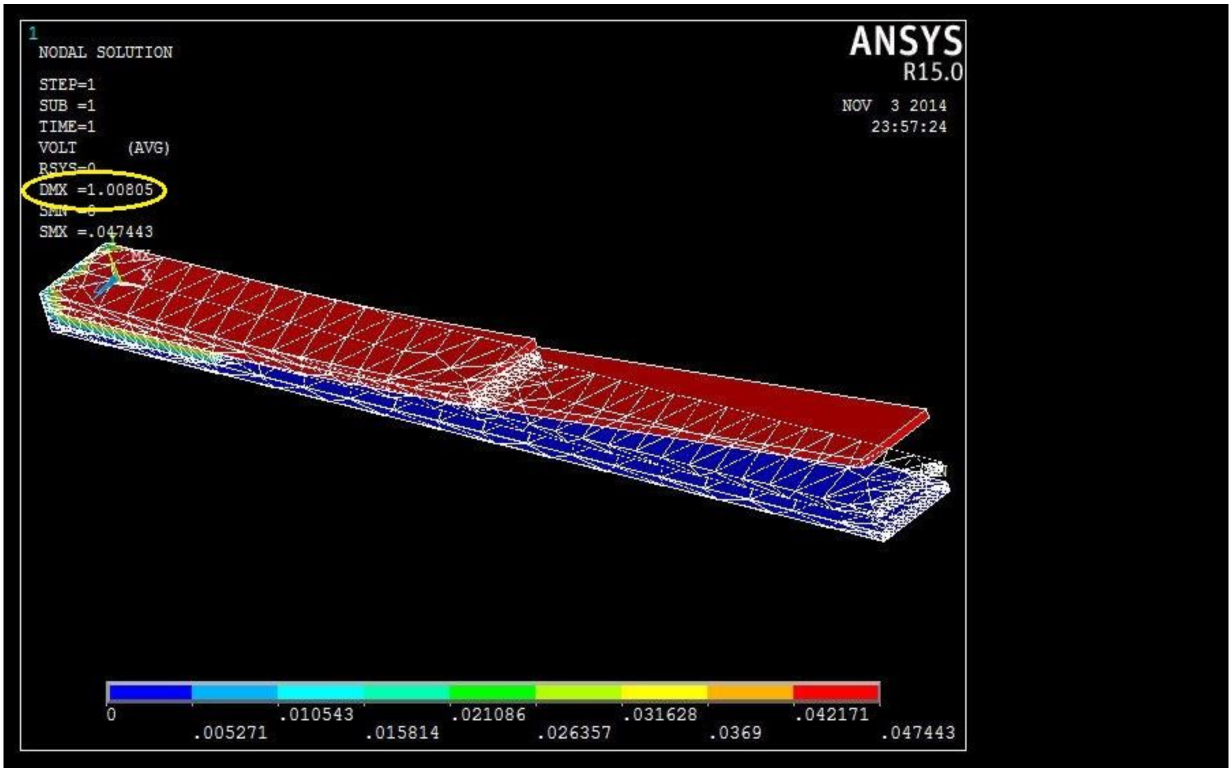


Figure (4.7): Electrical Potential and Amplitude of deflection under applied voltage (47 mV) for 40% covered

The DMX value that show in the above figure is the Maximum displacement (Amplitude of deflection) due to applied pull- in voltage (47 mV), as you know this applied voltage caused the amplitude of deflection exceed the one-third of the total gap which reach to the critical point, because the DMX=1.00805µm as shown above, as well as the one-third(1µm) of total gap (3µm) of cantilever is (1µm), So the 10% of cantilever covered with electrode pad reach to critical point of deflection when we applied (47 mV).

4.2.8 Electrical Potential andAmplitude of deflection under applied voltage (55 mV) when (L=60μm)Figure (4.8)

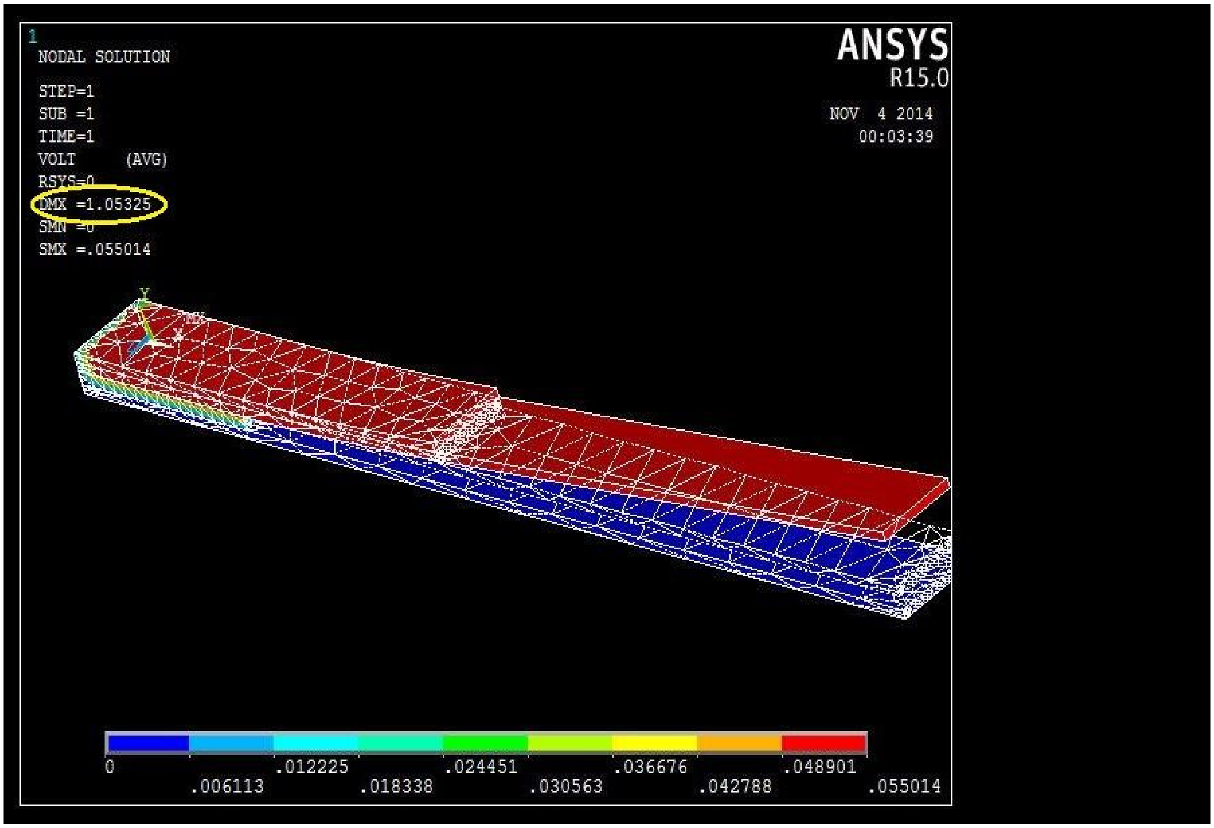


Figure (4.8): Electrical Potential and Amplitude of deflection under applied voltage (55 mV) for 30% covered

The DMX value that show in the above figure is the Maximum displacement (Amplitude of deflection) due to applied pull- in voltage (55 mV), as you know this applied voltage caused the amplitude of deflection exceed the one-third of the total gap which reach to the critical point, because the DMX=1.05325μm as shown above, as well as the one-third(1μm) of total gap (3μm) of cantilever is (1μm), So the 10% of cantilever covered with electrode pad reach to critical point of deflection when we applied (55 mV).

4.2.9. Electrical Potential andAmplitude of deflection under applied voltage (65 mV) when (L=40µm)Figure (4.9)

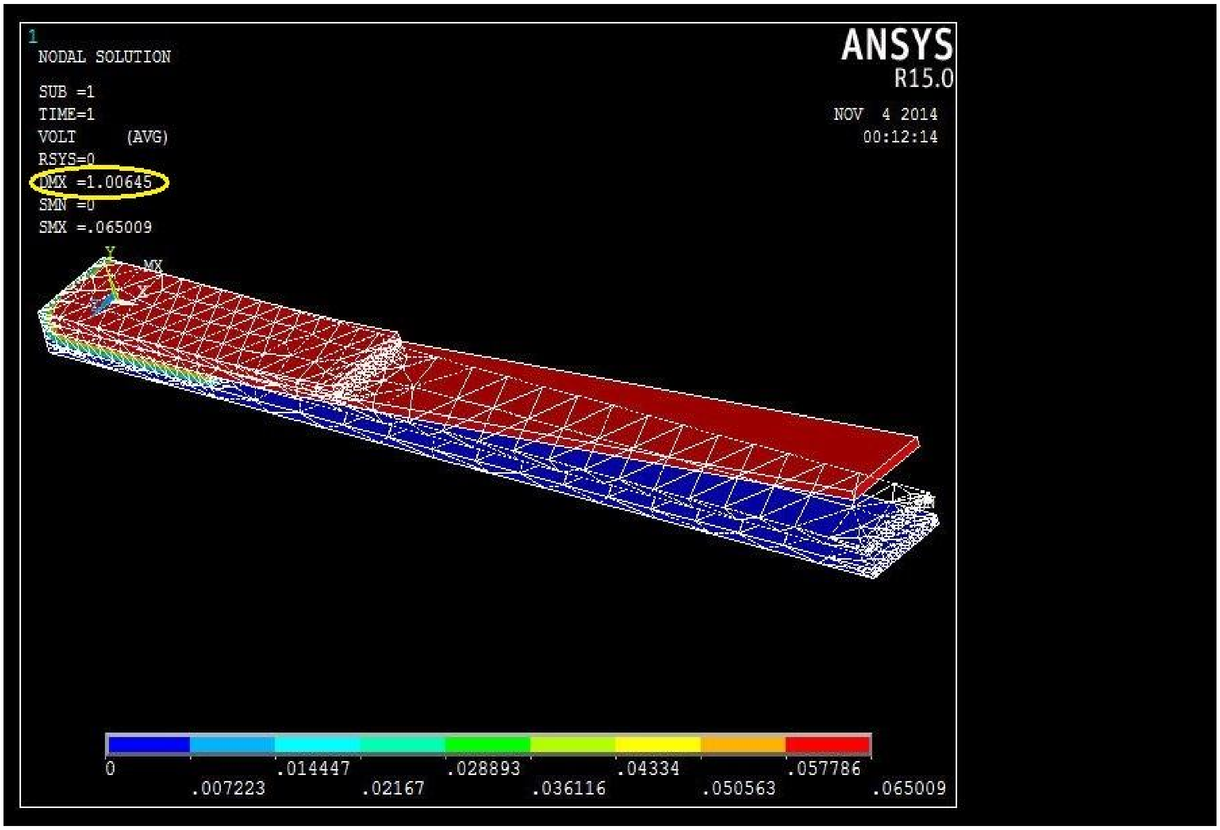


Figure (4.9): Electrical Potential and Amplitude of deflection under applied voltage (65 mV) for 20% covered

The DMX value that show in the above figure is the Maximum displacement (Amplitude of deflection) due to applied pull- in voltage (65 mV), as you know this applied voltage caused the amplitude of deflection exceed the one-third of the total gap which reach to the critical point, because the DMX=1.00645µm as shown above, as well as the one-third of total gap (3µm) of cantilever is (1µm), So the 10% of cantilever covered with electrode pad reach to critical point of deflection when we applied (65 mV).

4.2.10 Electrical Potential andAmplitude of deflection under applied voltage (89 mV) when (L=20µm)Figure (4.10)

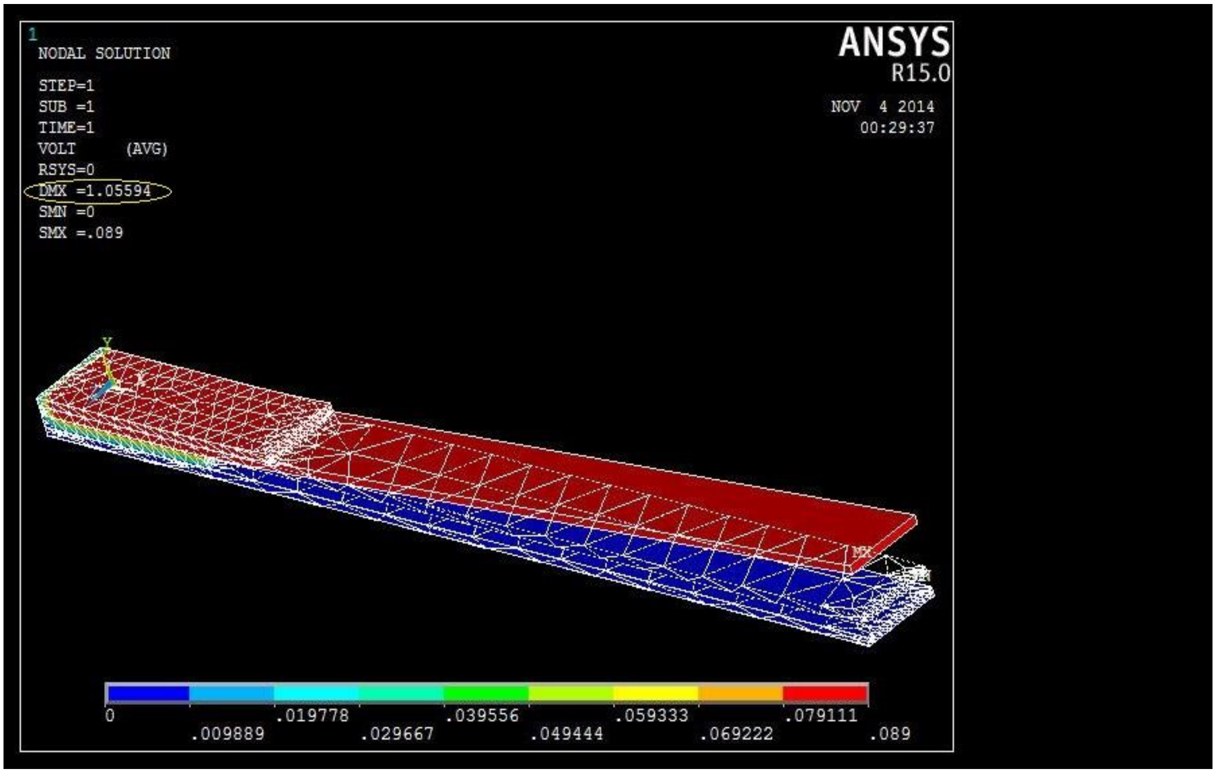


Figure (4.10): Electrical Potential and Amplitude of deflection under applied voltage (89 mV) for 10% covered

The DMX value that show in the above figure is the Maximum displacement (Amplitude of deflection) due to applied pull- in voltage (89 mV), as you know this applied voltage caused the amplitude of deflection exceed the one-third of the total gap which reach to the critical point, because the DMX=1.05594µm as shown above, as well as the one-third(1µm) of total gap (3µm) of cantilever is (1µm), So the 10% of cantilever covered with electrode pad reach to critical point of deflection when we applied (89 mV).

4.3. Amplitude of deflection Simulation Results:-

The below table shows gained results:

Table (4.2): Amplitude of deflection Simulation Results

Applied voltage (mV)	$A_{100\%}$	$A_{90\%}$	$A_{80\%}$	$A_{70\%}$	$A_{60\%}$	$A_{50\%}$	$A_{40\%}$	$A_{30\%}$	$A_{20\%}$	$A_{10\%}$
10	0.104759	0.098503	0.084013	0.07203	0.063562	0.055141	0.045634	0.034818	0.023821	0.013331
20	0.419035	0.394012	0.336051	0.28812	0.25425	0.220562	0.182535	0.139273	0.095285	0.053324
30	0.94283	0.886527	0.756114	0.648269	0.572062	0.496266	0.410704	0.313364	0.214391	0.119978
32	1.07273									
33		1.0727								
35			1.02916							
38				1.04011						
40	1.67614	1.57605	1.3442	1.15248	1.017	0.88225	0.73014	0.557091	0.38114	0.213294
43						1.01955				
47							1.00805			
50	2.61897	2.46257	2.10032	1.80075	1.58906	1.37852	1.14084	0.870455	0.595532	0.333272
55								1.05325		
60	3.77132	3.54611	3.02446	2.59308	2.28825	1.98506	1.64281	1.25346	0.857565	0.479912
65									1.00645	
70	5.13318	4.82664	4.11662	3.52947	3.11456	2.70189	2.23605	1.70609	1.16724	0.653213
80	6.70457	6.30419	5.37681	4.60992	4.068	3.529	2.92056	2.22837	1.52456	0.853177
89										1.05594
90	8.48547	7.97874	6.80503	5.83442	5.14856	4.46639	3.69633	2.82028	1.92952	1.0798
100	10.4759	9.8503	8.40127	7.20299	6.35625	5.51406	4.56337	3.48182	2.38213	1.33309
110	12.6758	11.9189	10.1655	8.71562	7.69106	6.67202	5.52168	4.213	2.88237	1.61304
120	15.0853	14.1844	12.0978	10.3723	9.153	7.94025	6.57126	5.01382	3.43026	1.91965
130	17.7042	16.6470	14.1981	12.1731	10.7421	9.31877	7.7121	5.88428	4.02579	2.25295
140	20.5327	19.3066	16.4665	14.1179	12.4582	10.8076	8.94421	6.82437	4.66897	2.61285
150	23.5707	22.1632	18.9029	16.2067	14.3016	12.4066	10.2676	7.8341	5.35978	2.99945
160	26.8183	25.2168	21.5072	18.4397	16.272	14.116	11.6822	8.91346	6.09824	3.41271
170	30.2753	28.4674	24.2797	20.8166	18.3696	15.9356	13.1882	10.625	6.88435	3.85263
180	33.9419	31.915	27.2201	23.3377	20.5942	17.8656	14.7853	11.2811	7.71809	4.31921
190	37.8179	35.5596	30.3286	26.0028	22.9461	19.9058	16.4738	12.5694	8.59948	4.81245
200	41.9035	39.4012	33.6051	28.812	25.425	22.0563	18.2535	13.9273	9.52851	5.33235

*$A_{100\%}$: Amplitude of deflection in micrometer when 100% of cantilever covered with electrode pad.

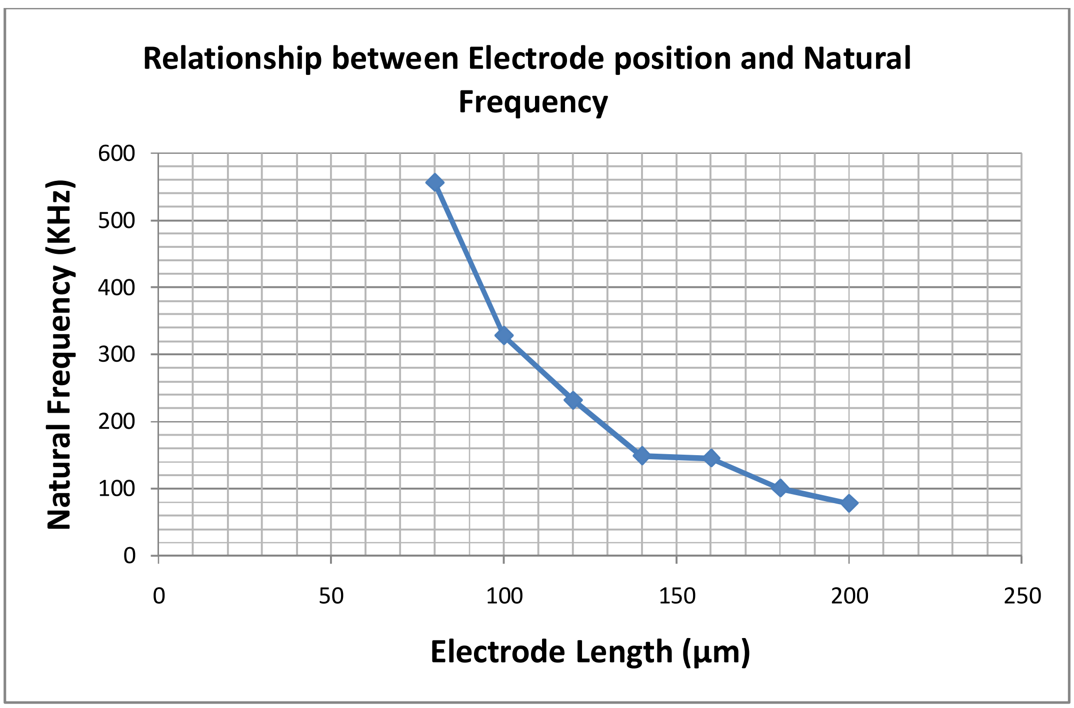
*$A_{90\%}$: Amplitude of deflection in micrometer when 90% of cantilever covered with electrode pad (starting from fixed part, and leaving the tip of the cantilever without electrode).

*The colored value is critical values for applied voltage(pull-in voltage) in which the amplitude of deflection exceed one-third of total gap.

*Notice that the Amplitude of deflection increase when the applied voltage and Electrode Length increase.

4.4. Charts:

4.4.1. Relationship between Electrode Position and NaturalFrequency:



Figure(4.11): Relationship between Electrode Position and NaturalFrequency

4.4.2. Relationship between Voltage and Amplitude of deflection at 100% of Cantilever covered with Electrode Pad:

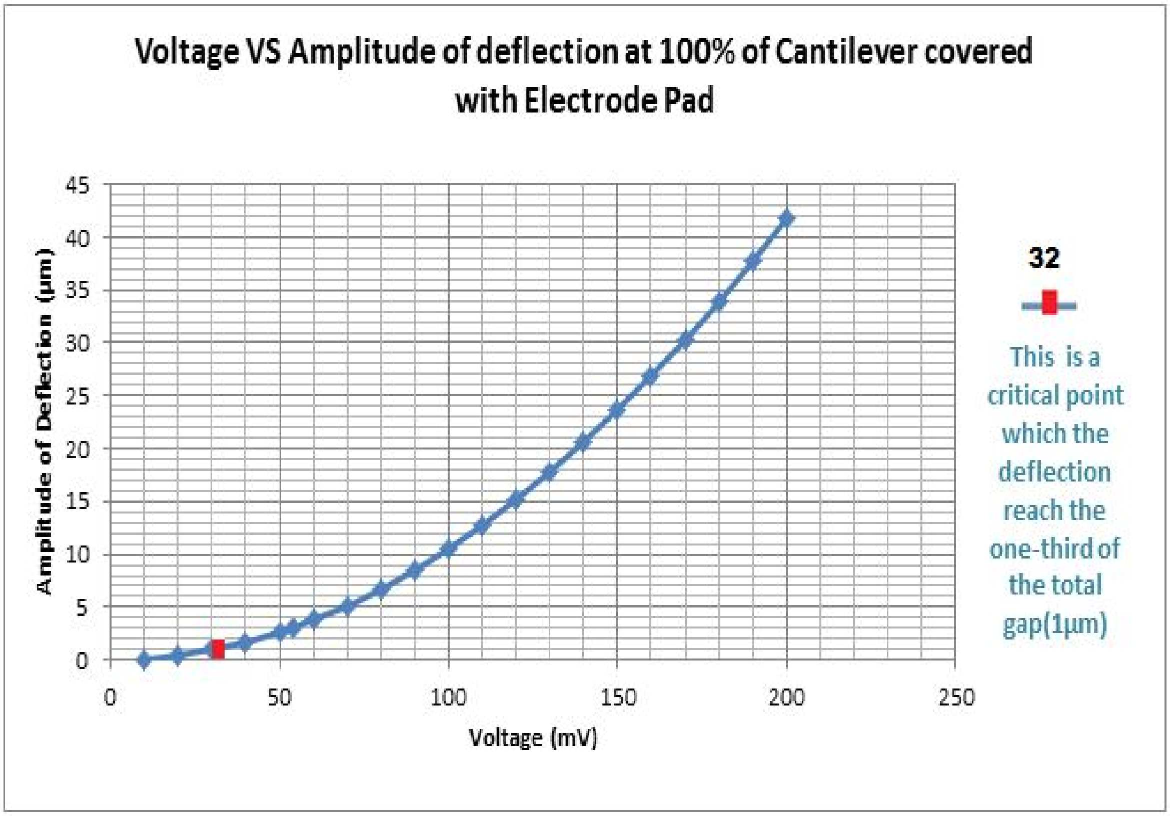


Figure (4.12): Voltage VS Amplitude of deflection at 100% of Cantilever covered with Electrode Pad

4.4.3. Relationship between Voltage and Amplitude of deflection at 90% of Cantilever covered with Electrode Pad:

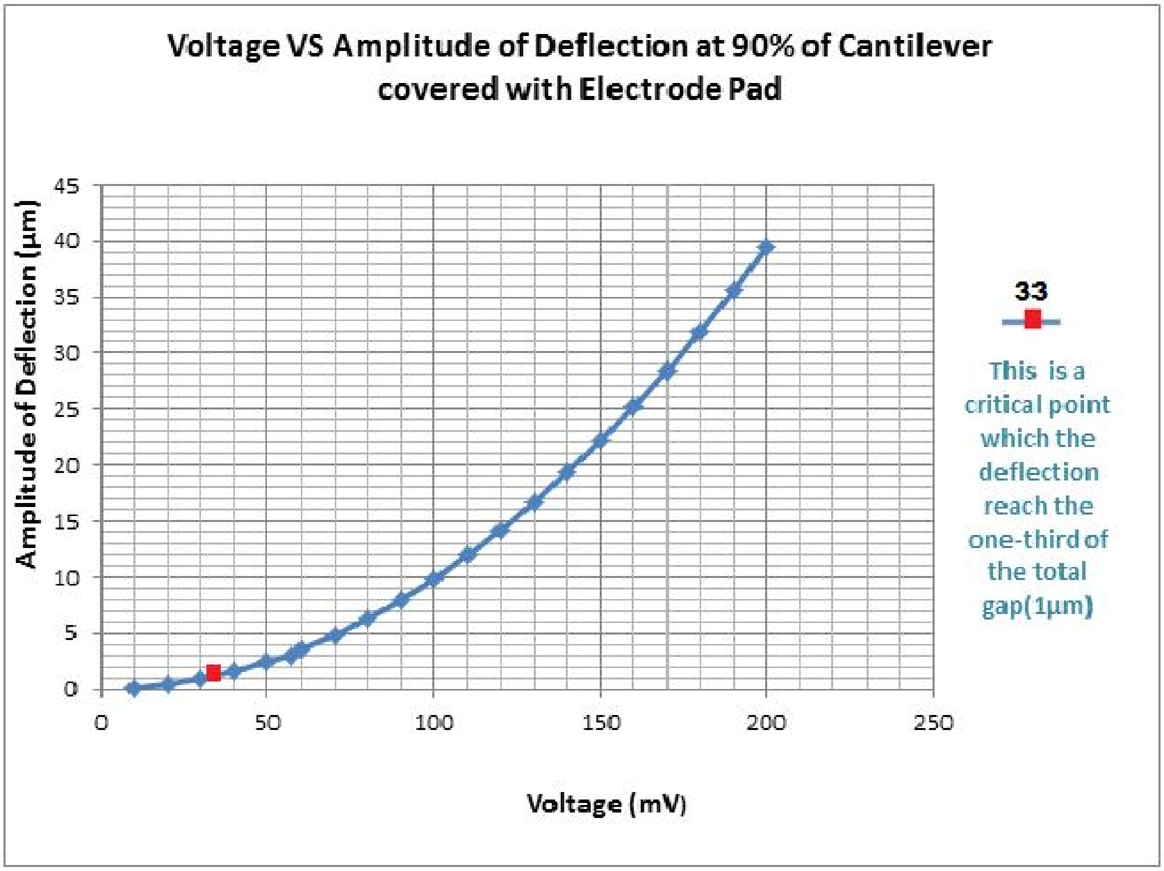


Figure (4.13): Voltage VS Amplitude of deflection at 90% of Cantilever covered with Electrode Pad

4.4.4. Relationship between Voltage and Amplitude of deflection at 80% of Cantilever covered with Electrode Pad:

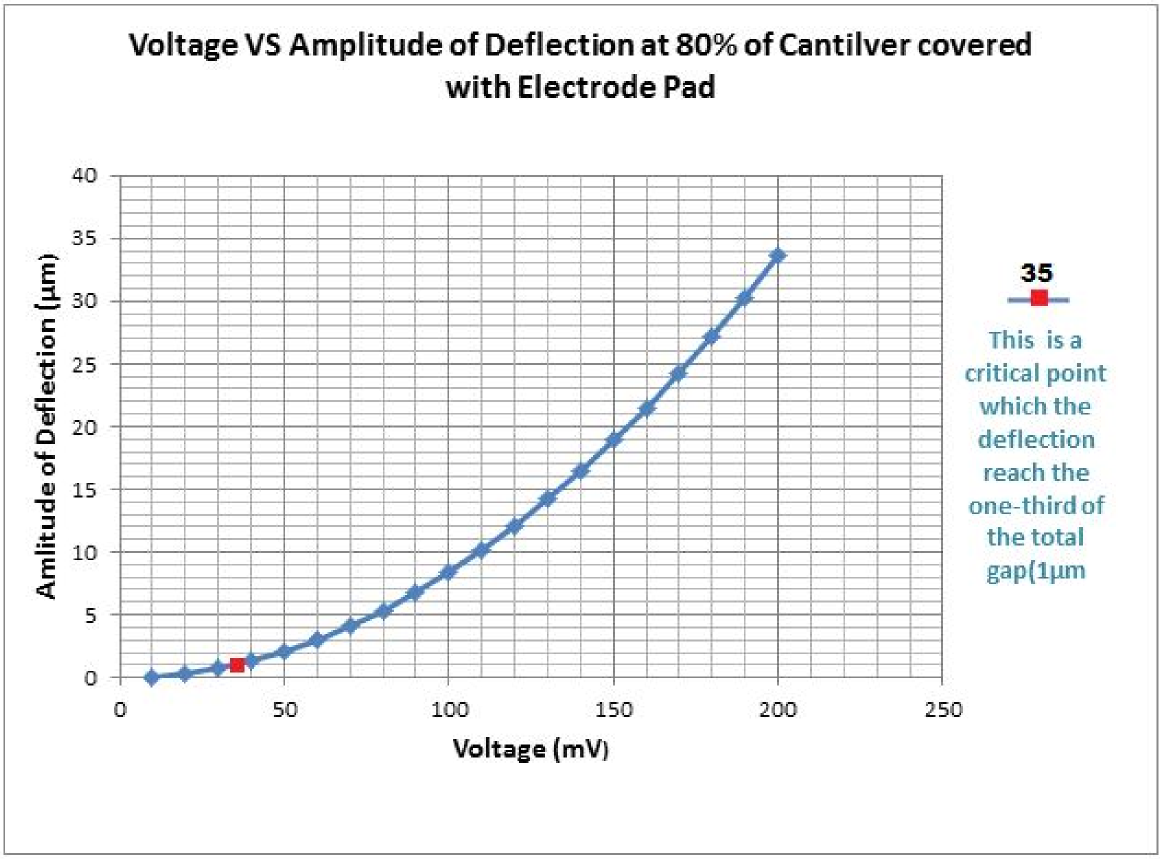


Figure (4.14): Voltage VS Amplitude of deflection at 80% of Cantilever covered with Electrode Pad

4.4.5. Relationship between Voltage and Amplitude of deflection at 70% of Cantilever covered with Electrode Pad:

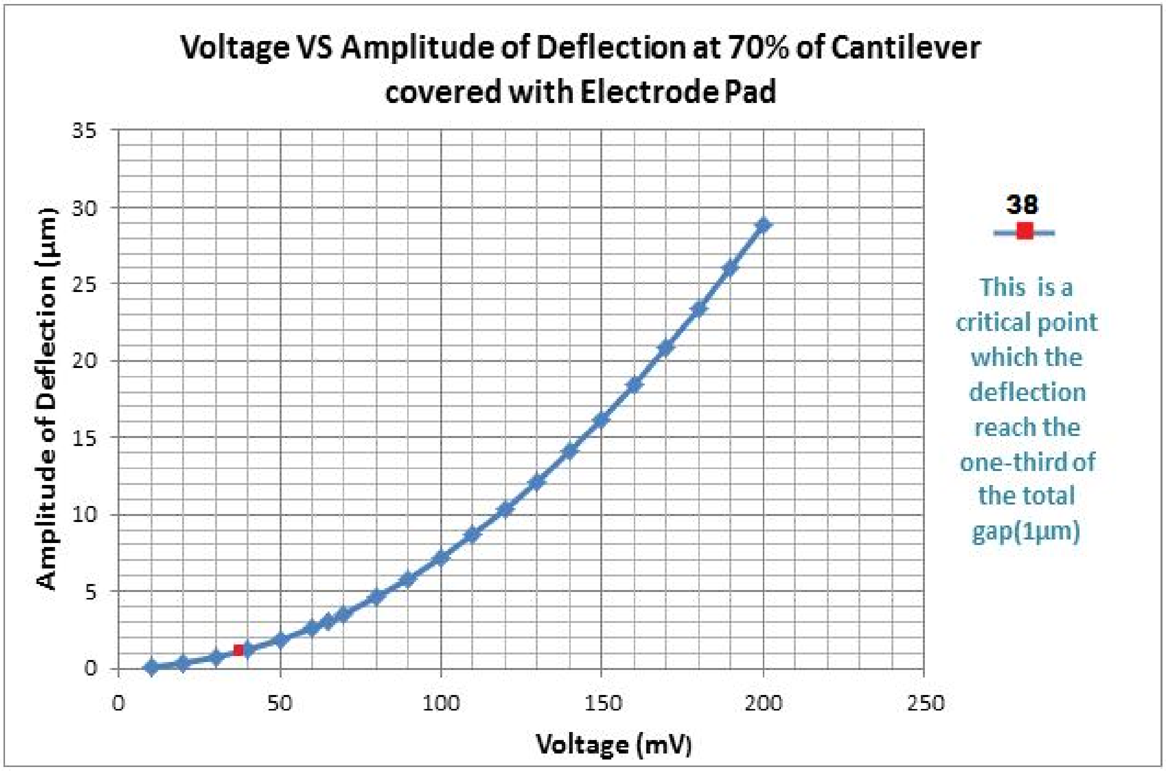


Figure (4.15): Voltage VS Amplitude of deflection at 70% of Cantilever covered with Electrode Pad

4.4.6. Relationship between Voltage and Amplitude of deflection at 60% of Cantilever covered with Electrode Pad:

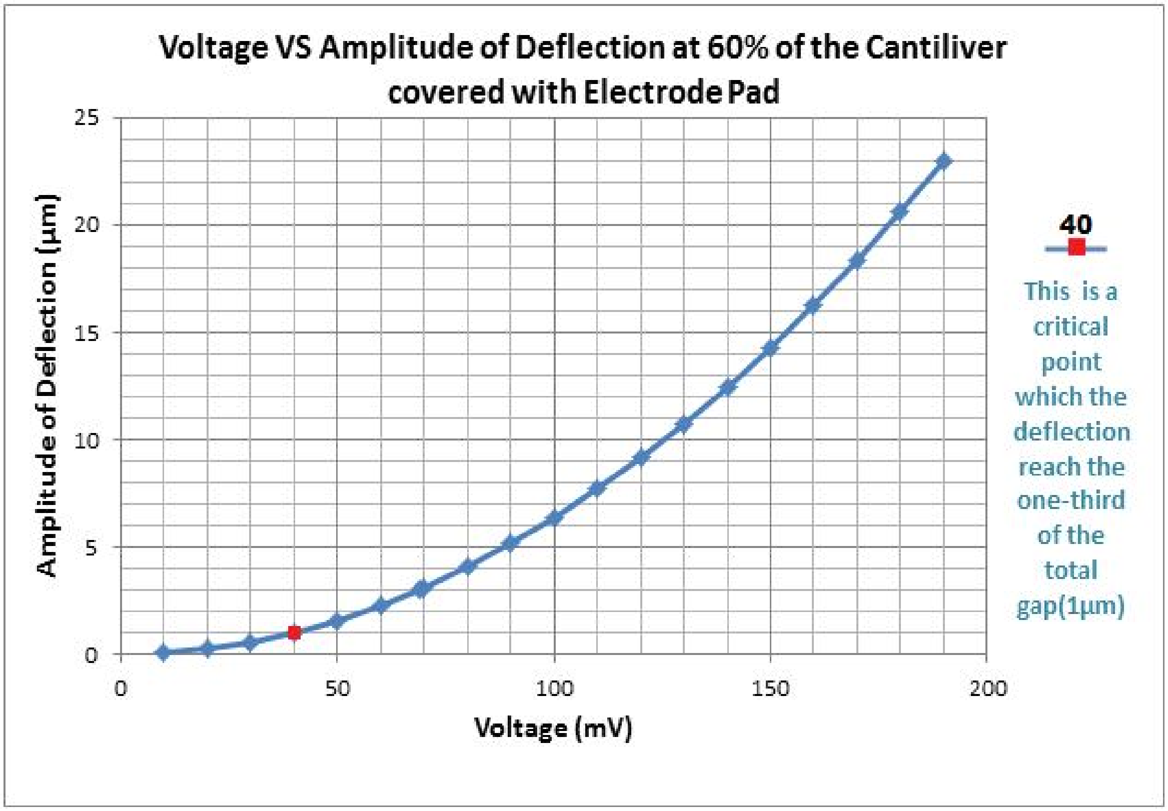


Figure (4.16): Voltage VS Amplitude of deflection at 60% of Cantilever covered with Electrode Pad

4.4.7. Relationship between Voltage and Amplitude of deflection at 50% of Cantilever covered with Electrode Pad:

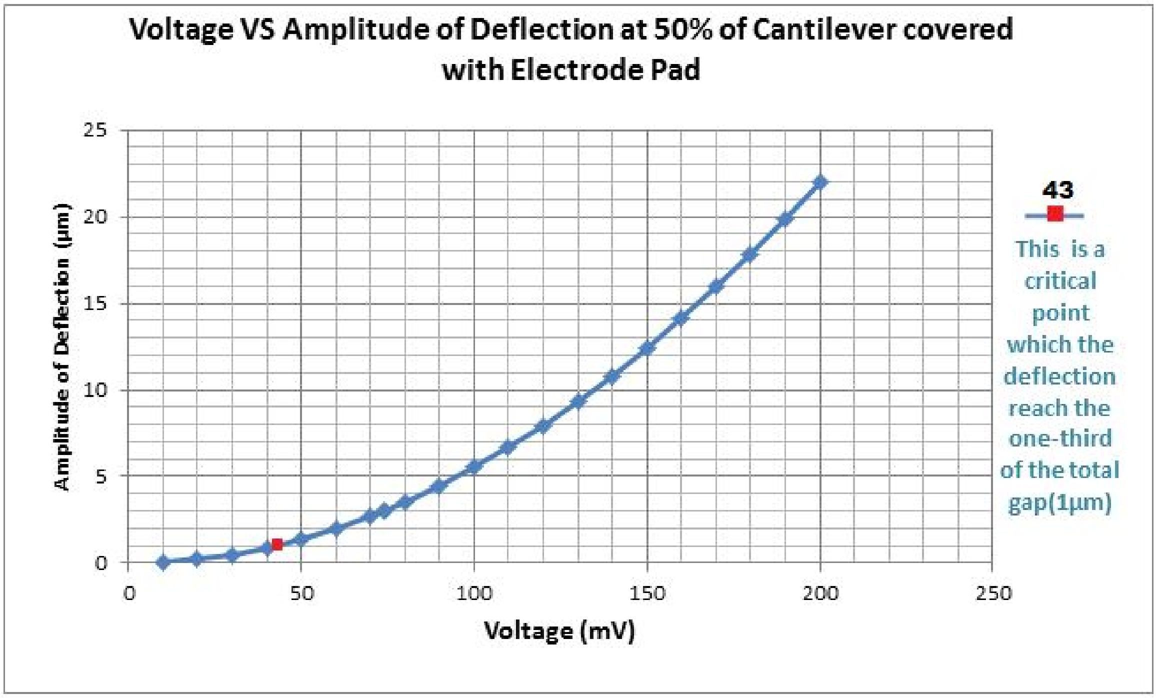


Figure (4.17): Voltage VS Amplitude of deflection at 50% of Cantilever covered with Electrode Pad

4.4.8. Relationship between Voltage and Amplitude of deflection at 40% of Cantilever covered with Electrode Pad:

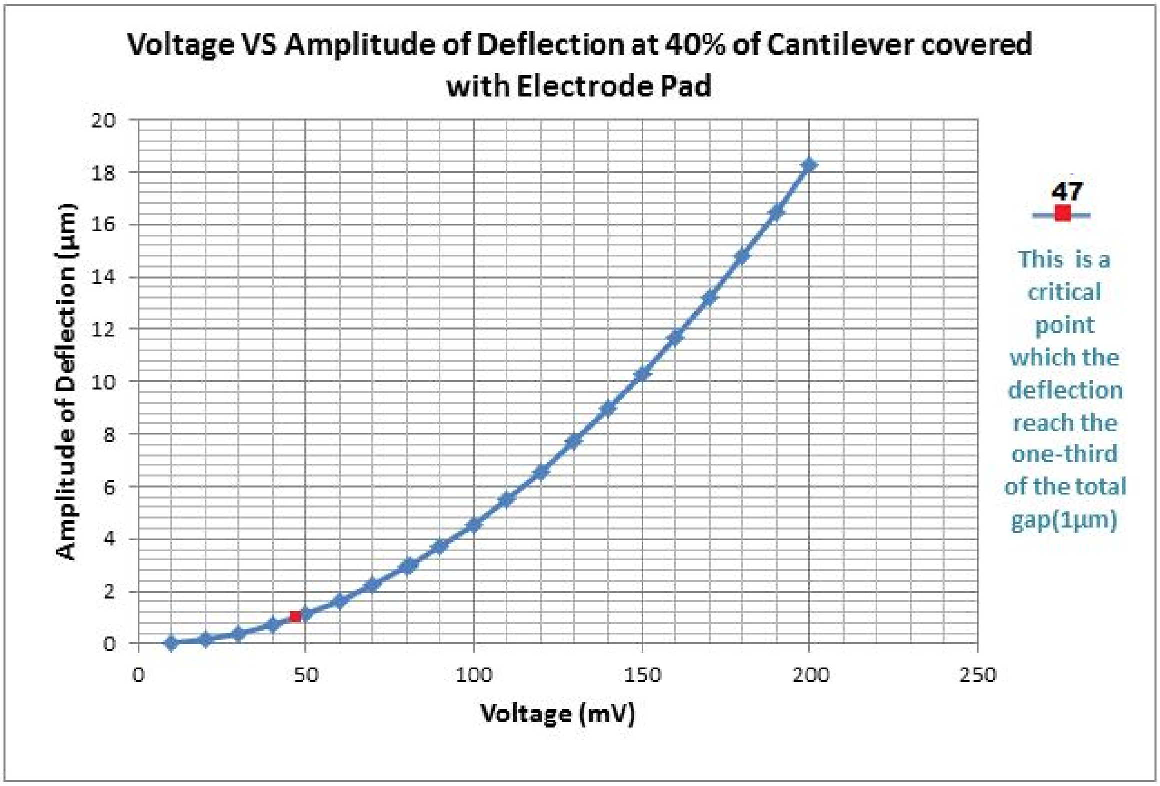


Figure (4.18): Voltage VS Amplitude of deflection at 40% of Cantilever covered with Electrode Pad

4.4.9. Relationship between Voltage and Amplitude of deflection at 30% of Cantilever covered with Electrode Pad:

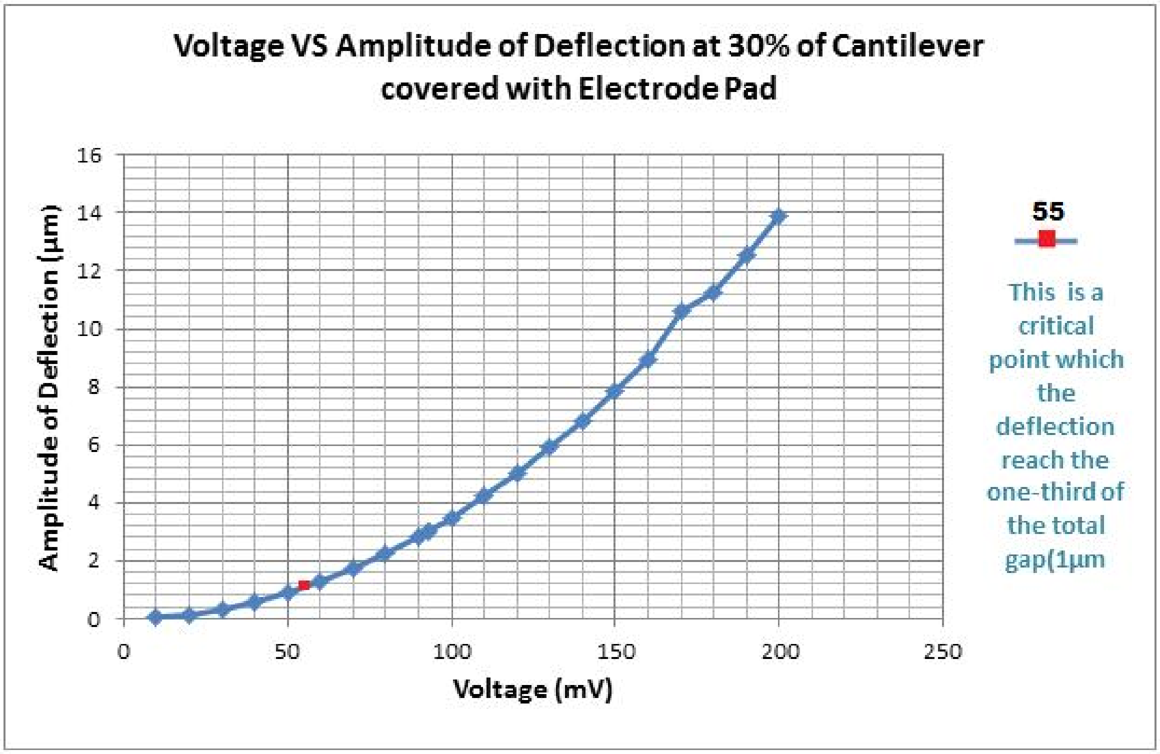


Figure (4.19): Voltage VS Amplitude of deflection at 30% of Cantilever covered with Electrode Pad

4.4.10. Relationship between Voltage and Amplitude of deflection at 20% of Cantilever covered with Electrode Pad:

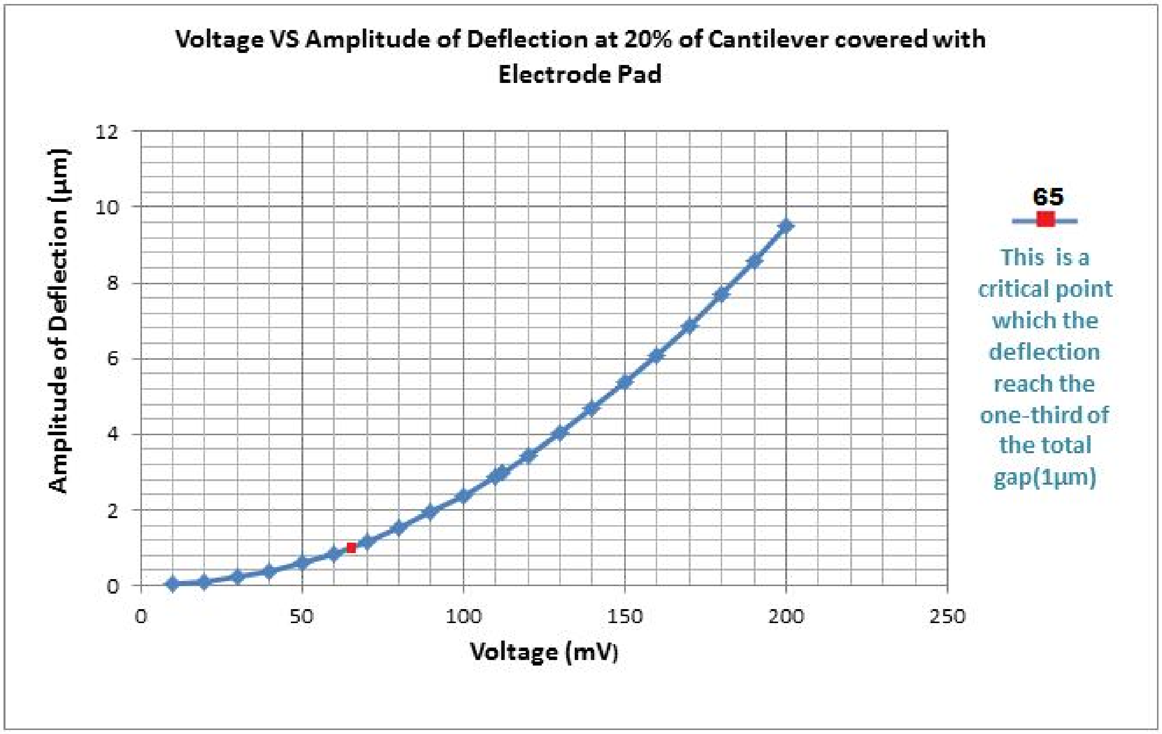


Figure (4.20): Voltage VS Amplitude of deflection at 20% of Cantilever covered with Electrode Pad

4.4.11. Relationship between Voltage and Amplitude of deflection at 10% of Cantilever covered with Electrode Pad:

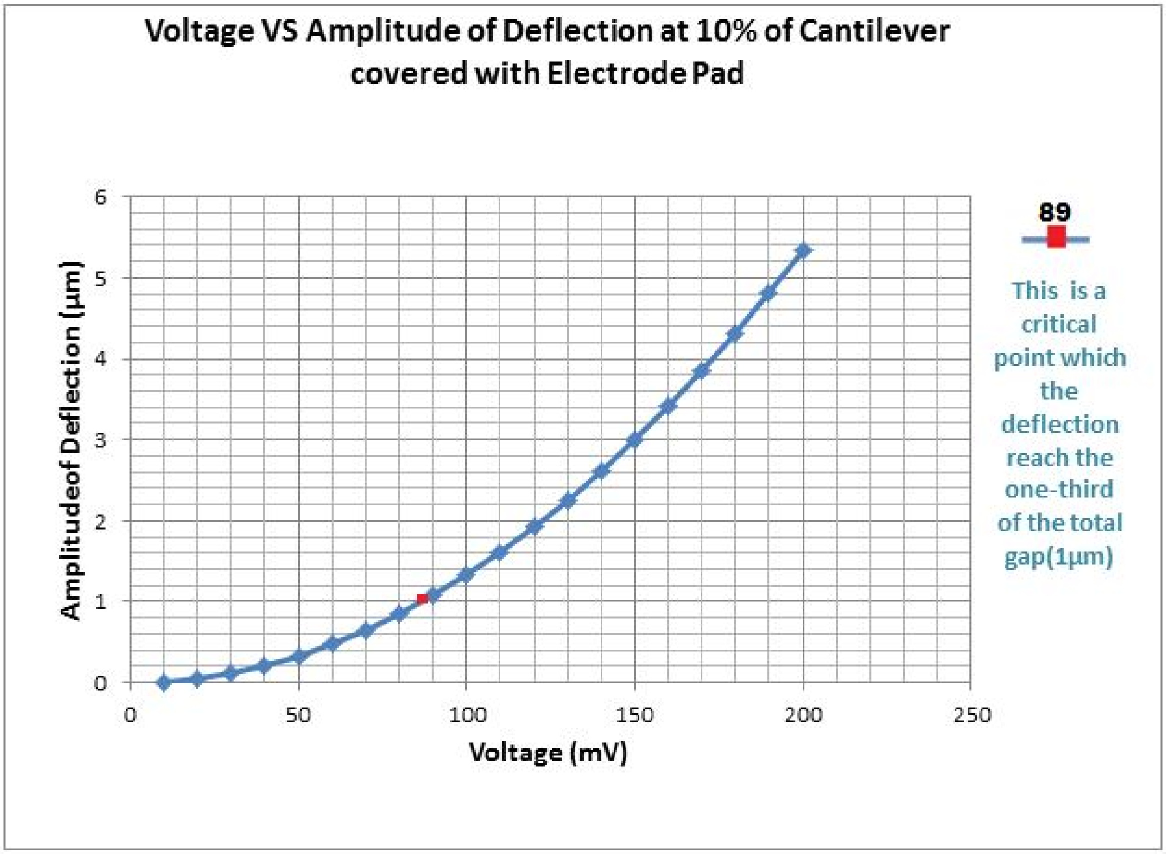


Figure (4.21): Voltage VS Amplitude of deflection at 10% of Cantilever covered with Electrode Pad