Thermal Metamorphosis of Cosmic Dust Aggregates: Experiments by Furnace, Electrical Gas Discharge, and Radiative Heating

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Terrestrial planets formed from micrometer-sized dust grains of which many had condensated in the initially hot solar nebula and which then grew to porous aggregates. In the same period and from the same material reservoir, meteoritic chondrules formed in unknown heating events by melting precursor aggregates. The investigation of these processes requires knowledge on the behavior of aggregates composed of micrometer-sized grains in heating events. Therefore, we experimentally investigated thermal modifications of porous aggregates by furnace, electrical discharge, and laser radiation heating. In the furnace, porous SiO_2 aggregates underwent surface diffusion sintering and finally viscous flow. Material constants describing neck growth as heating temperature and time were derived. Exposing aggregates of various grain types to electrical discharges dispersed most of the sample and left it thermally unprocessed. Nevertheless, some material was thermally processed to sintered aggregates and a tiny fraction to solidified melt spherules with diameters less than 180 μm and most with interior bubbles. In comparison, radiative laser heating turned out to be a much more efficient process to produce melt spherules. In general, most of the sample was converted to spherules of chondrule size, and voids were rarer than in discharge heating. Besides providing material data for further applications, our work also allows a direct conclusion. Low energetic efficiency and aggregate destruction exclude chondrule formation from loosely-bound aggregates inside hypothetical nebular lightning channels. However, radiative heating of whatever origin, including possible lightning, appears as viable process of chondrule formation.