SAND2012-1705P

Sandia National Laboratories

Project Accomplishment Summary

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Sandia National Laboratories

Operated for the U.S. Department of Energy by
Sandia Corporation
Albuquerque, New Mexico

PROJECT ACCOMPLISHMENTS SUMMARY

Cooperative Research and Development Agreement (#1765)

between **Sandia National Labs** and Charles Stark Draper Laboratory

Note: This Project Accomplishments Summary will serve to meet the requirements for a final abstract and final report as specified in Article XI of the CRADA.

Title: Chip Scale Mechanical Spectrum Analyzers Based on High Quality Factor Overmoded Bulk Acoustic Wave Resonators

Final Abstract:

The goal of this project was to develop high frequency*quality factor (fQ) product acoustic resonators matched to a standard RF impedance of 50 Ω using overmoded bulk acoustic wave (BAW) resonators. These resonators are intended to serve as filters in a chip scale mechanical RF spectrum analyzer. Under this program different BAW resonator designs and materials were studied theoretically and experimentally. The effort resulted in a 3 GHz, 50 Ω, sapphire overmoded BAW with a fQ product of $8x10^{13}$, among the highest values ever reported for an acoustic resonator.

Background:

Because of their small size and high quality factors, Q, acoustic resonators are widely used as filters and oscillator references in RF communications devices. One figure of merit (FOM) for acoustic resonators is fQ product. This FOM is used because the stability of oscillator references depends on fQ product and the Q of low loss acoustic resonators are inversely proportional to frequency, limited by phonon-phonon damping, at frequencies technically relevant to RF communications. The Q will also limit the minimum bandwidth filter that can be realized with low insertion loss at a given frequency. To excite waves in an acoustic resonator using electro-magnetic energy piezoelectric materials and metals are used. As piezoelectric materials and metals have relatively low quality factor when compared to low loss ceramics, semiconductors and complex oxides, a method of increasing Q beyond that available in piezoelectric materials and metals is desirable. Since $Q=E_{stored}*Cycles/E_{lost}$, many overtones or cycles of the carrier can be stored in a low loss substrate, increasing the Q to nearly the Q value of the substrate material. This approach overcomes the low Q value of piezoelectric resonators such as quartz.

Description:

The approach taken in this project uses overmoded bulk acoustic wave resonators. Here a piezoelectric layer, AlN, sandwiched between two metal, Al, electrodes is used to launch an acoustic wave into a wafer substrate. This transducer is sized to give a 50 Ω impedance. In order to increase the quality factor many cycles (or wavelengths) are stored through the wafer thickness. In this program many materials were studied theoretically for the wafer substrate including SiC, sapphire, Si, YAG, and AlN. SiC and sapphire were chosen as the substrate materials because of their very promising fQ products from theory. Since single crystal SiC was not available in 6 inch wafers, thus poly-SiC wafers were studied experimentally. In addition, Si substrates for increasing Q via overmoded BAW resonators were also studied. Implementing the BAW resonators in Si allowed the resonator design to be verified in an inexpensive substrate material where the material damping properties are very well known, which is not the case for SiC. Overmoded BAW resonators were designed and characterized in Si, Sapphire and SiC. The designs reached the fQ product limits predicted from theory in both Si and Sapphire. Despite having an even higher predicted fQ value, the fQ of the SiC resonators was poor, about a factor of 25 lower than expected. It is unknown at this time if this poor result was because a poly crystalline SiC wafer was used. Future work is planned to explore single crystal SiC. The 3 GHz sapphire overmoded BAW resonators demonstrated an fQ product of 8×10^{13}, among the highest values ever reported for an acoustic resonator, and formed a good match to a 50 Ω impedance. Because of their high quality factors, these resonators are promising candidates for chip scale spectrum analyzers where narrow band filters with Q's > 10,000 are desired.

Benefits to the Department of Energy:

The Department of Energy desires high quality filters and timing references for radars and other RF electronic systems. The resonators developed under this CRADA will allow for lower phase noise oscillators and narrow band filtering with exceptionally low insertion loss.

Economic Impact:

If commercialized, these resonators could improve the performance of mobile phones, GPS receivers and other consumer wireless devices.

Project Status:

Completed

ADDITIONAL INFORMATION

Laboratory/Department of Energy Facility Point of Contact for Information on Project

Roy H. Olsson
Sandia National Laboratories
PO Box 5800 MS 1069
Dept 1749, Bldg 858EL
Albuquerque, NM 87185

505.284.6375 (office)
505.844.2991 (FAX)

Company Size and Points of Contact

Charles Stark Draper Laboratories is a Non-Profit Company focused on US National Security.

Point of contact:
Dr. Amy Duwel

CRADA Intellectual Property

None

Technology Commercialization

The technical developments under this small CRADA are premature for commercialization.

Project Examples

The devices are being used in an attempt to construct a chip scale spectrum analyzer at Rockwell Collins.

PROJECT ACCOMPLISHMENTS SUMMARY
Cooperative Research and Development Agreement (SC10/01765)
between **Sandia National Laboratories** and **Charles Stark Draper Laboratory**

This summary has been approved for public release by Sandia and Charles Stark Draper Laboratory

Sandia National Laboratories

By ______________________ 8/15/2011
Roy H. Olsson — Date
Principal Investigator

Sandia National Laboratories

By ______________________ ______________
Manager — Date
WFO/CRADA Agreements

Charles Stark Draper Laboratory

By ______________________ 11.2.11
Title: Contracts Manager — Date

In order to expedite the process, if we do not receive your signed reply by 09/14/2011 we will assume your concurrence for the release of this document to the public.