Modelling and analysis of MEMS capacitive microphone with compliant diaphragm

Robin Singh, S M Kulkarni
Department of Mechanical Engineering
National Institute of Technology Karnataka, Surathkal, India
robinsinghme@gmail.com

Audio applications such as hearing aid devices and mobile communication mandate a small size, very high performance, sensitive, stable microphone design to reproduce a high quality sound. Capacitive microphones have proved to be promising candidates to full fil the above requirements. Their development has been greatly triggered by the various advances in microsystem design and fabrication technologies. Improving the performance of the MEMS microphone has evinced great interest amongst researchers.

Performance of microphone greatly depends on the diaphragm behavior. Various diaphragm designs have been proposed of which circular and square diaphragms are popular. Few improvement and modifications like corrugations and small slits are proposed for performance improvement. These diaphragms are mostly edge clamped or vertices clamped. The type of end fixity greatly affects the deflection of the diaphragm and thus performance of the device .The type of diaphragm fixture needs to take care of trade-offs between sensitivity, operating frequency range and noise level. Thus, diaphragm and its fixture play an important role in performance of the device. A circular diaphragm with semicircular slits to make it compliant is proposed. These slits not only provide gap for air flow air and reduce squeeze film damping but also provide better deflection due to increase in compliance [1].

Analytical models like Zuckerwar's model [2] are best suited to simple edge clamped circular diaphragms. But complex diaphragm shapes require a more rigorous model. Unfortunately, none of such models have not been previously attempted. Thus, a modified Zuckerwar's model has been proposed and followed in the analysis of the proposed design. The compliant diaphragm is analyzed using both conventional theoretical model as well as finite element analysis. The proposed design offers an increased sensitivity and higher deflection by virtue of compliance. The analysis of results show that the sensitivity of the device is increased from 1mV/Pa to 5.4mV/Pa for the same dimensions which is almost 5.5 times increase in sensitivity. The device has a useful bandwidth to operate upto 15 KHz with a frequency roll-off around 1200Hz. The thermal noise in the microphone is also estimated and is found to decrease from 20dB to 16dB for the proposed design.

References:

1. **N. Mohammad**, "Modelling and optimization of a spring-supported diaphragm capacitive MEMS microphone", Swinburne University of Technology, Hawthorn, Australia.

2. **Chee Wee Tan,** “Analytical modeling for bulk-micromachined condenser microphones”, NTU, Singapore.

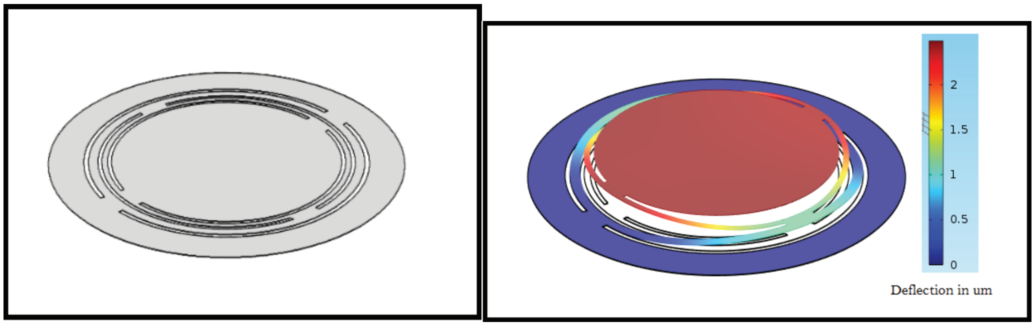

Figure1-(a) The compliant diaphragm with semicircular slits (b) deflected (around 2.5um)

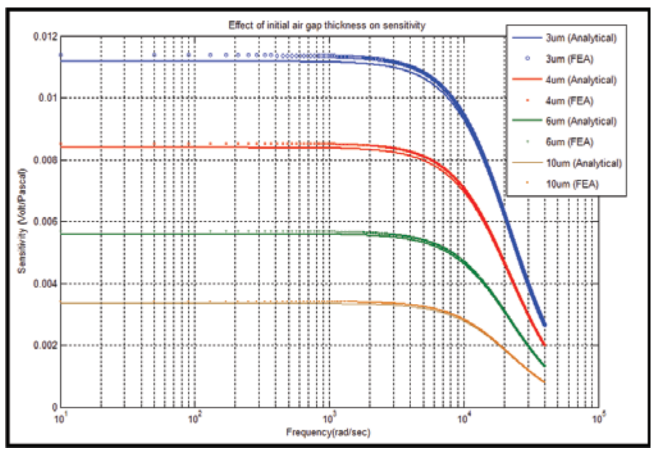

Figure- 2- Open circuit sensitivity of the proposed design (5.4mV/Pa) for radius=600um

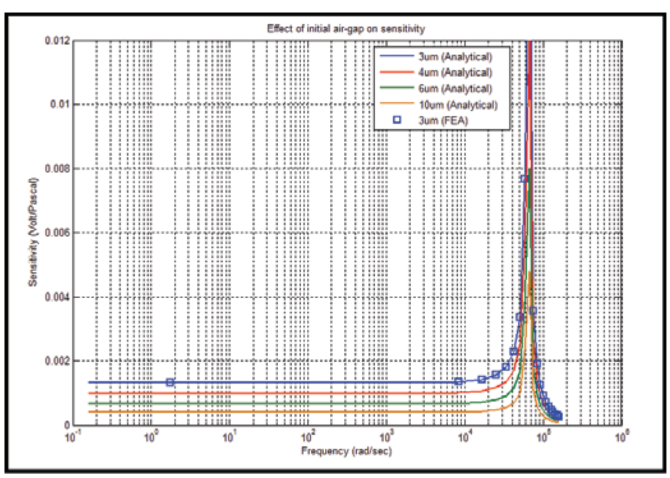

Figure3 - Open circuit sensitivity of conventional diaphragm design (1mV/Pa) for radius =600um