Design and Simulation of Piezoelectric Vibration Energy Harvesters of Various Shapes Using COMSOL Multiphysics®

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Abstract

Introduction:
Energy harvesting is an emerging area of research where wasted ambient energy is converted into useful electrical power thus providing a promising solution to the environmental issues associated with battery powered systems [1-3].

Among the various sources of ambient energy, vibration based energy harvesting is one of the popular choices. MEMS based microcantilevers have been a popular choice for vibration based energy harvesting [4-6]. The deflection of a cantilever for a particular applied force depends on the stiffness of the cantilever and its spring constant. A lower stiffness and a lower value of spring constant would result in greater deflection for a particular value of applied force [7]. In sensing applications, we would ideally like to get maximum deflection for minimum change in the value of the quantity being sensed. Hence, for sensing applications, cantilevers with greater sensitivity are preferred [8,9].

A layer of piezoelectric material (ZnO, AlN and PZT are modeled) is added to the cantilever and using COMSOL Multiphysics' Piezoelectric Devices physics, we determine the piezoelectric voltage that is generated in each of these cases.

Use of COMSOL Multiphysics:
We use COMSOL Multiphysics' Piezoelectric Devices physics to numerically solve for the various cantilever geometries and compare the obtained deflection, stress and generated piezoelectric voltage.
We study four geometries namely, conventional rectangular cantilever, pi -shaped cantilever, T shaped cantilever and finally a triangular cantilever. Properties of Si and the piezoelectric layer (ZnO, AlN and PZT are modeled) are taken from the COMSOL material library. One of the cantilever ends is assigned a fixed boundary condition and the other ends are given a free boundary condition. We keep the bottom of the piezoelectric layer as ground and assign a floating potential condition to the top surface of the piezoelectric layer. A constant force of 0.5μN is applied on the ends of all the cantilevers. The applied force results in a deflection in the cantilever. The deflection creates a stress in the piezoelectric layer and this stress generates a

voltage in a direction perpendicular to the stress (d31 mode). The displacement, stress created and the generated piezoelectric voltages are compared for various geometries.

Results:

We observe a greater deflection in the triangular and T shaped cantilevers as compared to the conventional cantilever (Figure 1). The greater deflection results in a greater stress and strain in the piezoelectric layer resulting in greater generated piezoelectric voltage (Figure 2). Thus we observe that the triangular geometry is most suitable for piezoelectric based energy harvesting cantilevers (1.89 times higher voltage as compared to conventional cantilever) followed by T shaped cantilevers.

The regular geometry cantilever based energy harvester has already been fabricated and characterized under the Indian Nanoelectronics Users Program (INUP) at Centre for Nano Science and Engineering (CeNSE), IISc, Bangalore. Those results have been reported in an earlier work [10]. In the future, we would like to validate our theoretical and simulation studies by the fabrication and characterization of the designed devices with non-conventional geometries.

Reference

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Figures used in the abstract

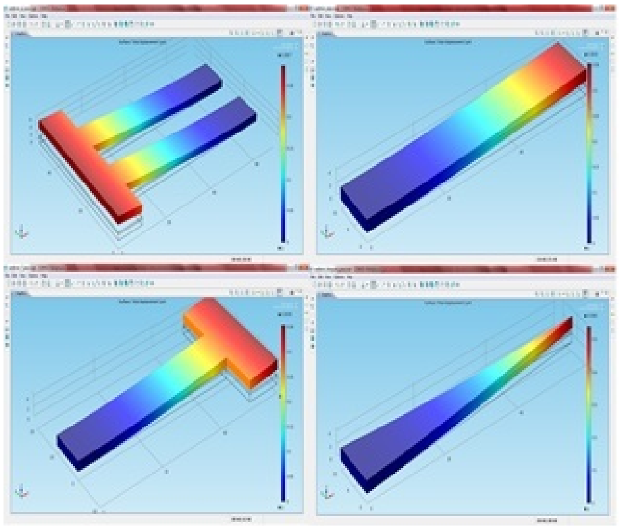

Figure 1: Cantilever deflections for various geometries

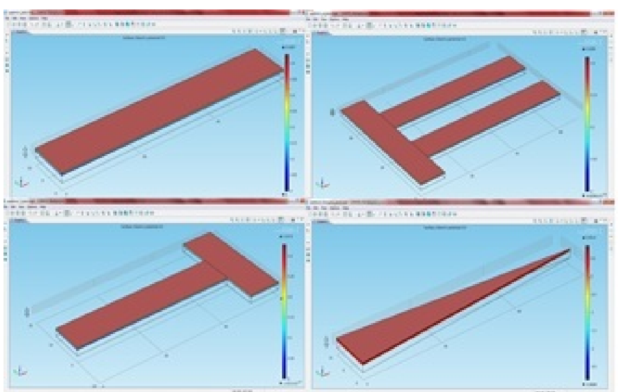

Figure 2: Piezoelectric voltages for various geometries