The Mueller Matrix, Optical Rotation and Circular Dichroism in Biological and Chemical Complex Chiral Materials – Engineering Applications

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ABSTRACT

Biological materials, including human tissue, chemical materials including drugs, as well as photonic devices, have chiral properties that need to be analyzed and measured. These chiral properties are of considerable interest in the fields of biochemistry, chemistry, medicine, drugs and engineering. The chiral properties occur naturally in a host of materials and more recently they are induced artificially through very small nanometer inclusions in materials that are characterized by positive or negative refractive indices.

The chirality of the material is characterized by a complex chiral parameter that appears in the constitutive relations in electromagnetic theory. These chiral properties are characterized by the Optical Rotations (OR) of linearly polarized waves and the Circular Dichroism (CD) which introduces ellipticity to linearly polarized incident waves. More recently optical/infrared polarimetric scatterometry has been used to sense the chirality of the material based on the measurement of the elements of the (4 x 4) Mueller matrix that completely characterizes scattered light. The impact of chirality on the elements of the Mueller matrix manifests itself primarily through the cross polarized reflection (or transmission) coefficients. Thus only the quasi off diagonal elements of the Mueller matrix are impacted by the chiral properties of the material. The chiral parameters are usually very small compared to the wavelength (even for artificial materials). A first order analysis provides the explicit relationship between the cross polarized reflection (or transmission) coefficients and the chiral parameter which is complex (associated with the Optical Rotation and Circular Dichroism). This yields the desired relationships between the Mueller matrix elements and the complex chiral parameters. The explicit relationships between the parameters that characterize optical activity (OR and CD) and the elements of the Mueller matrix are derived.

Applications to the determination, identification and characterization of biological and chemical materials as well as novel engineering devices are considered.

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