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A Stepwise Approach for Piezoresistive Microcantilever Biosensor Optimization

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Abstract : Due to the low concentration of the analytes in biological samples, the use of Biological Microelectromechanical System (Bio-MEMS) biosensors for biomolecules detection results in a minuscule output signal that is not good enough for practical applications. In response to this, a need has arisen for an optimized biosensor capable of giving high output signal in response the detection of few analytes in the sample; the ultimate goal is being able to convert the attachment of a single biomolecule into a measurable quantity. For this purpose, MEMS microcantilevers based biosensors emerged as a promising sensing solution because it is simple, cheap, very sensitive and more importantly does not need analytes optical labeling (Label-free). Among the different microcantilever transducing techniques, piezoresistive based microcantilever biosensors became more prominent because it works well in liquid environments and has an integrated readout system. However, the design of piezoresistive microcantilevers is not a straightforward problem due to coupling between the design parameters, constraints, process conditions, and performance. It was found that the parameters that can be optimized to enhance the sensitivity of Piezoresistive microcantilever-based sensors are: cantilever dimensions, cantilever material, cantilever shape, piezoresistor material, piezoresistor doping level, piezoresistor dimensions, piezoresistor position, Stress Concentration Region's (SCR) shape and position. After a systematic analyzation of the effect of each design and process parameters on the sensitivity, a step-wise optimization approach was developed in which almost all these parameters were variated one at each step while fixing the others to get the maximum possible sensitivity at the end. At each step, the goal was to optimize the parameter in a way that it maximizes and concentrates the stress in the piezoresistor region for the same applied force thus get the higher sensitivity. Using this approach, an optimized sensor that has 73.5x times higher electrical sensitivity (ΔR⁄R) than the starting sensor was obtained. In addition to that, this piezoresistive microcantilever biosensor it is more sensitive than the other similar sensors previously reported in the open literature. The mechanical sensitivity of the final senior is -1.5×10-8 Ω/Ω ⁄pN; which means that for each 1pN (10-10 g) biomolecules attach to this biosensor; the piezoresistor resistivity will decrease by 1.5×10-8 Ω. Throughout this work COMSOL Multiphysics 5.0, a commercial Finite Element Analysis (FEA) tool, has been used to simulate the sensor performance.

Keywords : biosensor, microcantilever, piezoresistive, stress concentration region (SCR)
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