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Flash Heating

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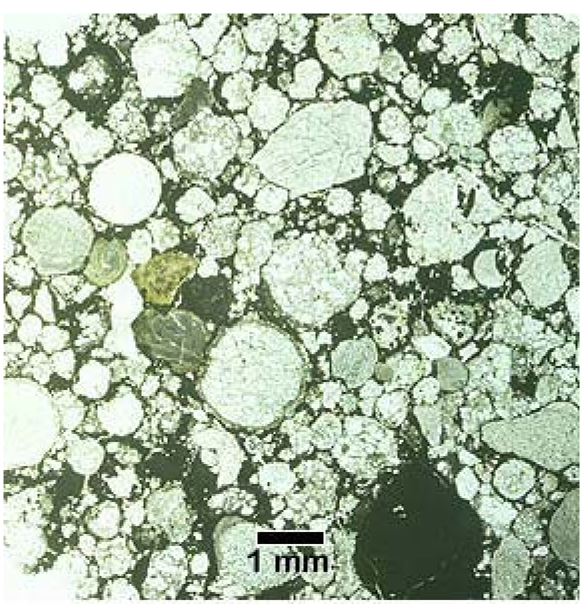
Meteorites contain millimeter-sized objects called chondrules. They were melted in the solar nebula, the cloud of gas and dust in which the Sun and planets formed. Numerous experiments on rock powders have been done to understand the melting process and the cooling rates chondrules experienced. Most meteorite specialists believe that chondrules formed by flash heating, with almost instantaneous melting, though the length of time they remained molten is uncertain. Can conventional laboratory furnaces heat rock powders rapidly enough to flash melt them? Susan Maharaj and Roger Hewins (Rutgers University, New Brunswick) tested this idea by inserting tiny wires of pure elements (which have precise melting temperatures) into compressed rock powders about 3.5 mm in diameter, and placing the samples into a furnace heated to a range of temperatures. They found that at 1600 ^{o}C, a sample took only six seconds to reach 1538 ^{o}C. When placed into a furnace at 1500 ^{o}C, samples took ten seconds to reach 1495 ^{o}C. This shows that the flash heating process can be studied in conventional laboratory furnaces.

Reference:

Maharaj, Susan V. and Hewins, Roger H. (1999) Simulating flash heating in a muffle tube furnace. *Meteoritics and Planetary Science,* v. 34, p. 885-890.

Chondrules: drops of fiery rain

Chondrites are a common type of meteorite that contain little round objects called chondrules. H. C. Sorby was the first to describe them, way back in 1877, noting that they appeared to have been melted. He called them "drops of fiery rain." Since then chondrules have been the subject of many studies and endless debate. Ideas for their origin seem to exceed the number of people who work on them. However, one prominent school of thought suggests that chondrules formed by extremely rapid heating of pre-existing dust in the solar nebula, around the time that the Sun and planets were forming.



(photomicrograph by G. J. Taylor)

The Semarkona chondrite (shown on the left) is composed of numerous chondrules, the round objects evident in this photograph of a thin slice of the meteorite. The chondrules are about a millimeter across. Many meteorite specialists believe that chondrules formed by flash heating of dust balls in the solar nebula.

To understand the environment in which chondrules formed, scientists have performed numerous melting experiments on powders with the same chemical compositions as chondrules, paying close attention to reproducing the crystal shapes and intergrowths seen in natural chondrules. This work was valuable in assessing the rates at which chondrules cooled and in demonstrating that many were not completely melted when they formed. [See **PSRD** article: Dry Droplets of Fiery Rain.] Only a minority of experiments tried to reproduce the conditions of flash heating, however, and even in those it was not clear how much heating had taken place. Many investigators doubted that flash heating was possible in a normal laboratory furnace.

(Image courtesy of S. Maharaj.)

The furnace used in this research is inside the white protective box. It is not designed to study flash heating, but Maharaj and Hewins have investigated if it is possible to instantaneously heat samples a few millimeters across to simulate chondrule formation.

Monitoring Rapid Temperature Rise

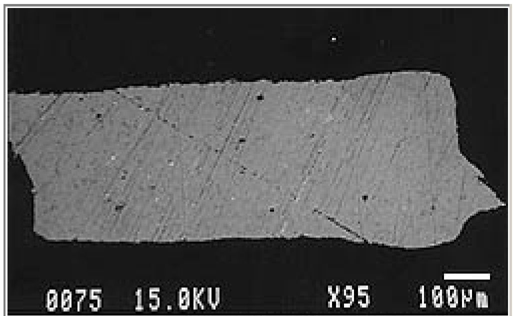
Maharaj and Hewins wanted to see how fast the temperature rises in a small compressed pellet when it is inserted into the hot spot of the typical kind of furnace used in rock experiments. All furnaces come equipped with thermocouples, which are devices used to monitor temperature. However, there is a time lag between insertion of a sample into a hot furnace and the temperature recorded by the thermal couple, and this lag exceeds the amount of time required for flash heating (only seconds). What we need is a technique to measure how the temperature varies with time inside each charge.

Maharaj and Hewins thought it would be useful to place small wires of metals or alloys inside the experimental samples. By choosing metals with a range of melting temperatures, they could estimate the temperature by examining the charges and seeing which metal melted. They used the metals in the table below.

Metal or Alloy	Melting Temperature (°C)
Gold	1064
Chromel-A (alloy)	1399
Chromel-P	1430
Cobalt	1495
Iron	1538
Palladium	1555

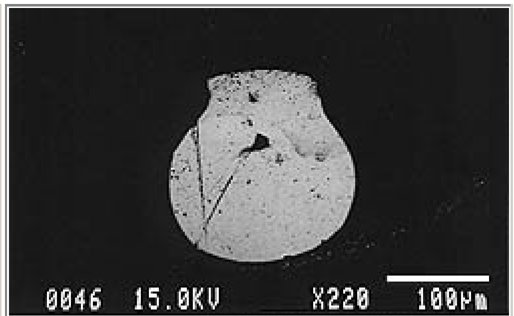
They suspended the samples, which were initially at 25 °C, in a furnace heated to 1400, 1500, and 1600 °C, and held the sample there for 1 to 90 seconds. Each experiment contained only one type of metal, so they had to do a total of 142 experiments! After the experiment, each sample was mounted in epoxy and ground down to expose the metal wire for examination. The melted wires formed spheres, making them easy to distinguish from the long thin shapes when not melted.

Metal wire before melting



(Image courtesy of S. Maharaj.)

Melted metal wire



(Image courtesy of S. Maharaj.)

The results show that the samples heated very rapidly at all temperatures, but especially when the furnace was at 1500 and 1600 °C. In a furnace at 1600 °C, samples can be heated uniformly to about 1500 °C in less than ten seconds, fulfilling anyone's definition of flash heating. This shows that flash heating experiments are possible with standard laboratory furnaces, and opens new avenues for understanding chondrules and processes that operated very early in the history of the Solar System.

Additional Resources

Maharaj, Susan V. and Hewins, Roger H. (1999) Simulating flash heating in a muffle tube furnace. *Meteoritics and Planetary Science,* v. 34, p. 885-890.

Taylor, G. Jeffrey "Dry Droplets of Fiery Rain." *PSR Discoveries*. Nov. 1998. <http://www.psrd.hawaii.edu/Nov98/chondrules.html>.

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