Design Optimization of a Fiber Bragg Grating Accelerometer Using COMSOL Multiphysics

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Abstract

Fiber Bragg grating accelerometers are widely used in seismic and civil structural measurements where it is required to acquire low frequency, low 'g' signals under harsh environmental conditions, without any influence of electromagnetic fields, with multiplexing capabilities [1],[2]. Amongst the various types of FBG accelerometers, the cantilever based designs are suitable for low frequency measurements with high sensitivity and low cross-axis sensitivity [3]. The cantilever based FBG accelerometers basically comprise of a vibrating cantilever with a FBG bonded on the surface or attached to it. The bending strain of the cantilever is transferred to the FBG which results in a wavelength shift proportional to the strain. The bending strain of the cantilever being proportional to the vertical acceleration, the FBG wavelength shift is a direct measure of the vertical acceleration. For high sensitivity, an inert mass is attached to the cantilever tip. However, the highest achievable sensitivity by conventional cantilever-mass design is insufficient for signals of ultra low magnitude such as those in seismic and civil structural measurements. It is obvious that larger the distance of the FBG from the surface, higher would be the strain experienced by the FBG and thus higher would be the sensitivity. In our previous work we achieved an enhancement in sensitivity using a Polyimide backing patch to increase the separation between the neutral axis of the cantilever and the FBG [4]. Sensitivity ~450 pm/g was achieved for a specific cantilever-mass arrangement with this simple architecture. However, the limit up to which the patch thickness could be increased was not clearly specified and the experiment was restricted to a patch of thickness 150 micron , which had a negligible weight compared to that of the cantilever.

In this paper, the concept of using a backing patch to mount the FBG on a cantilever-mass based accelerometer is thoroughly explored by simulations using COMSOL Multiphysics version-4.2a. The primary objective was to study the influence of patch thickness and also the Young's modulus of the patch material on trhe sensitivity of the accelerometer. The geometry is shown in Figure1. A physics-controlled normal mesh comprising of 20438 free-tetrahedral elements was generated by the software (Figure 2). The above geometry was analyzed for the three patch materials Teflon, Polyimide and Aluminum by a Frequency Domain Parametric study. The patch thickness was varied upto 2200 micron . The excitation frequency was scanned upto 10Hz. Assuming that the FBG is located 5mm from the cantilever pivot, the strain experienced by the FBG in is plotted against varying patch thickness at 10Hz excitation frequency for the three different patch material, in Figure 3. It is evident that the strain experienced by the FBG increases with patch thickness up to a certain thickness and then decreases. The maximum strain is experienced by the FBG when a Teflon patch of thickness 1100 micron is used. The resonant frequency of the geometry in Figure1

was computed for various patch thicknesses made up of the three different patch materials using a Eigenfrequency Parametric study. The corresponding plots are shown in Figure 4. The resonant frequency increases with patch thickness and the increase is highest for Aluminium, intermediate for Polyimide and lowest for Teflon. The increase in resonant frequency of the system is due to the composite action of the cantilever and the patch.

Experiments with the suitable patch material (Teflon) are conducted and the experimental results confirm the simulation analysis. For a particular configuration, sensitivity 1062 pm/g has been achieved with a 1000 micron Teflon patch.

Reference

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Figures used in the abstract

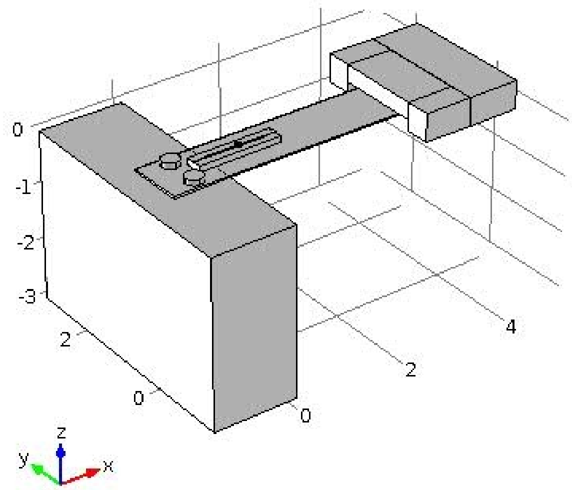

Figure 1: Geometry of the fiber Bragg grating accelerometer.

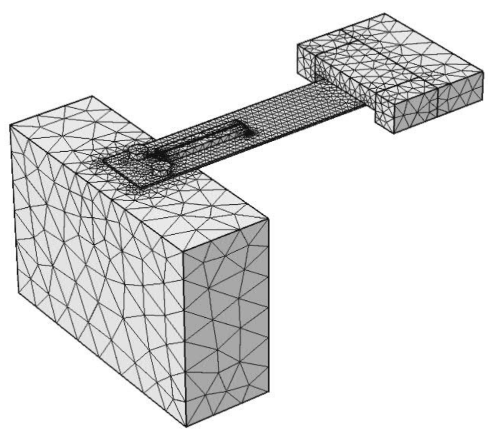

Figure 2: Mesh.

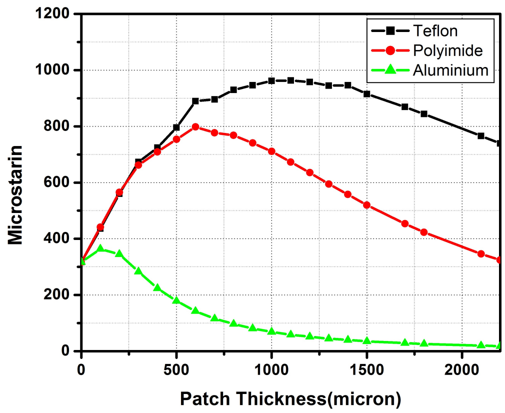

Figure 3: Strain at the FBG vs patch thickness at 10 Hz excitation frequency for Teflon, Polyimide and Aluminium patches.

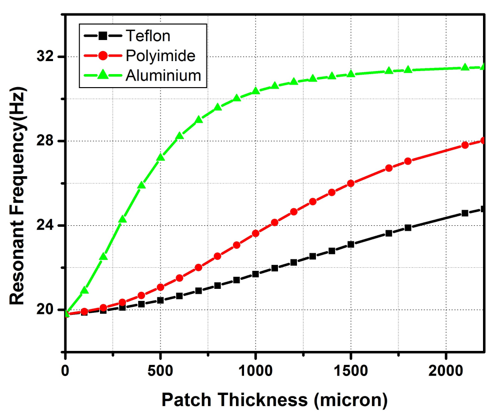

Figure 4: Resonance frequency vs patch thickness forTeflon, Polyimide and Aluminium patches.