Recent Advancements in HiSOR-VUVCD Spectrophotometer for Characterizing Biomolecule Structures

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Circular dichroism (CD), which refers to the difference in absorbance between left- and right-circularly polarized light, is a well-established technique for monitoring the steric structures of chiral molecules, particularly biomolecules (e.g., natural products, proteins, DNA, and polysaccharides). The usage of synchrotron radiation (SR) as a light source has further enhanced the usefulness of this spectroscopic method. This enhancement includes extending the wavelength range of CD spectra into vacuum-ultraviolet (VUV) region (down to 140 nm) [1, 2], developments of new VUV-CD analytical methods combined with computational science, and the installation of the linear dichroism (LD) and spatial- and time-resolved measurement systems. In this study, we introduce the recent progress in VUVCD techniques using SR in HiSOR for characterizing the structures of biomolecules.

The relationship between chromophores of steric configurations and their substituents in organic compounds or natural products can be analyzed based on the sign of CD (positive or negative). For instance, the absorption of allene occurred around 180 nm, and the absolute configuration of its substituents was determined from the CD sign in the VUV region [3]. Similarly, acetal bonds and hydroxyl groups of sugars also exhibited CD peaks around 170 nm. However, determining configurations from the CD sign was a challenge, as even mono-saccharides exist in an equilibrium state composed of six isomers. While molecular dynamics simulation and time-dependent density functional theory have successfully reproduced the unique CD of each isomer, disclosing their steric configurations including intra- and inter-molecular hydrogen bonding network [4].

The CD analysis of globular proteins combined with bioinformatics and LD enables estimating of the contents, numbers of segments, sequences, and orientations of secondary structures of proteins. This combination method was applied to elucidate the mechanism of protein-membrane interaction related to drug transportation into cell, myelin formation around neuron cells, and antimicrobial activity in immune system [5,6,7]. Further, the time-resolved system installed into the CD instrument realized the kinetics analysis of conformational changes of protein during membrane interaction processes. The use of micro beam with Schwarzschild objective or lenses enables CD measurement of microvolume rare sample and position-dependent CD. This system facilitated elucidating the mechanism of DNA damage response in X-ray irradiated human HeLa cells [8] as well as measuring the spatial-resolved CD of liquid and solid samples.

VUVCD analysis was extended to investigate the structuration of microbial exopolysaccharides (EPS) sourced from the marine environment, along with biocompatible polymers (i.e., bioplastics) synthesized by bacteria. Structural variations due to sample sources, concentrations, and pH levels, as well as their compatibility with cell membranes, were examined to compare their distinct biological functions, such as proinflammatory activity [9,10].

The CD technique with SR light source would further enhance the performance of chiral spectroscopy and open a pathway of next-generation of molecular chirality research.

References:

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