SIMULATION OF SHORT-TERM HIGH-TEMPERATURE IMPACT PROCESSES BY USING A HIGH-ENERGY LASER BEAM

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Introduction: There are several small and young impact craters, e.g., Meteor Crater (USA), Kamil (Egypt), or Wabar (Saudi Arabia), where intense mixing of target and projectile melts is a common petrologic feature [1–4]. This study applies high-energy laser beam experiments to better understand the high-temperature chemical interaction processes between iron meteorite projectiles and siliceous target material analog to meteorite impacts.

Experimental setup: The laser-induced melting experiments (LE) were conducted at the laser welding facility of the Technical University Berlin. The Trumpf Haas HL 3006D facility is equipped with a Nd:YAG-laser that operates in the infrared spectra (wavelength 1064 nm) and has a maximum power output of 3 kW. Laser point irradiation was carried out in an experiment with a 2 × 2 × 2 cm cube of Seeberger sandstone. For the other laser experiments, centimeter-sized pieces of Seeberger sandstone were fixed either individually or laterally together with pieces of the Campo del Cielo iron meteorite or D290-1 steel, respectively, on an aluminium bottom plate (4 × 4 cm in size). The laser beam was rastered along 1 cm lines across the two materials with robotic machinery. The laser was operated in continuous wave mode (no pulsing mode), through air, on to the samples with a focal point position at 0 mm. One additional experiment was performed at the laser technology laboratories of the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institute, Freiburg, Germany. In order to measure the temperature changes during laser irradiation and subsequent quenching, this experiment was carried out with an ytterbium fiber laser system (IPG YLS 10000; max. output power 10 kW) and recorded with a FLIR A655sc infrared microbolometer. In addition, an optical camera system was used for high-speed recording of this experiment. Samples were cut out from the melt tracks parallel to the laser beam trajectory and prepared for microprobe analyses (JEOL JXA-8500F field emission microprobe at Museum für Naturkunde Berlin).

Results and Discussion: The LE were able to produce features very similar to those of impactites from meteorite craters and cratering experiments, i.e., formation of lechatelierite, partially to completely molten sandstone, and injection of metallic projectile droplets into the target melts. The target and projectile melts have experienced significant geochemical modifications during interaction of these coexisting metal and silicate melts. Silicate emulsion textures, observed within projectile-contaminated target melts, indicate phase separation of silicate melts with different chemical compositions during quenching. Similar emulsion textures were recently described for the impact glasses of Wabar and Meteor crater [3], further strengthening the applicability of our method.

The LE are able to produce temperatures characteristic of impact-induced melting, which can reach several thousand degrees Celsius. In our experiments, at least 2100 °C were reached, as indicated by bolometric measurements. The element partitioning and phase separation processes occur, depending on the chemical composition of the target melt, during quenching at temperatures between ~1900 °C and ~1500 °C or ~1900 °C and ~1100 °C. These temperature ranges are given for only ~0.6 sec or 1.4 sec in the laser experiments, respectively (measured by time-depended temperature profiles with the bolometric detector). We assume comparable reaction times between projectile melts and targets melts in small impact craters, such as Kamil, Wabar, or Meteor Crater (and craters within the same size range). These craters produced mm- to cm-sized impactites that were hot enough to trigger the chemical mixing and fractionation processes, and small enough to quench rapidly. So far, our laser experiments were focused on the interaction between iron meteorite (steel) and silica-rich targets. Nevertheless, the new technique can be used to analyze impact melt formation of any projectile and target material. For example, recently, we have reported first evidence of carbonate melting and degassing in laser experiments [5].

Conclusions: LE allow (i) separate high-temperature melting to better constrain primary melt heterogeneities before mixing of projectile and target, (ii) the quantification of element partitioning processes between coexisting projectile and target melts, (iii) to estimate upper limits for cooling rates of natural, rapidly quenched impact melts, and (iv) to estimate reaction times in these melts. Moreover, processes of incipient melting of individual minerals up to complete melting and homogenization of target and projectile can be simulated within one experiment.

References: [1] Hörz F. et al. 1989. *Proceedings, 19th Lunar and Planetary Science Conference* pp. 697–709. [2] Hörz F. et al. 2002. *Meteoritics & Planetary Science* 37:501–531. [3] Hamann C. et al. 2013. *Geochimica et Cosmochimica Acta* 121:291–310. [4] Fazio A. et al. 2016. *Geochimica et Cosmochimica Acta* 180:33–50. [5] Hamann C. et al. 2015. Abstract #1093. Bridging the Gap III.