# What Is Needed for the PiezoMEMS Applications of the Future?

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For years there has been significant effort to improve the piezoelectric constants in thin-film ferroelectric materials, however there are other important factors that offer promise of dramatic improvements at the device level. Of particular interest are the mechanical quality factor, permittivity, and zero-bias performance. Mechanical quality factor, $Q_m$, is extremely important for any resonant application. A high $Q_m$ is extremely attractive because the quality factor of the system amplifies the motion of the system. Beyond the motion amplification provided by high $Q_m$, the characteristics of the motion also change. For radio frequency (RF) devices, the sharpness of the frequency response is of utmost importance, allowing for rejection of nearby spurious signals, especially in transmit/receive diplexers, Fig. 1. In gyroscopes, the quality factor also governs the ring-down time, which is essential for operation in whole-angle mode. In both of these applications, having low $Q_m$ will prevent proper system functionality, regardless of any improvements in piezoelectric coefficients. While PZT thin-films offer large piezoelectric constants, $e_{31}$ and $e_{33}$, often an order of magnitude larger than other piezoelectric materials, the low $Q_m$ has prevented its adoption into many resonant applications. Interestingly, some bulk PZT materials boast large quality factor up to 2000 and correspondingly large figure of merit (FOM), Fig. 2 [1], which if realized in thin films, would enable wideband RF filters, and navigation-grade MEMS gyroscopes.

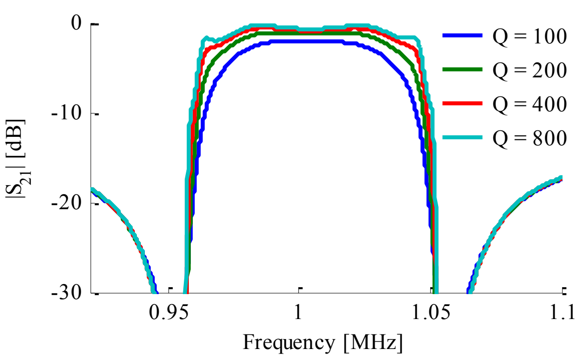


Fig. 1. Improvement in ladder filter with better $Q_m$.

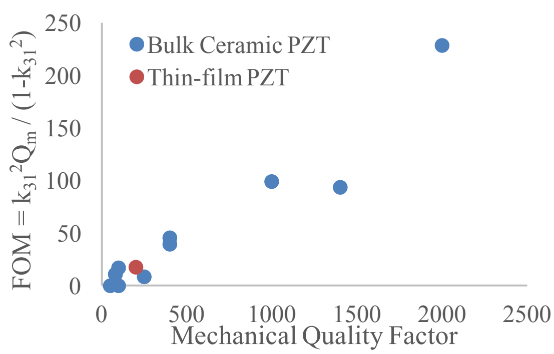


Fig. 2. Coupling factor and $Q_m$ for select bulk PZTs.

Permittivity is another important consideration for piezoelectric MEMS. In many applications, such as the piezoelectric micromachined ultrasonic transducer (pMUT) or energy harvesting, the high piezo coefficient would be attractive except that the permittivity degrades the figure of merit, $e_{31}^2 / \varepsilon_{33}$ [2,3]. If this permittivity could be lowered, larger distances could be sensed and more energy harvested from the environment, just as fingerprint scanning, gesture recognition, multi-touch screens, and energy harvesting markets are expanding.

Finally, operation at high bias electric fields often dramatically improves the performance of PZT thin-films. Not only do the piezoelectric coefficients improve at high electric fields, the permittivity and dielectric loss also decreases. While control of the film properties through bias can be attractive for making tunable systems, it often becomes an impediment. When packages and parts are limited by packaging pinout and routing complexity, accommodating biasing connections will seldom be attractive. To achieve the hoped-for wide-scale device performance improvements, PZT thin-film MEMS will likely need to shed the promise of tunability and embrace zero-bias operation. This zero-bias operation, however, need not eliminate the performance benefits seen at high-bias. The improved piezoelectric coefficients and decreased permittivity can be realized by intentionally imprinting the film, shifting the coercive fields so dramatically that 0 V looks like high field. To achieve this would enable adoption of PZT films into a wide array of systems.

References

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