Complex organics formed in Titan atmosphere and their astrobiological significance

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Titan is the largest satellite of Saturn. It is quite unique satellite since it has a dense atmosphere composed of nitrogen and methane, and has been sometimes considered as a model of primitive Earth. In Titan atmosphere, a wide variety of organic compounds and mists made of complex organics. A number of laboratory simulation experiments have been conducted. In most of them, ultraviolet light and discharges (simulating actions of electrons in Saturn magnetosphere) were used, which were simulation of the reactions in upper dilute atmosphere of Titan. We examined possible formation of organic compounds in the lower dense atmosphere of Titan, where cosmic rays are major energies.

A Mixture of 35 Torr of methane and 665 Torr of nitrogen was irradiated with high-energy protons (3 MeV) from a van de Graaff accelerator (TIT, Japan) or from a Tandem accelerator (TIARA, QUBS, JAEA, Japan). In some experiments, ^{13}C-labelled methane was used. The resulting solid products (PI-*tholins*) were observed with SEM and AFM. They were characterized by Pyrolysis-GC/MS, gel permeation chromatography, FT-IR, etc. Amino acids in PI-tholins were analyzed by HPLC, GC/MS and MALDI-TOF-MS after acid hydrolysis. ^{18}O-Labelled water was used in some cases during hydrolysis.

Filamentary and/or globular-like structures were observed by SEM and AFM. By Pyrolysis-GC/MS, ammonia and hydrogen cyanide were detected, which was the same as the results obtained in Titan atmosphere during the Huygens mission. A wide variety of amino acids were detected after hydrolysis: It was proved that oxygen atoms in the amino acids were incorporated from water during hydrolysis.

It is strongly suggested that *tholins* (or mists) can be produced in cosmic ray-induced reactions in the lower Titan atmosphere. The tholins could contain amino acid precursors, and they could be concentrated on some part of Titan surface by liquid methane flow. It was suggested that *tholins* containing amino acid precursors could be formed in the higher Titan atmosphere by the action of plasma discharges. We compared such *tholins* (PD-*tholins*) with the PI-*tholins*, and found that much more amino acid precursors should be supplied from the lower atmosphere than the higher atmosphere. Amino acid precursors on the surface of Titan is promising targets in the next generation of Titan mission (TSSM).