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# Effects of Viscoelastic and Fluid Damping on the Quality Factor for a Resonant Microcantilever

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## ABSTRACT

The different sources of damping in a resonant microcantilever sensor, including damping from the medium of operation and from viscoelastic properties of the device itself, play a significant role in the determination of the device's quality factor and operational characteristics. In order to accurately estimate the quality factor of this device, all sources of damping must be taken into account. However, the damping due to the viscoelasticity of the device and the medium of operation are often neglected. In this work, the damping of a resonant microcantilever from each of these sources is characterized.

Resonant microcantilevers have been successfully utilized as chemical sensors in gas phase chemical detection. However, in liquid phase detection, the viscous damping of the medium must be taken into account when calculating the quality factor. Low loss approximations used in the literature to account for the effect of the medium of operation on the microcantilever are inappropriate for characterizing losses in viscous liquid media. Furthermore, the polymer coatings used as the sensing layer on the microcantilevers can result in additional damping. These coatings normally consist of viscoelastic materials with Young's moduli several orders of magnitude below that of the base layer and can be comparatively thinner. Thus, some researchers choose to neglect the effect of the polymer's viscoelasticity when calculating the expected quality factor of a polymer-coated microcantilever. However, in many cases, the loss caused by the viscoelastic polymer layer is significant when compared to other dominant loss sources.

An analytical expression for the quality factor has been derived taking into account the effects of the medium of operation and the viscoelastic sensing layer. This includes the coupling between the loss terms, which have not been previously investigated because of the assumption that the loss sources where independent. An iterative method for calculating the quality factor has also been devised that accounts for the frequency dependence of the viscous forces acting on the microcantilever. This frequency dependence is shown to be significant as the viscosity of the medium increases, thus is important when operating in viscous liquid media.

Increasing the thickness of the microcantilever increases its rigidity. However, if the sensing layer thickness is increased, the viscoelastic loss becomes more significant in the calculation of the quality factor. It has been shown that there exists an optimal layer

thickness for a given microcantilever configuration with regards to the quality factor, as shown in Fig. 1. The quality factor for various sensing layer thicknesses and microcantilever dimensions in air, water, and glycerol has been simulated, and this optimum thickness is noted.

When undergoing analyte sorption, the viscoelastic layer also undergoes plasticization and swelling due to coating-analyte interactions. The result is also a change in the damping characteristics of the sensing layer. The change in the quality factor can be significant given an analyte-coating pair and microcantilever configuration. Simulations demonstrating the significance of this plasticization effect are also given using data available in the literature for commonly used polymer layers.

The results of these simulations illustrate the significance of the viscoelastic coating properties on the overall damping characterization of resonant microcantilevers. This work will allow one to develop rules for accurately accounting for the viscoelastic and viscous dampings in various applications.

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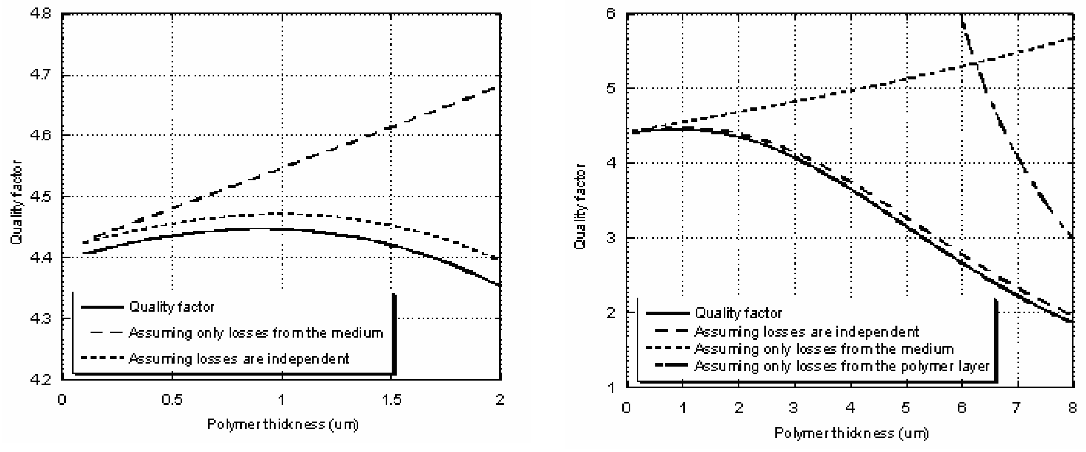

**Figure 1a and b: Quality factor for a polymer-coated microcantilever in water with varying polymer thicknesses (assumed to be PIB). For this cantilever geometry (100x20x2 μm), there exists an optimum coating thickness with regards to the quality factor of approximately 1 μm.**