CALCULATING THE RATE OF DEPOSITION OF MICRO DUST PARTICLES USING A QUARTZ CRYSTAL MICROBALANCE. A. Palat[1], S. W. Ximenes[1], D. M. Hooper[1], E. L. Patrick[2], R. Battaglia[3], M. Mauro[3], H. Shin[4], T. Chung[4], [1]WEX Foundation,110 E. Houston Street, 7th Floor, San Antonio, TX 78205, [2] Southwest Research Institute®, [3] Novaetech S.r.l., Piazza Bartolo Longo, n. 2880045, Pompeii (NA), Italy, [4]Korea Institute of Civil Engineering and Building Technology (KICT), Republic of Korea. (arjun@wexfoundation.org).

Introduction: Charged dust particles lofted due to surface disturbances on the lunar surface pose an issue to both humans and equipment. Apart from equipment facing abrasions due to the particles, the dust particles could cause serious damage if they come in contact with electronics. As a part of the Lunar Caves Analog Test Sites (LCATS) program, a quartz crystal microbalance (QCM) is being developed for dust detection as a part of a larger project that encompasses a student payload to the Moon[1]. The QCM measures mass variation in nanograms per second. Multiple tests were conducted in different environments to best estimate the functioning of the sensor and to evaluate a proper equation for in situ research on the lunar surface.

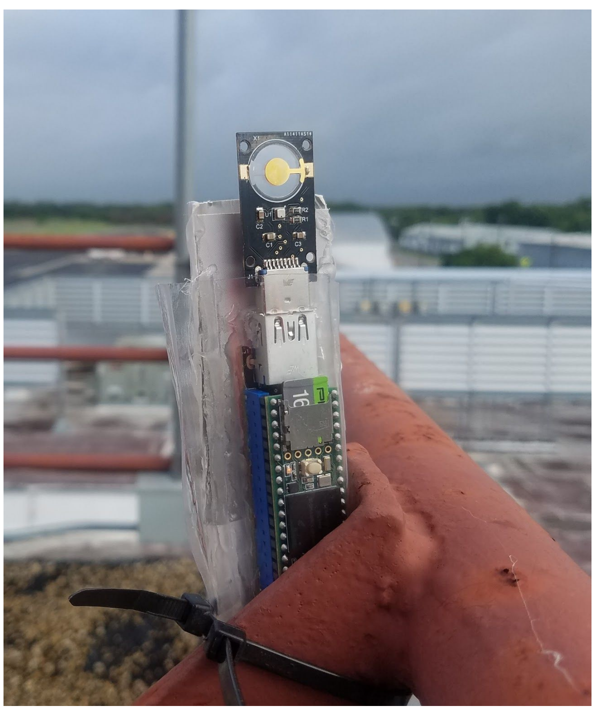

Figure 1. QCM test in open air.

Tests were conducted in open air (Figure 1); atop a high altitude balloon; and in the dusty thermal vacuum chamber (DTVC) at the Korea Institute of Civil Engineering and Building Technology (KICT). The main goal of these tests was to establish the rate of mass accumulation of micron-scale particles on the surface of the crystal. These tests were also used to characterize the relationship of the frequency response as a function of both temperature and mass accumulation.

Analysis: The QCM is based on the piezoelectric properties of the quartz crystal. The crystal is set to oscillate at about 10 MHz and the mass accumulated is calculated by the shift in frequency. The mass variation and frequency change are inversely related, where the frequency reduces as more mass is added to the crystal. The mass of the dust deposited is calculated with the Sauerbrey equation, which describes the mass-frequency relationship on the surface of the crystal [2].

$$\Delta m = -\frac{A\sqrt{\rho_q * \mu_q}}{2{f_0}^2} * \Delta f$$

The device was tested in a vacuum chamber and with a lunar simulant in the DTVC at KICT. These tests helped characterize the instrument for the rate of deposition of particles as well as the maximum loading of the crystal. The graph for the test in the DTVC (Figure 2) shows the frequency dampen after a considerable amount of dust had settled on the active area of the crystal. The frequency dropped and oscillated between 80kHz and 150kHz. The mass accumulated on the crystal in the DTVC test was 14.78ng.

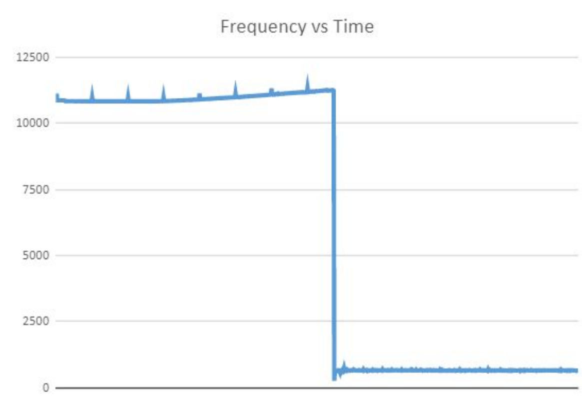

Figure 2. Graph representing the maximum load on the crystal.

The open air test run atop a tower at Stinson Airport produced valuable data representing the relationship of frequency and temperature. The sensor was in open air with average weather of 28ºC. The data show an inversely proportional behavior that has a drop in frequency as the temperature rises (Figure 3). The test conducted on the LCATS high altitude balloon, unfortunately, was not successful in the calculation for dust deposits as the stability and force of the air disturbed the oscillation of the crystal. The Sauerbrey equation used above does not take both the Gaussian distribution of mass sensitivity and the influence of the metal electrodes into consideration[3]. Further calculations would involve overcoming those disadvantages by taking the integral of the mass sensitivity.

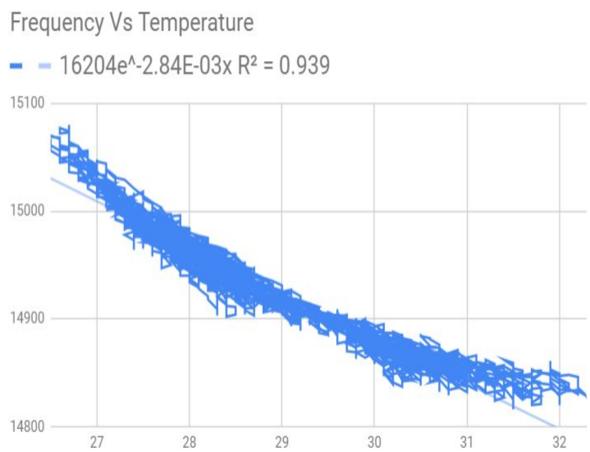

Figure 3. Frequency vs Temperature.

Conclusion and Future Tests: The QCM as mentioned is very sensitive and minor impacts from the surroundings can cause a shift in the frequency. A test will be conducted in a clean room to ensure a controlled environment for testing.

Figure 4. QCM inside the DTVC.

We intend to conduct more tests in the DTVC at KICT (Figure 4) using crystals oscillating at different frequencies to fully elucidate crystal performance under maximum load, in addition to its behavior under various orientation angles. We will also explore the development of a Sticky QCM (SQCM) to enhance the binding strength between the crystal and dust. The use of Apiezon H vacuum grease as a sticky film was successfully tested on a SQCM sensor of the Chang'E-3 mission to the lunar surface[4]. Construction of the protective shroud (Figure 5) will take place early this year. Also, future calculations will take into account the influence of the electrodes on the active crystal area and the effect of the temperature. The development plan proposes to advance the sensor from a TRL 4 to a TRL 7, with an eventual goal of the lunar surface deployment of a QCM lunar dust instrument prototype to demonstrate and validate in situ mass accumulation measurements.

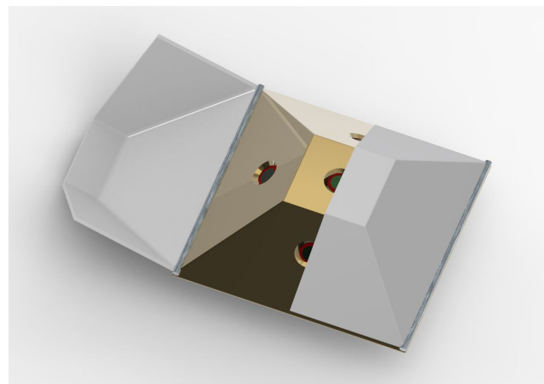

Figure 5. Protective shroud design for the QCM.

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