AFM MEASUREMENTS OF COHESION ON CI SIMULANT PARTICLES.

Keanna Jardine[1], Adrienne Dove[1], Laurene Tetard[1,2], [1]Department of Physics, University of Central Florida, Orlando, FL, [2] NanoScience Technology Center, University of Central Florida, Orlando, FL, keannajardine@knights.ucf.edu

Introduction: In this work we expand our measurements of the contact forces between single regolith grains. By characterizing the cohesive/adhesive values of these different surfaces we can make inferences on the structures of asteroids, their evolutionary history, and surface features, which are all influenced by the grain-scale behavior of surface materials [1]. Material surface properties like adhesion and cohesion can also help us understand processes that formed asteroids and the early solar system, better develop models of asteroid surfaces past and present, and help us to prepare for future asteroid exploration.

Research on NEAs and main belt (MB) asteroids has evolved from observational properties to mechanical properties, which are a result of environmental interactions and the forces that act on it. Most of these insights are currently approximated through numerical modeling based on interpretations of observations [2]. To validate these models and acquire more accuracy and precision in the measurements, laboratory measurements of physical properties of the particles in the asteroid environment are needed.

The most common asteroid type are the C types which are carbon rich, volatile rich, low albedo, and low density [3][4]. Spectrally, C type asteroids are similar to carbonaceous chondrites of types CI and CM. Compositionally, CI meteorites very closely match the condensable elements of the Sun and early solar nebula. They are also very rare, porous, weak and are of petrologic type 1 which indicates aqueous alteration. CI meteorites are mineralogically composed of mostly fine-grained phyllosilicates like serpentine-saponite, oxides, sulphides and carbonates [5][6][7][8][9].

Asteroid simulants are often created and needed for many scientific experiments and tests and are developed using models of asteroid regolith, meteorites, data from sample return missions, and observational data [10].

In this work, Atomic Force Microscope (AFM) techniques are used in vacuum to characterize the cohesive/adhesive values of a high-fidelity CI simulant based on the CI1 meteorite Orgueil using force distance curves. In addition, we used the major mineral components of the simulant and extracted adhesion values from combinations of simulant grain contacts to assess the contribution of each constituent to the overall adhesion. The simulant was obtained from the Exolith Lab (UCF) with a 51.3 % wt. of mg-serpentine, 10% wt. of Magnetite, 7% wt. of Olivine [11], so these individual components were used in addition to the bulk CI simulant in experiments.

Experimental Methods and Initial Results:

In our initial experiment, we performed deformation tests in ambient conditions of the simulants to ensure that the grains can withstand the force and repetitions of measurement throughout the experiment. This was done to ensure that repeated measurements would be sampling the same surface, not modified by a deformation that might change the surface area or roughness. The four samples of grains were CI simulant, Serpentine, Magnetite and Olivine, which were each sieved to include grains <45 µm.

We made sample plates of each and randomly selected a grain and attached it to the AFM cantilever using the technique described by Gan [12]. After attachment we performed calibration tests on a sapphire window (for its hardness) to test if the grains deformed after taking 25,100, 500, and 1000 curves at 0.3 V force. Prior to and after each trial, we took SEM images of the grains to evaluate the grains before and after to see if deformation occurred as shown in **Figure 1**. Our results indicated that the grains were able to withstand all the tests and had no indication of deformation. Carbonaceous material is often weak and is expected to deform although our tests indicated otherwise. This result leads us to in the future perform these tests at a stronger force set point and repeat these measurements until we see deformation in the samples.

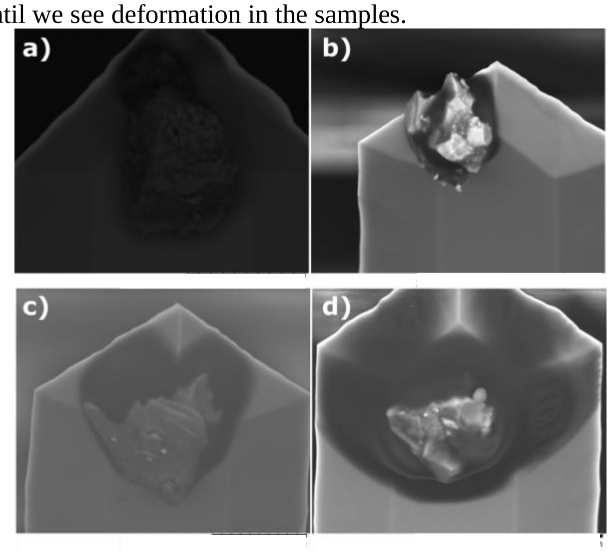

Figure 1. Image of cantilever tip with attached simulant grains before measurements. a) Serpentine grain b) Magnetite grain c) Olivine grain d) CI simulant grain

Ongoing Work: To further our investigation, we will begin performing grain-to-grain contact measurements in vacuum. Vacuum measurement is more representative of the asteroid environment and eliminates factors like capillary forces which has influenced our adhesion previously by introducing a water meniscus that lessened the true tip sample contact. We will first perform measurements on one grain of each sample, in 5 different spots on the grain, taking a minimum of 25 force curves on each spot at rates of 0.5Hz (2s) per curve. Each grain and tip will be calibrated before and after measurement, SEM imaged before and after measurement, and surface profiled to extract the average roughness (RMS roughness) of each spot/ area and the tip, characterize surface features and irregularities that can influence contact area, and to determine if any particles were passed from tip to sample or vice versa during the experiment. We will attempt to vary both the sample composition and tip composition to explore the effect each major constituent of the CI simulant has on each other, and on the conglomerate CI grain. We will then analyze the force curves, extracting the adhesion forces and energy dissipated through the interaction by using our in-house analysis software. In conclusion, we compare how the force is distributed over the surface, and effects of particle size, composition, and surface structure. The adhesion measurements give a range of possible cohesive forces that may be present on the asteroid based on composition.

References:

[1] Hestroffer, D., Sánchez, P., Staron, L. et al. Astron Astrophys Rev (2019) 27: 6. https://doi.org/10.1007/s00159-019-0117-5

[2] Scheeres D.J, Hartzell C.M, Sanchez P, Swift M, “Scaling forces to asteroid surfaces: The role of cohesion”, Icarus, Volume, 210, Issue 2, 2010, Pages 968-984

[3] Gradie et al. pp. 316-335 in Asteroids II. edited by Richard P. Binzel, Tom Gehrels, and Mildred Shapley Matthews, Eds. University of Arizona Press, Tucson, 1989, ISBN 0-8165-1123-3

[4] P. Vernazza et al. (2021) VLT/SPHERE imaging survey of the largest main-belt asteroids: Final results and synthesis. *Astronomy & Astrophysics* 54, A56

[5] Tomeoka K, Buseck PR (1988) Matrix mineralogy of the Orgueil CI carbonaceous chondrite. Geochim Cosmochim Acta 52:1627–1640

[6] Zolensky ME, Barrett R, Browning L (1993) Mineralogy and composition of matrix and chondrule rims in carbonaceous chondrites. Geochim Cosmochim Acta 57:3123–3148

[7] Endress M, Bischoff A (1996) Carbonates in CI chondrites: clues to parent body evolution. Geochim Cosmochim Acta 60:489–507

[8] King AJ, Schofield PF, Howard KT, Russell SS (2015) Modal mineralogy of CI and CI-like chondrites by X-ray diffraction. Geochim Cosmochim Acta 165:148–160

[9] King, A. J., Solomon, J. R., Schofield, P. F., & Russell, S. S. (2015). Characterising the CI and CI-like carbonaceous chondrites using thermogravimetric analysis and infrared spectroscopy. *Earth, Planets and Space*, *67*(1). doi:10.1186/s40623-015-0370-4

[10] Metzger, P. T., & Britt, D. T. (2020). Model for asteroid regolith to guide simulant development. *Icarus*, *350*, 113904. doi:10.1016/j.icarus.2020.113904

[11] Britt, D. T., Cannon, K. M., Hanna, K. D., Hogancamp, J., Poch, O., Beck, P., . . . Metzger, P. T. (2019). Simulated asteroid materials based on carbonaceous chondrite mineralogies. *Meteoritics & Planetary Science*, *54*(9), 2067-2082. doi:10.1111/maps.13345

[12] Gan, Y. (2005). Attaching Spheres to Cantilevers for Colloidal Probe Force Measurements: A Simplified Technique. *Microscopy Today*,*13*(6), 48-50. doi:10.1017/s155192950005402x