Robust AlN MEMS Resonators for High Temperature Space Environment

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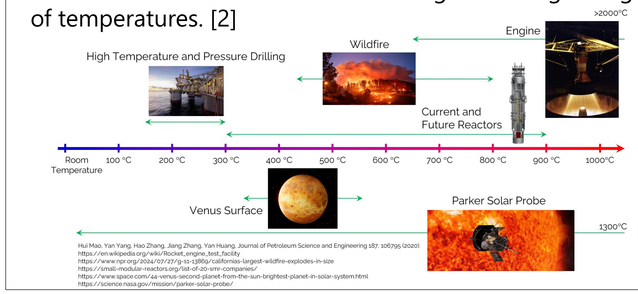
Introduction

A big limiting factor with sending payloads into space is weight. The cost of missions rely heavily on the weight of the payload being lifted off into space. Using advanced semiconductor manufacturing processes, sensors and devices can be miniaturized down to the micron scale. Such devices that rely on both mechanical and electrical behaviors are considered micro-electromechanical systems, or MEMS.

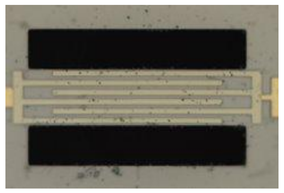
Background

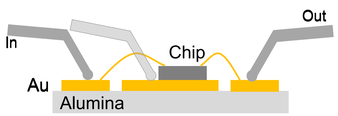
Piezoelectric MEMS devices have shown to be very effective for sensor applications and oscillators. Among piezoelectric materials, Aluminum Nitride (AlN) maintains a very good piezoelectric coefficient at temperatures up to >1100C. [1] AlN is also known for having a very wide bandgap (6.2 eV) making its characteristics more consistent than other materials throughout a high range of temperatures. [2]



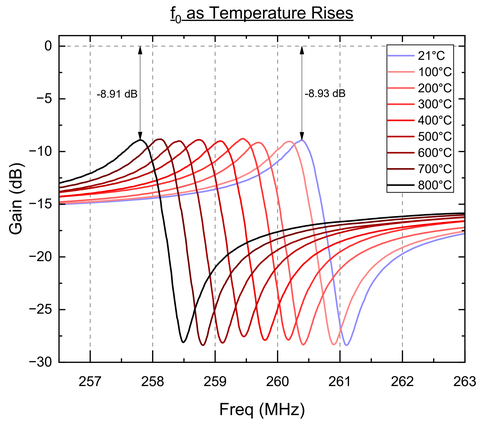
Methods

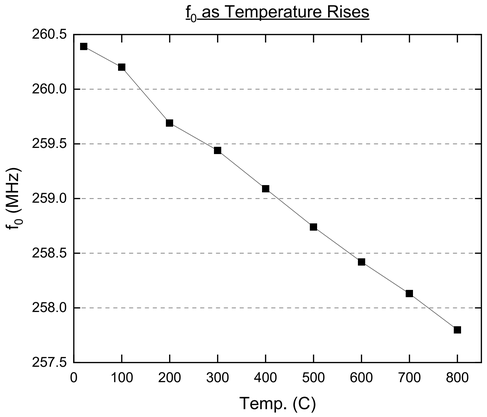
The MEMS device was designed and fabricated from a Molybdenum/AlN/Molybdenum/AlN(Seed)/Si wafer in different frequency configurations around 200, 430, and 920 MHz. In order to test within vacuum and controlled temperature environment, the device must be adapted to accommodate the large probes housed within the vacuum chamber. Using High T Conductive Cement, the chip can be mounted onto an alumina PCB with larger gold contacts.

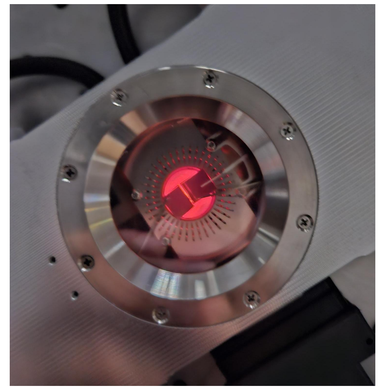




Results

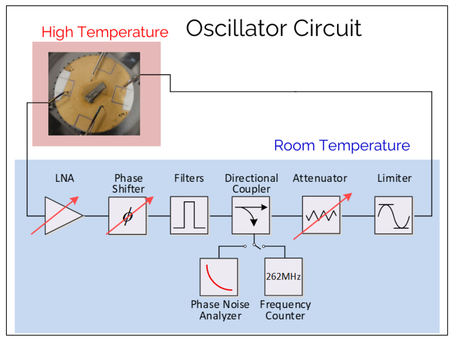


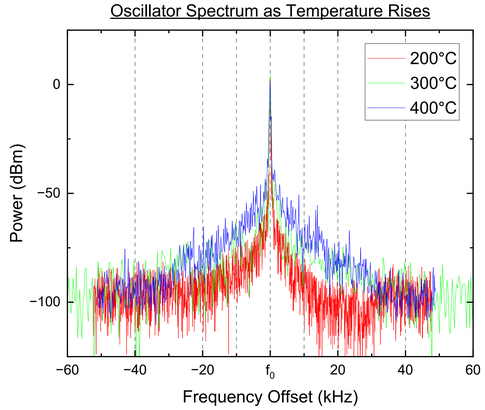


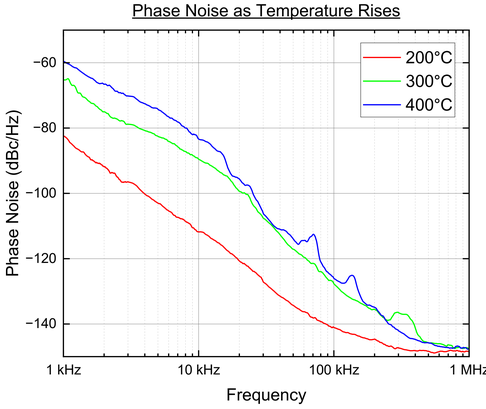


Testing of the resonator was mainly done in two configurations. Seen left are measurements from open loop testing of just the resonator connected to a VNA. Frequency shifts down as temperature rises under vacuum, with a Temperature Coefficient of Frequency ≈ -12.8 ppm/°C. Insertion loss remains mostly stable from 21°C to 800°C.

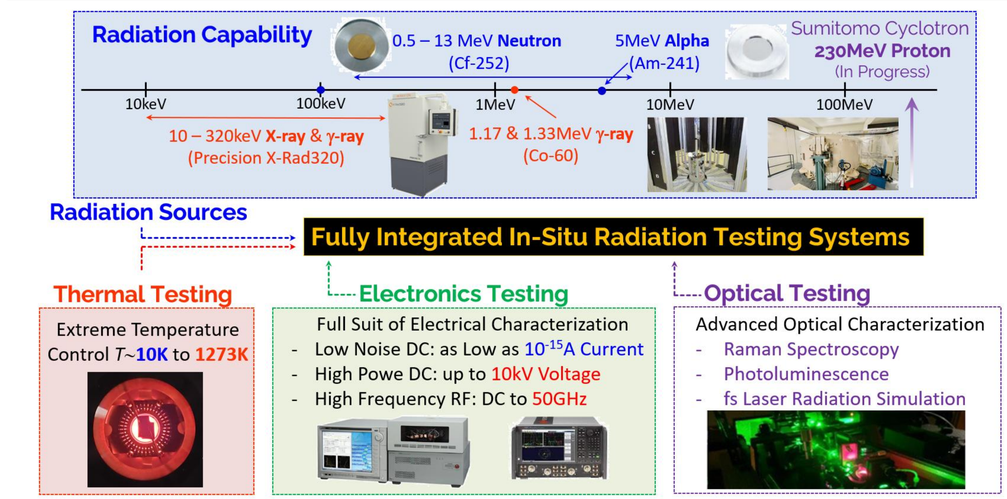
For testing the device to be used as a self-sustaining oscillator, it is connected into the circuit configuration seen right. Only the resonator is under vacuum and temperature. Phase noise degradation can be seen increasing as temperature rises due to increasing thermal noise.







Future Work

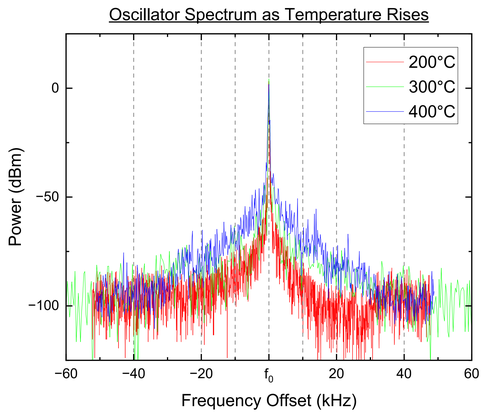


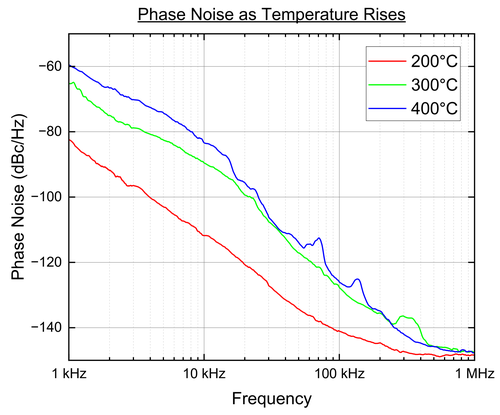
Conclusions

This work presented the experimental measurements of a piezoelectric AlN MEMS resonator across a vast span of temperatures up to 800°C. The measurements show a minimal Temperature Coefficient of Frequency and loss which prove the effectiveness of Aluminum Nitride stability over a wide range of temperatures. Future plans include high-temperature measurements while in radiation environment and sensor development utilizing the designed AlN resonator.

References

[1] *Adv. Mater.* 21, 593–596 (2009)
[2] IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control 62, 1880-1887 (2015)


Oscillator Spectrum as Temperature Rises
Power (dBm)
0
−50
−100
−60
−40
−20
f0
20
40
60
Frequency Offset (kHz)
200°C
300°C
400°C


Phase Noise as Temperature Rises
Phase Noise (dBc/Hz)
−60
−80
−100
−120
−140
1 kHz
10 kHz
100 kHz
1 MHz
Frequency
200°C
300°C
400°C