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Emergence of Chirality in Thin Solid Film of Phenylalanine with Circularly Polarized Synchrotron Radiation

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The origin of homochirality in bioorganic compounds is one of the most mysterious issues in the study of the chemical evolution of life. Experiments on the emergence of homochirality in solid-phase (rather than liquid-phase) bioorganic molecules are important for constructing models of solid-phase or surface-catalytic reactions on the surfaces of such space materials as meteorites or interstellar dust. To clarify the emergence of homochirality in a solid phase experimentally, we measured the optical anisotropy of amino acid films after they had been excited by a physically asymmetric excitation source; namely circularly polarized light (CPL).

As the sample of solid-phase bioorganic molecules, we formed thin solid films of racemic phenylalanine, an aromatic amino acid, on a silica substrate by deposition using a thermal-crucible–type vacuum evaporator from crystal powders of DL-phenylalanine. To clarify the optical anisotropy of the films, we measured the circular dichroism (CD) spectra of the deposited films using a spectropolarimeter. The CD spectra of the film exhibited no peaks although the 188, 204, and 226-nm peaks were observed in the spectra of non-racemic films deposited from D- and L-phenylalanine. The 204 and 226-nm peaks are originated in the aromatic ring and the carboxyl group, respectively.

To introduce asymmetry into the racemic film deposited from DL-phenylalanine, we irradiated separately it with left- and right-handed CPL introduced by from synchrotron radiation (SR) from the normal conducting accelerator (NAR) ring of NTT's SR facilities. After the irradiation with the CPL, broad peaks appeared in the CD spectra at 180 and 201 nm with a shoulder near 225 nm. The intensity and the sign of the CD peaks changed with the sample rotation angle with respect to the optical axis of a spectropolarimeter. Furthermore, the intensity dependence on the angle differed between the left- and right-handed CPL-irradiated samples. These results suggest that a chiral construction was introduced into the racemic film by the CPL.

The emergence of enantiomeric excesses in bioorganic molecules in the solid phase after irradiation with CPL is effective enough to demonstrate asymmetric reactions on the surfaces of space materials, which will lead to the origins of terrestrial homochirality. The mechanism of the photochemical asymmetric reactions in "soft materials" such as amino acid films must be investigated further.