Design of MEMS-based Microcantilever for Tuberculosis Detection

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Introduction: *Tuberculosis is caused by a bacterium* called *Mycobacterium tuberculosis. The fusion protein,* ESAT-6/CFP-10 is secreted by the extended region of RDX- 1 which encodes ESX-1, a novel protein secretion system and known to contribute to virulence and pathogenicity in the host. The most prominent cantilever type of detection is preferred (figure 1). The objective of the study was to select the best suited cantilever for tuberculosis detection.

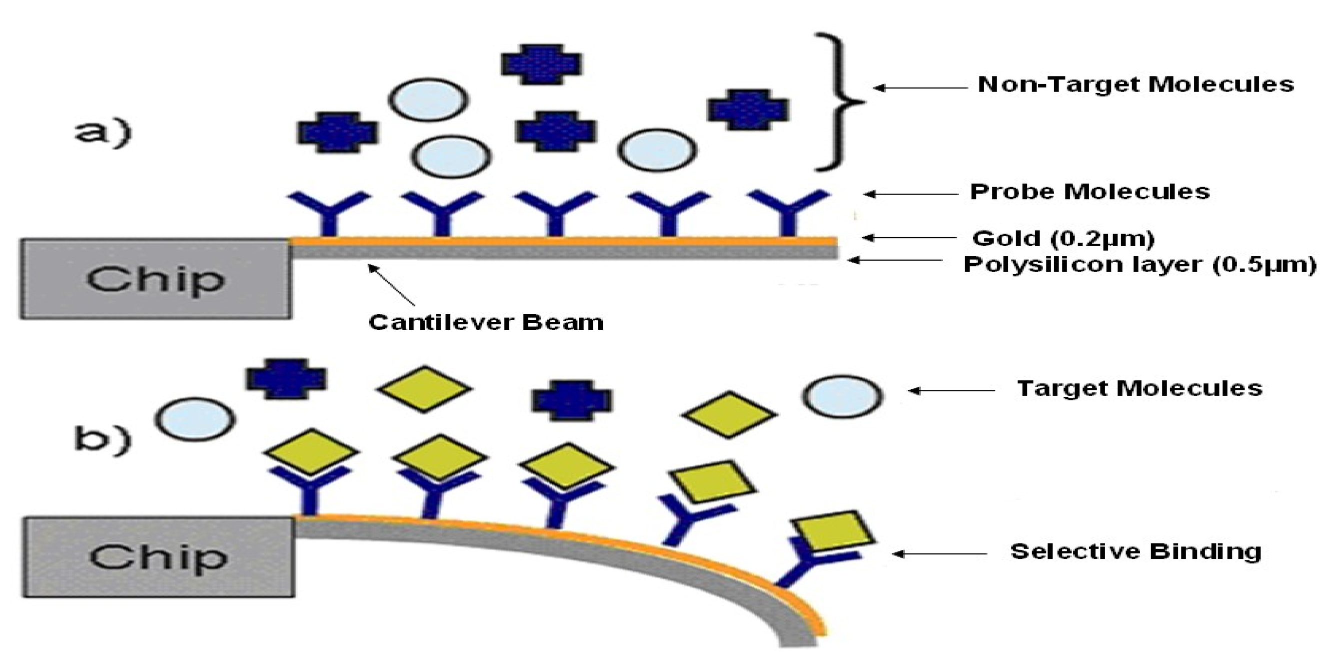

Figure 1. **Deflection of the Cantilever upon selective binding**

Computational Models: The three dimensional geometry of the Cantilever was simulated using ***COMSOL Multiphysics 4.3b software*** (figure 2).The Stoney's formula, which relates cantilever end deflection 'δ' to applied stress 'σ' given by:

$$\delta = \frac{3\sigma(1-\vartheta)}{E}\left(\frac{L}{t}\right)^2 \quad \text{--- (1)}$$

Where 'ϑ' is Poisson's ratio,
'E' is Young's modulus,
'L' is the beam length and
't' is the cantilever thickness

The total force being applied to the cantilever is much more related to the number of analyte molecules attaching to the cantilever. The resonance frequency (f) on a cantilever working in dynamic mode is given by:

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m_{eff}}} \quad \text{--- (2)}$$

Where 'k' is the spring constant,
'm_{eff}' is the effective or dynamic mass.

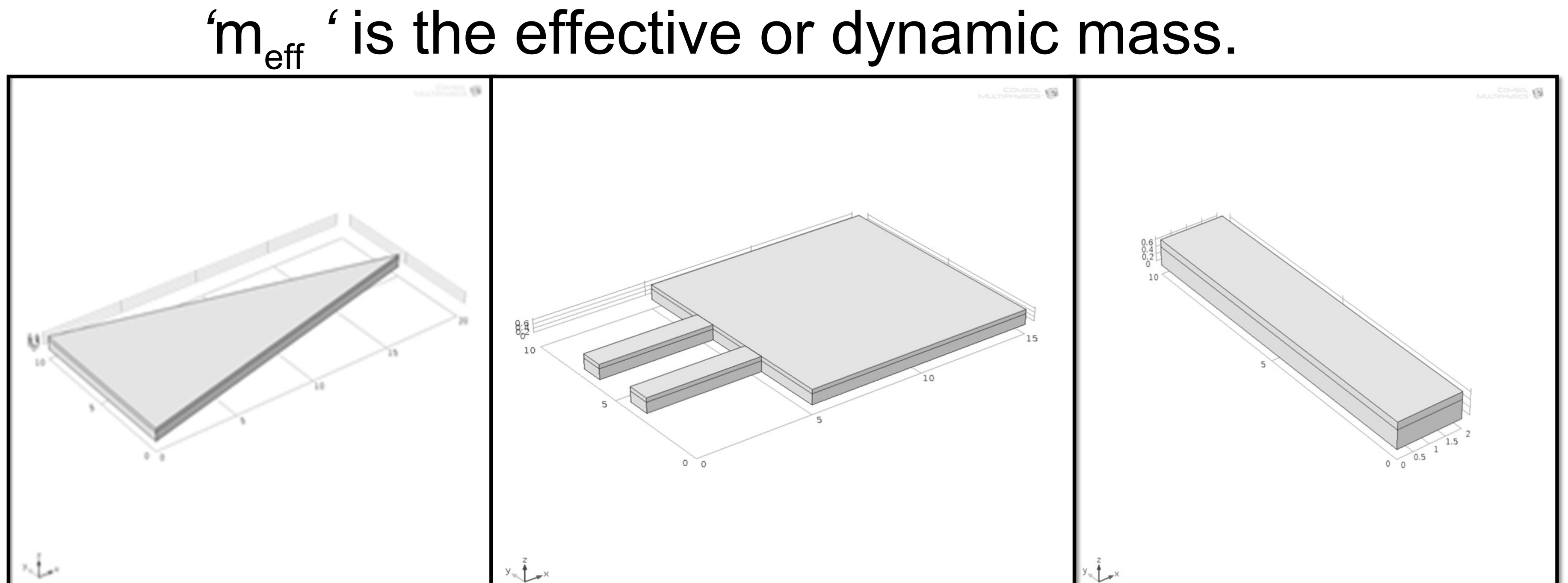

Figure 2: Proposed Geometry of the Cantilever Structures

Results: The Stationary and Eigen frequency studies are performed. The simulated results of the Cantilever structures are given in figures (3) and (4). The lowering of the resonant frequency is attributed due to the increase in the mass of analyte over the thiolated gold surface.

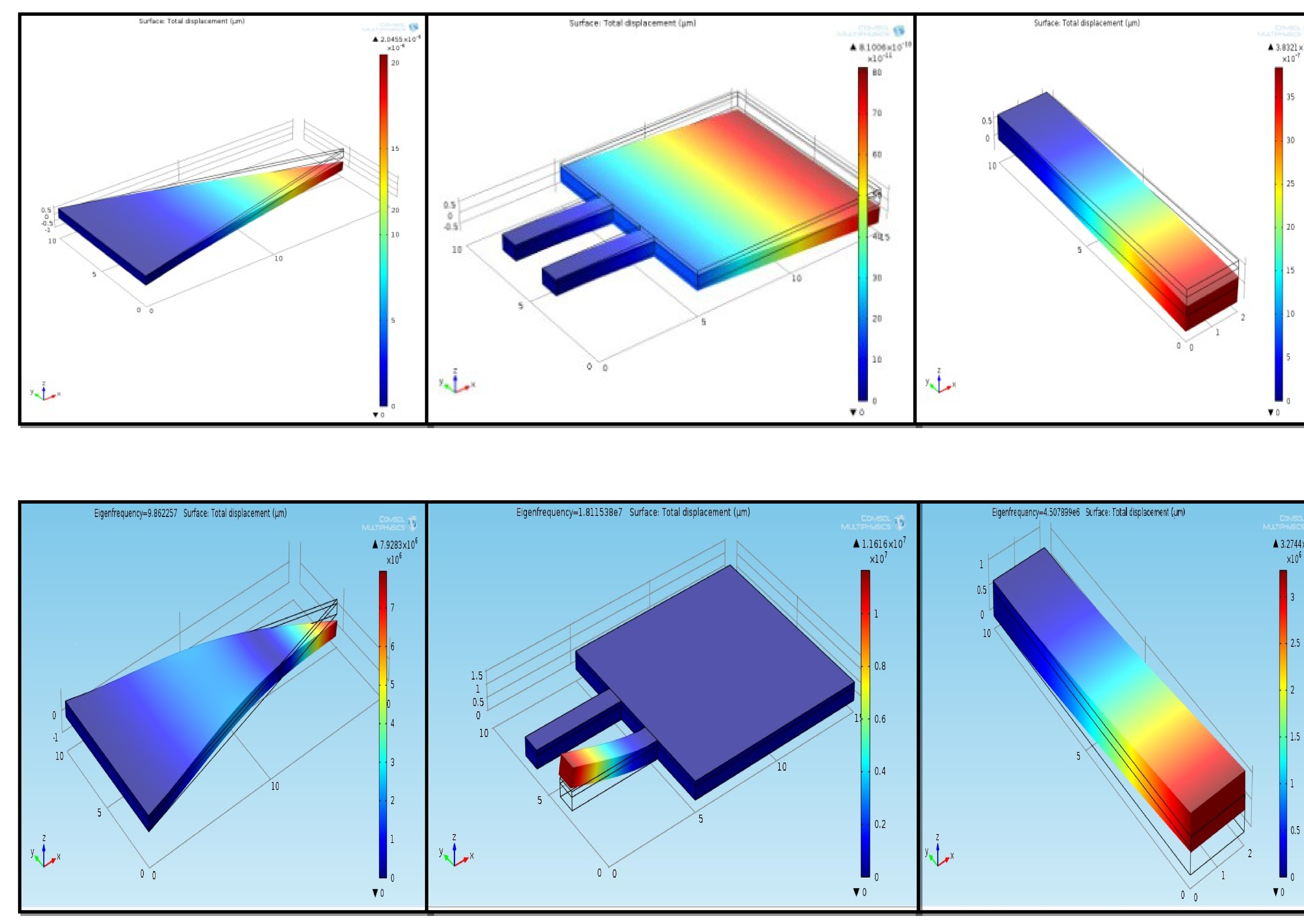

Figure 3 & 4. **Simulation results of the different types of Cantilever**

Cantilever type	Displacement (μm)	Eigen Frequency (Hz)
Triangular shape	$1.0023*10^{-13}$	9.86225
Pi- shape	$3.9693*10^{-21}$	$1.8115*10^{7}$
Rectangular shape	**$9.3887*10^{-9}$**	**$4.5078*10^{6}$**

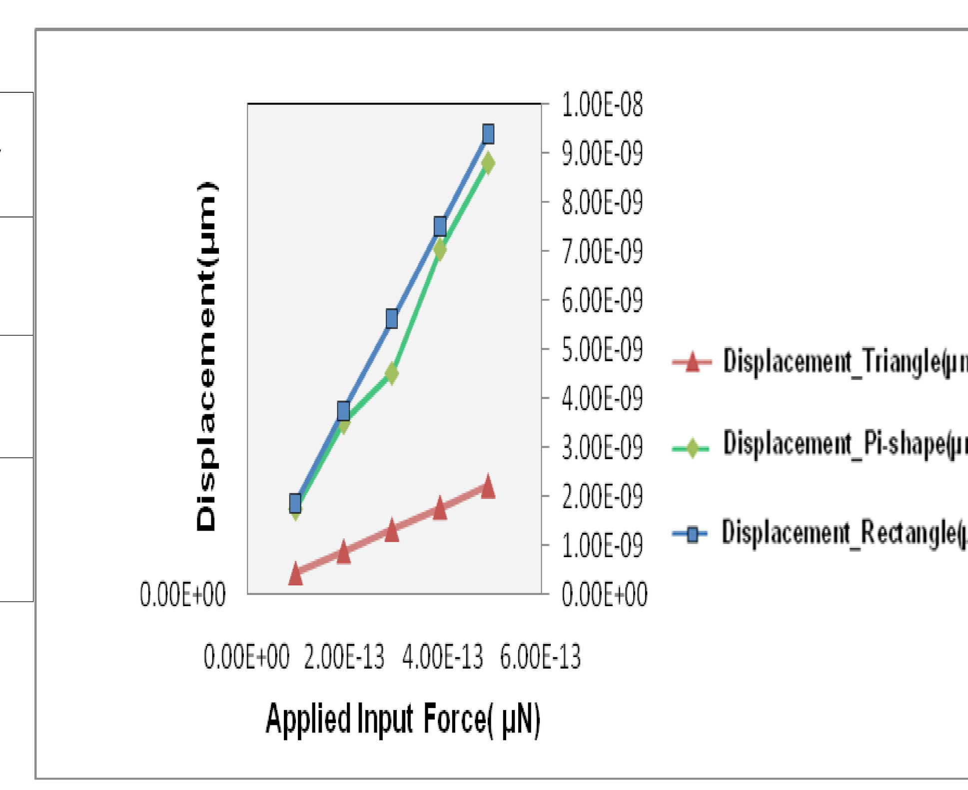

Figure 5. Displacement Vs Input force for different types of Cantilever structures

Conclusions: The Eigen frequency and the maximum displacement were observed for rectangular shaped cantilever sensor. The sensor is highly sensitive since it can detect even attomolar concentration of the analyte molecules. For an input mass of **50 ESX-1 antigens**, a maximum displacement of **$9.3887*10^{-19}$** was observed (figure 5). Thus, a highly sensitive and selective sensor based on cantilever is simulated using COMSOL Multiphysics 4.3b.

References:

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Excerpt from the Proceedings of the 2013 COMSOL Conference in Bangalore