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Vaporisation and condensation of natural planetary materials in laser irradiation experiments

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Hypervelocity impacts of asteroids or comets onto planetary surfaces at velocities >15 km/s typically produce a vapor plume above the impact crater that subsequently condenses upon reaching the liquid–vapor coexistence curve [1,2]. Compared to impact melts, impact condensates have rarely been studied in nature [e.g., 3,4] or experiment [e.g., 5,6]. Here, we constrain mineralogy and composition of impact condensates formed from typical planetary rocks by using a continuous-wave fiber laser of 1.07 μm wavelength and similar experimental conditions as described in [7] to irradiate pieces of the H5 chondrite Hammadah al Hamra 077, basalt, dioritic, and granite in ambient air at 1 bar and room temperature. The resulting condensates precipitated by the vapor plumes were sampled by witness plates (aluminum metal or ceramics) positioned opposite–parallel to the target surface. Textural and compositional characterization of the condensates employed field-emission scanning electron microscopy, low-voltage energy dispersive spectroscopy, and 3D X-ray microscopy.

Laser irradiation resulted in formation of self-luminous vapor plumes that precipitated onto the witness plates white or tan to dark brown, fine-grained, fluffy coatings or layers. The laser also excavated melt droplets that were transported to the witness plates. The condensate coatings consist of fluffy, dust-like, globular, $\sim$100-nm-diameter nanoparticles that accreted to continuous, chemically alternating sequences/layers. Individual condensate sub-layers evolve from more refractory to more volatile (e.g., from Si-rich to Na-rich) compositions with decreasing depth. In some experiments, platy to acicular, idiomorphic crystallites (presumably sodium sulfate) of 2–5 μm size formed that are interbedded into rod-shaped aggregations of nanoparticles.

We estimate that the irradiation intensities used in our study result in entropy increases that correspond to impact velocities in the range of 10 to some 25 km/s [cf. 7,8]. Our condensate deposits share similarities to condensates formed in previous experiments that used pulsed laser irradiation [e.g., 5,6]. The chemical zoning of individual condensate layers observed here likely reflects slight changes in temperature and, thus, composition [9] of the vapor plume of a given experiment. In future work we plan to perform similar experiments in vacuum to simulate impact vaporization on atmosphere-less bodies.

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