

# Graphene as virtually massless top electrode for RF bulk acoustic wave (BAW) resonator

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Bulk acoustic wave (BAW) resonators are gaining more and more attraction as key-building blocks for RF filters as used in wireless communication devices. The rapid increase of data transfer rates requests RF filters to be more and more efficient regarding energy conversion and accurate signal handling. A BAW resonator consists of a piezoelectric thin film material (e.g. Aluminum nitride AlN), where a standing acoustic wave in the bulk of the thin film is excited by top and bottom electrodes. Both electrodes strongly influence the resonators behaviour due to electrical and mechanical losses. Massless and conductive electrode materials can tackle these loss problems [1]. At this point virtually massless graphene comes into play. Using the modified Butterworth van Dyke (mBVD) equivalent circuit model [2], we show in our work that graphene is working in principle as electrode material in RF domain and leads to a significant resonance frequency shift of the BAW device compared to Ti/Au metallisation, which we used as a reference. Furthermore we obtained higher Q-values at anti-resonance, which shows the potential of graphene in minimizing mechanical losses. These findings highlight the advantages of Graphene and other 2D conductive materials for alternative electrodes in electroacoustic resonators for the RF frequency region.

## References

- [1] Z. Qian, F. Liu, Y. Hui, S. Kar, and M. Rinaldi, "Graphene as a Massless Electrode for Ultrahigh-Frequency Piezoelectric Nanoelectromechanical Systems," *Nano Lett.*, p. 50605140657009, 2015.
- [2] J. F. Rosenbaum, *Bulk acoustic wave*

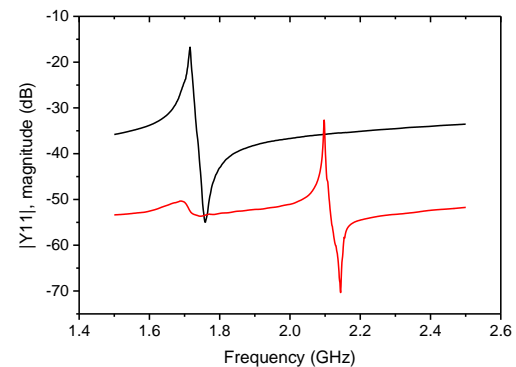
*theory and devices*. Artech House Acoustics Library, 1988.

## Figures

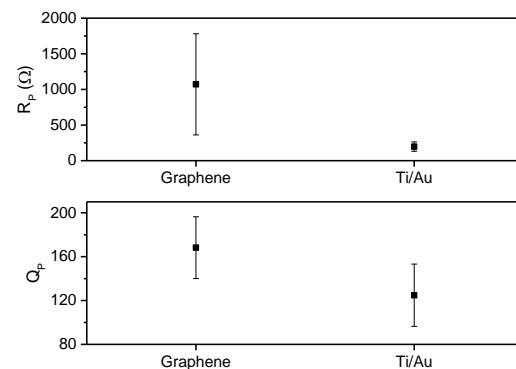
### Device module



**Figure 1:** Schematic of a solidly mounted bulk acoustic wave resonator (SMR-BAW) with AlN as piezoelectric material and graphene as top electrode.



**Figure 2:** Frequency response of admittance for graphene (red) and reference Ti/Au (black) top electrode in a SMR-BAW.



**Figure 3:** Acoustic losses (represented by parallel resistance  $R_p$ ) and Q-values at anti-resonance ( $Q_p$ ) for both graphene and Ti/Au as top electrode derived from the data in figure 2.