LASER-IRRADIATION OF AN ORDINARY CHONDRITE: SIMULATION OF ATMOSPHERIC ENTRY OF CHONDRTIC MATERIALS AND LINKS TO THE FORMATION OF MICROMETEORITES.

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Introduction: Atmospheric entry of asteroidal or cometary planetary materials typically involves fragmentation, melting, evaporation, mass loss, metal–silicate segregation, sudden changes in oxygen-fugacity (O2) conditions, and finally subsequent rapid quenching of superheated melts. Typically, this leads to the formation of fusion crusts around meteorites (e.g., [1,2]) and the formation of micrometeorites or cosmic spherules that form by partial to complete melting of cosmic dust (e.g., [3,4]). Particularly in primitive, highly reduced chondritic materials, atmospheric entry and the associated flash heating induces significant changes in chemical and mineralogical compositions [2,5]. Since our understanding of the formation, evolution, and composition of planetary bodies in the solar system relies in part on micrometeorites, understanding of the processes and products of flash heating during atmospheric entry is needed for their unbiased interpretation. Here, we present a comparison of the melts produced in a laser-irradiation experiment performed with the H5 ordinary chondrite Hammadah al Hamra (HaH) 077 against a subset of pristine urban micrometeorites [6] and fusion crusts developed around ordinary chondrites [2]. Our aim is to test whether our experiments allow faithful simulation and detailed investigation of melt-forming processes during atmospheric entry of planetary materials. In addition, such experiments have general relevance for the understanding of silicate–metal fractionation.

Materials and Methods: We used a continuous-wave infrared fiber laser at Fraunhofer-Institut für Kurzzeitdynamik to irradiate a piece of HaH 077 in air at 1 bar, using methods and instrument parameters described in [7]. Laser-induced flash heating of the chondrite resulted in formation of massive, tens of millimeters sized lumps of melt on the sample surface as well as millimeter to submillimeter sized spherules of melt that were ejected away from the irradiation zone. Thermal imaging by an infrared pyrometer suggests that peak surface temperatures were >2100 °C for about 5 s and that the melts quenched to room temperature within a few seconds after cessation of laser irradiation. A petrographic characterization of the laser-produced melts as well as the subset of recently described, pristine urban micrometeorites [6] was done using SEM/EDS and EMPA methods.

Results and Discussion: Flash heating of the chondrite produced metal–silicate emulsions that quenched to sulfide–metal assemblages and hypocrystalline silicate domains, respectively. The silicate melts quenched to a mixture of hopper-shaped, acicular, or tabular, distinctly zoned (Fa15–40) olivine quench crystals set in a glassy matrix that contains dendritic or skeletal magnetite crystals, a second generation of olivine nanocrystals, and occasionally chromite grains, botroidal or spherical troilite and FeNi metal droplets. The observed microtextures and modes of the quenched silicate melts are similar to those recently described by [5] and to fusion crusts developed around H chondrites such as Asuka (A) 09004 and 09502 [2]. Reminiscent of the fusion crusts on A 09004 and A 09502, relit forsteritic olivine clasts (Fa19–22) disseminated in the experimentally produced silicate glasses are overgrown by sub-micrometeorites [6] was done using SEM/EDS and EMPA methods.