Nature of the Organic Signature in Dust from the Interstellar Medium: Laboratory Analog Studies

Friedemann T. Freund
SETI Institute and San Jose State University

Minoru M. Freund
NASA Goddard Space Flight Center

Aaron Staple
Stanford University

John Scoville
University of Kentucky

The infrared (IR) spectrum of dust in the interstellar medium and of dust- shrouded stars carries an "organic" signature in the form of a group of ν_{CH} bands around 3.4 μm (2800-3000 cm^{-1}). These bands suggest C-H stretching vibrations of aliphatic -CH_2- and -CH_3 entities. We show that a very similar spectral signature is observed in laboratory-grown MgO and natural olivine single crystals which have crystallized from $CO/CO_2/H_2O$-saturated melts. In the case of these crystals the ν_{CH} bands arise from C-H entities that are clearly imbedded in the mineral matrix in form of polyatomic C_n entities with some of the C atoms bonded to H. By heating the crystals to temperatures between 550-1000 K the C-H bonds are pyrolyzed, and the ν_{CH} bands disappear. Upon annealing between 300-390 K the ν_{CH} bands reappear within a few days to weeks, their intensities increasing linearly with the square root of time. This indicates that, while heating breaks the C-H bonds, causing H to disperse in the mineral matrix, C-H bonds are re- established rapidly during annealing. Dust grains that condense in gas-laden environments such as the outflow of late-stage stars probably contain the same type of C_n-H entities in their solid matrix rather than an organic veneer covering the grain surfaces. Because dust grains are small, the amount of carbon that can be contained in solid solution is significantly larger than in large crystals.