From Animal Hair Cell To MEMS Sensor

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Introduction

Prior research has resulted in the development of a prototype MEMS sensor *(figure 1).* This sensor can determine fluid velocity at very low flow rates. The development of such a sensor has been achieved through mimicking the function of hair cells found inside of animal ears. The MEMS sensor, just like the hair cells, consists of multiple rows of micro-pillars called stereocilia. However a hair cell has been mimicked, a relative simple stereocilia design is currently used for the prototype sensor. The level of complexity in stereocilia design can be increased more towards nature. Because the sensor is still in prototype phase, there is an interest in the improvement of the sensor's sensitivity. From this the research question follows:

'Will the sensor sensitivity increase when the complexity of the model design is increased towards nature?'

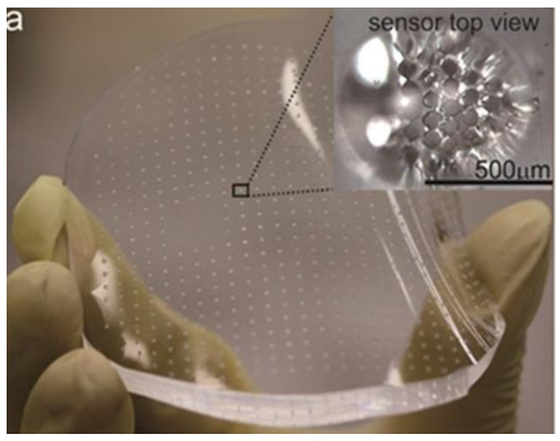


Figure 1: MEMS sensor prototype (Asadnia et al., 2016)

System

The MEMS sensor generates a current as output through the deflection of the stereocilia. Because of this, the sensitivity is to be analyzed through measuring the total tip displacement of the stereocilia bundle.

Models

Computer simulation in COMSOL was used to determine the model sensitivity. Two models were analyzed *(figures 2 & 3).*

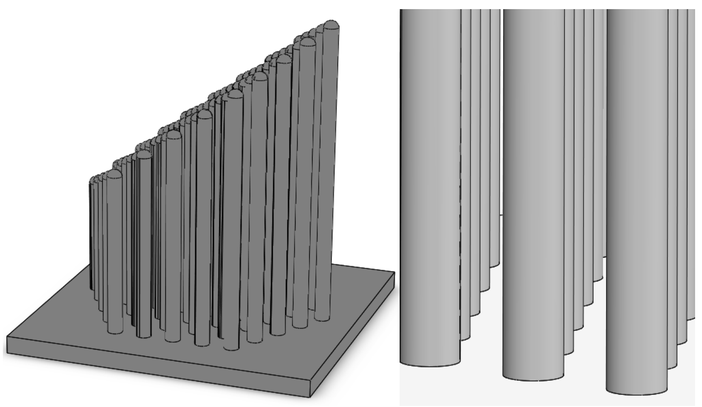


Figure 2: The (current) simple Straight-wall model

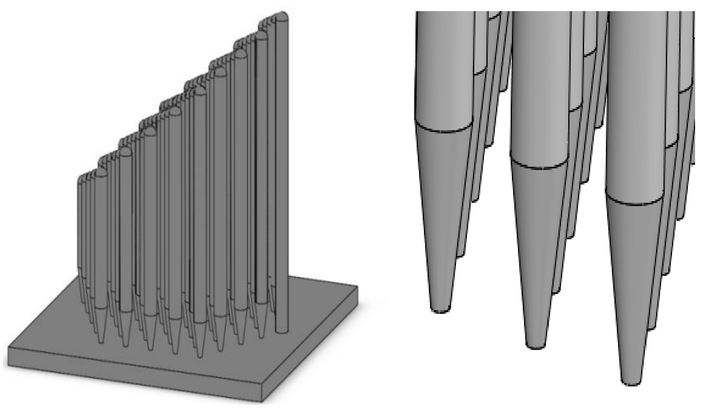


Figure 3: The more complex Tapered-base model

Stress Profile & Displacement Behavior

➢ Straight-wall

From the stress profile of the straight-wall model *(figure 4)* it can be observed that the stress is located over a relatively large part of the stereocilia surface. The highest stress is located near the base and decreasing slowly over the length of the stereocilia. From the displacement profile *(graph 1)* a non-linear function is shown, indicating bending of the stereocilia when deflecting.

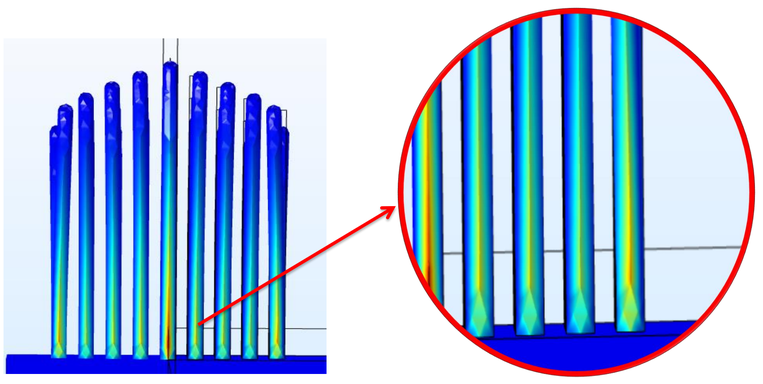
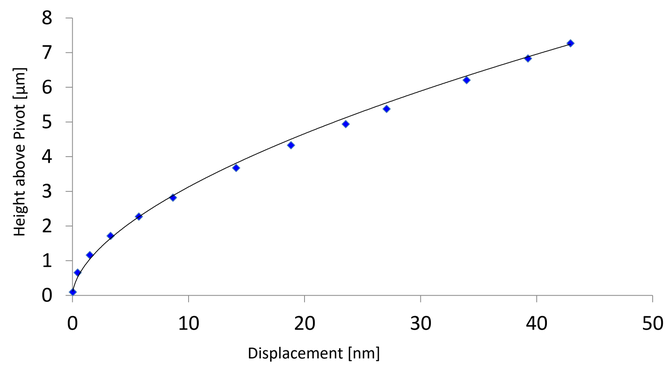


Figure 4: Straight-wall stress profile



Graph 1: Displacement profile of tallest stereocilia Straight-wall

➢ Tapered-base

However, for the tapered-base model *(figure 6)* a completely different stress profile is to be observed. Here the stress is only located in the small region near the base, decreasing fast when going up towards the tip of the stereocilia. From the displacement profile *(graph 2)* a linear function can be observed, indicating pivoting of the stereocilia when deflecting.

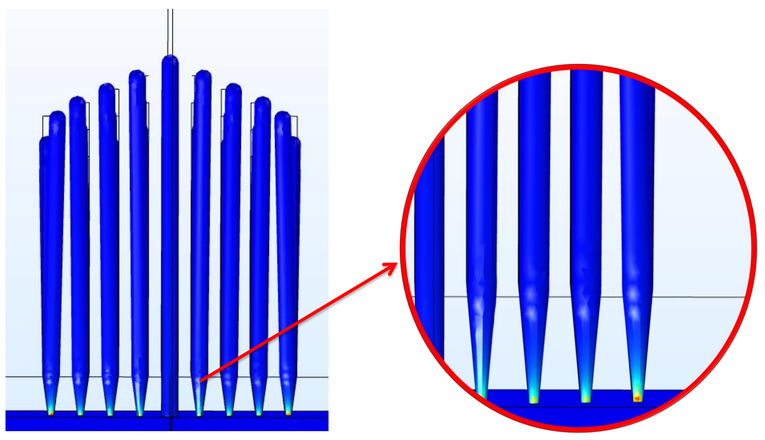
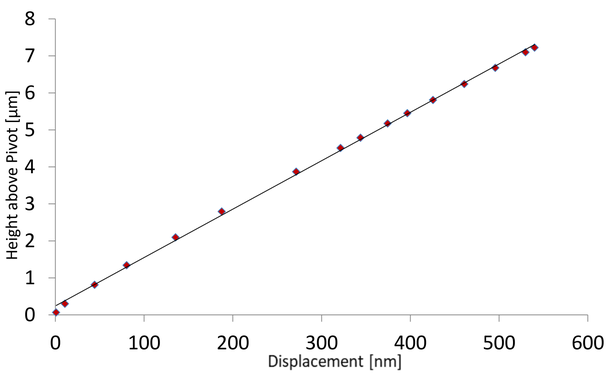


Figure 4: Tapered-base stress profile



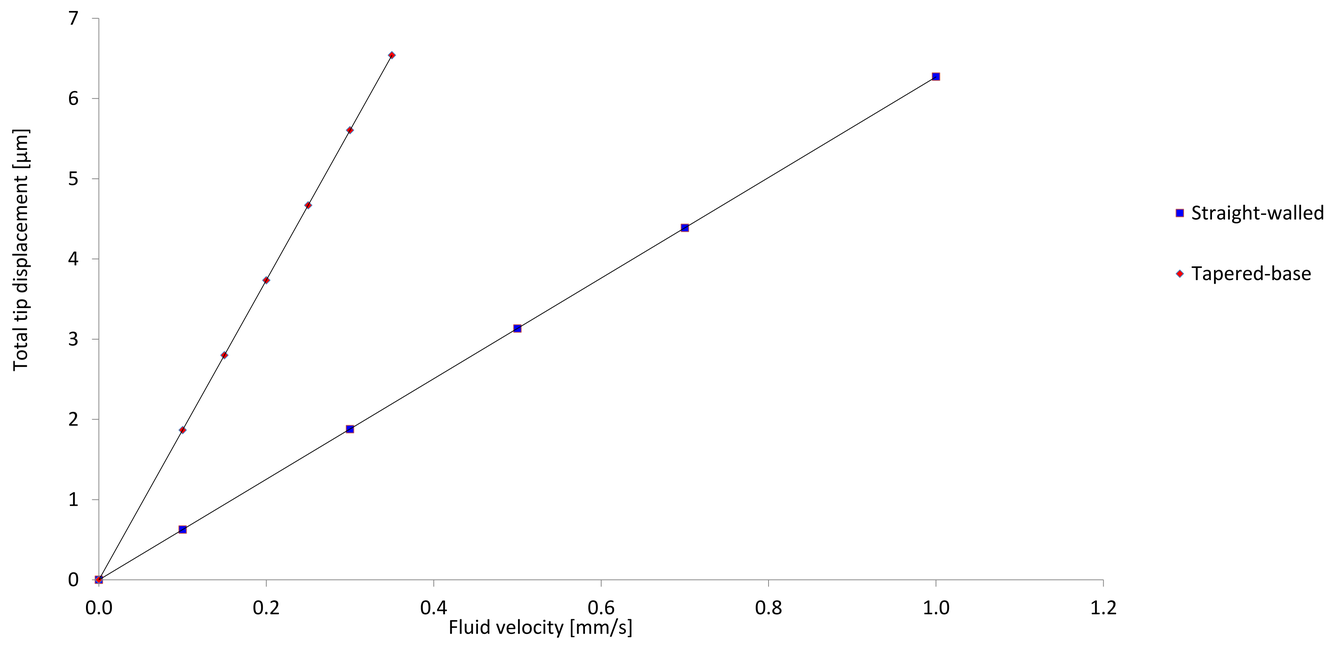
Graph 2: Displacement profile of tallest stereocilia Tapered-base

Model Sensitivity

Here, the total tip displacement at different velocities is represented *(graph 3).* The sensitivity of the model is the slope of the trend line which are:

➢ Straight-walled*:* 6.2688 $\left[\frac{\frac{\mu m}{mm}}{s}\right]$

➢ Tapered-base*:* 18.677 $\left[\frac{\frac{\mu m}{mm}}{s}\right]$



Graph 3: Total tip displacement at different velocities for both models

Conclusion

Finally, will the sensor sensitivity increase when the complexity of the model design is increased towards nature? Yes it will, by a factor of 3. Also, stereocilia with a tapered-base design pivot instead of bend when deflecting. Still, the level of design complexity can be increased even more. Further research on this is to be conducted in order to determine the possible gain in sensitivity when the stereocilia design is increased towards nature.