Experimental studies on the formation of chondrules under microgravity conditions

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Theory and motivation

Primitive meteorites found on earth consist of very many millimeter-sized spherules, which make up their main part in mass. These so-called chondrules are believed to have formed in the early solar system, although the heating process still is not understood. Trying to reproduce the spherules will hence be a new step to the understanding of the environment in the early solar system. To be able to make a predication about heating conditions, the environment has to be reproduced as closely as possible. Those parameters are primary the pressure and the microgravity condition. The pressure environment is important for the heating mechanisms, micro-gravity is important to prevent convection and influence outgassing. Additionally, contact points (e.g. sample holder), that may favor crystalization, can be avoided in microgravity.

To achieve this environment, experiments will be performed in the Drop Tower in Bremen. Samples shall be heated and cooled down in low pressure and during the 5 seconds drop.

Setup 1: Melting with an IR-Laser

Experimental design:
- 30W IR laser (980nm) to melt the dust-sample
- Camera (high speed if necessary)
- Pyrometer to measure cooling rates
- Pressure control: 0,1 ... 1000mbar
- Sample holder with fast drop mechanism
- down-pipe for preliminary microgravity experiments

If the precursor material is black to absorb the laser radiation, dust samples of 1mg (top left) are molten in less than 3s. They typically cool down in 2s (time between two pictures: 0,4s).

Solidified samples form perfect spherules, if no outer forces take effect. They should hence be heated and cooled down contact free and gravitation free. Microgravity is no problem, so that convection is prevented, whereas freedom of contact still faces technical problems.

Solidified spherules show gas inclusions, which seem to be correlated to the ambient pressure while heating. Higher pressure → more bubbles.

Samples that are heated at pressures of less than 20mbar explode and are not molten. Possible explanations are for example Coulomb forces or photophoretic forces. This requires further investigation since the pressures in the early solar system were about 0,1mbar.

Materials are high porous dust aggregates, which are similar to predicted early solar system bodies. They are produced by a new technique, forming macroscopic agglomerates by random ballistic deposition. Dust for the samples are Iron, SiO₂, Obsidian, Albite, Fayalid and Peridot or mixtures of these.

In most previous experiments samples were slowly heated in a furnace, whereas we are melting the well-defined dust samples in a very new way. They are flash-melted by a 30W IR laser in the one experimental setup and by an electric discharge of 500J in another setup. A combination of both ways is imaginable in the future.

The produced solid spherules are sent to a collaborating laboratory at the UCLA to be analyzed using scanning electron microscopy. Results are then compared to real first generation chondrules found in meteorites.

Setup 2: Melting with a lightning discharge

Experimental design:
- Capacitor with high voltage supply (W= \frac{1}{2} \cdot C \cdot U² = 500J) for two electrodes with 4mm distance
- Sample holder between electrodes (no drop mechanism yet)
- High Speed Camera
- Pressure control: 0,1 ... 1000mbar
- (Pyrometer)

Dust samples explode in the very short lightning (less than 0,5ms). Molten spherules and unprocessed dust spread in all directions with high initial velocities. This makes it difficult to observe the experiment and collect the processed material. Hitherto the material is picked from the chamber floor and walls and then analyzed under the microscope. A better method for quantitively collecting all material is being developed.

The initial sample is partly processed, between the primordial dust one can find many spherules of sizes up to 80µm - typical sizes are 5-10µm.

Cutting and polishing solidified samples is being developed at least for the 80µm spherules.

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