Introduction:
In outer space, micron sized particles, hereafter referred to as meteorites, can travel with significant velocities (> 3 km/s) [1]. Meteorites can be divided into three main categories, with the largest being stony meteorites, mainly composted of silicate minerals. Traditional studies on high velocity particle impacts in space have been done using either a gas gun or a laser ablation with a high power pulsed laser irradiation. The gas gun approach simulates high velocity impacts, but requires thousands of particle impacts at once and only allows for characterization of material after impact. To allow for in flight characterization of the particle impact we used a "table-top" laser induced particle impact tester (LIPIT) apparatus which includes an ultra-high-speed camera used to take multiple images of particles in flight.

The LIPIT allows for the acceleration of 1 to 100+ particles at a time. Using the LIPIT, particle size, velocity and impact angle can be measured between frames and used in conjunction with post impact characterization to develop a complete understanding of the target material response when impacted at high velocities. These experiments involved impacts onto a reduced graphene oxide polymer composites which may have useful properties for space-suit applications.

Experimental:
- A monolayer of micron sized SiO2 particles are deposited on a launch pad
- Each launch pad consists of a glass slide with a layer of gold sputter coated on top
- A 1064nm pulsed laser is fired towards a launch pad and focused so that a single particle is launched
- The flight of the particle is viewed with a ultra-high-speed camera

Results:
Preliminary results show that lift off from the launch pad at velocities greater than several hundred m/s. However, because a new high speed camera is in the process of being installed the exact velocities are not known yet. Post mortem characterization of the impacted samples show single SiO2 particles imbedded into the reduced graphene oxide polymer composite samples. Additionally these particles produced an impact crater in the polymer that was 3-4 times larger than the particle.

Figure 1: (Left) A side view of the table top LIPIT experimental set up. The blue camera represents the high speed camera used to images the particles in flight while the red camera is used to select a single particle for launch on the substrate. (Right) A top view of the LIPIT. The red line represents the path of the 1064nm laser used to launch the particles while the green line represents the path of a secondary laser used to illuminate the particle in flight for high speed camera.

Figure 2: (Left) A single 25µm SiO2 particle as viewed from the high speed camera upon impact with an aluminum substrate. The particle did not reach a sufficient velocity to imbed itself in the aluminum substrate. (Right) An optical microgram of a 4µm SiO2 particle (circled in red) after impact with a reduced graphene oxide polyethylene composite. The particle had sufficient velocity to imbed into the polymer as well as leave a crater that is 3-4 times the size of the particle.

Summary:
- Particle impacts using LIPIT have been shown to give a more complete picture of how materials behave upon high velocity impact because of the ability to view a single particle upon impact and gather direct measurements of each particle
- Direct measurements of the particle size, impact angle, and velocity can be made
  - Eliminates assumptions used when calculating material properties
- Using both in-flight data and post mortem characterization the mechanical response of target or substrate material at high strain rates be fully understood experimentally, something that has not been able to be done with a LIPIT apparatus
- Future work
  - Installing a new high-speed camera that allows for 4 images of the particle in flight to be taken
  - Impacts on polymer composites that are of interest for astronaut spacesuits
  - The installation of a vacuum chamber to test materials in relevant environmental conditions
  - Modeling of impacts using simulations to develop a theoretical understanding of material behavior upon impact

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