Formation and evolution of molecular cloud organic matter: Thermal and photo-irradiation effects

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Simulation experiments on UV-photochemistry of molecular cloud ice have shown that complex organic matter remains as a residue after warming up to room temperatures [e.g. Greenberg, 2002]. These compounds could be the precursors of a part of the organic matter found in comets and meteorites, but it is not clear how the organic-bearing ice formed in the ISM may have evolved through temperature increase and irradiations by UV-photons and cosmic rays until their incorporation into Solar System bodies.
We developed an experimental apparatus called PICACHU, an acronym for Photochemistry in Interstellar Cloud for Astro-Chronicle in Hokkaido University [Piani et al., 2014] in order to simulate the formation and evolution of ice and organic residues through UV irradiation and heating. Typical ISM gases (a mixture of H2O, CO, NH3, and CH3OH) were deposited onto the substrate cooled down to ~12 K and simultaneously irradiated by UV photons under high vacuum. Gases, desorbed from the ice during heating and post-irradiation, were monitored by a quadrupole mass spectrometer (QMS). In-situ observation of the deposited ice during warm-up and/or irradiation was also made with an optical microscope. A part of the organic residues formed by warming-up was re-irradiated with UV photons at room temperature. The residual organic materials were examined with a laser microscope, an atomic force microscope, a field-emission secondary electron microscope and transmission electron microscopes. Viscoelastic measurements were performed with a nano-indentation technique.
During the warming-up of the UV-photoprocessed ice (H2O:NH3:CH3OH = 2:1:1, 5:1:1, 10:1:1 and, 2:1:0), we observed the deformation of ice film and the formation of bubbles at ~ 65 -140 K, which was not observed for non-irradiated ice. The formation of bubbles was associated with outbursts of gases mostly composed of hydrogen. The formation of bubbles indicates that the ice at low temperature behaves like a supercooled liquid.
The organic residue irradiated by UV-photon (~ 10^14 photons cm-2 s-1) at room temperature for 3-10 days, which corresponds to ≤10^4-year irradiation in diffuse clouds, showed a significant morphological change from the residues with no room-temperature UV irradiation. The porosity and roughness of the residue increased and discrete and round nanoparticles were observed that may be similar to some nanoglobules found in meteorites. Viscoelastic properties were also changed by the room-temperature UV-irradiation, indicating that organic-coating on inorganic dust could play as efficient glue on dust aggregation but, at the same time, could also enhance the aggregate brittleness.

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