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New insight into origin and evolution of insoluble organic matter in meteorites

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Organic matter in meteorites provides us clues to understand the early Solar System history. Our recent study revealed that insoluble organic matter (IOM) in primitive chondritic meteorites is predominantly derived from the polymerization of interstellar formaldehyde with incorporation of ammonia, evidenced by molecular spectroscopic characters. Here we show molecular structures of laboratory synthesized formaldehyde polymer and compare with the formose solids to chondritic IOM using various spectroscopic methods; solid state ¹³C nuclear magnetic resonance (NMR), Fourier transform infrared (FTIR) spectroscopy and X-ray absorption near edge structure (XANES). We will discuss about the kinetics of polymer yield, and effects of silicate minerals coexisting with chondritic organic matter. Isotopic exchange experiments with formaldehyde polymer and water also can explain the origin of deuterium enrichment in the IOM from carbonaceous chondrites. We featured ¹H-²H cross polarization NMR which allows us to see site-specific deuterium enrichment in organic polymers. The results show that organic hydrogen is very exchangeable with water. The deuterium enrichment of chondritic IOM could be explained by the deuterium exchange with water during aqueous alteration.

The final molecular structure of chondritic IOM has been shown to reflect the extent of parent body processing, and to have significant variations among chondrite classes and groups. The principal inference has been that the molecular structure of IOM changes as a result of environmental conditions in the parent body. Our recent studies of individual lithology of the Tagish Lake meteorite provides insight into the wide range of molecular structure complexity that existed locally in a single parent body. We conducted heating experiments of most pristine IOM from Tagish Lake. The molecular structure evolution observed in Tagish Lake is representable with flash heating with several hundred degree C. Thus, the changes in Tagish Lake IOM from different lithologies may reflect differing degrees of flash heating due to impact processes.

Keywords: insoluble organic matter, chondrites, NMR, FTIR, XANES