UAM

BIREFRINGENCE AND THE STRUCTURE AND DYNAMICS OF BIOMACROMOLECULES IN SOLUTION

Faculty of Physics

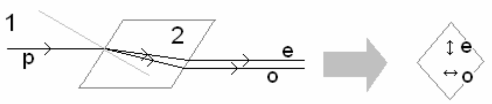
THE AREA OF RESEARCH

The research work at the Department of Molecular Biophysics is focused on the optical birefringence induced by electric field of a strong laser beam (the optical Kerr effect, OKE) in solutions of nucleic acids and that induced by a strong constant magnetic field in protein solutions (the Cotton-Mouton effect - CME). By these methods it is possible to obtain the information on geometry, electric, optical and magnetic properties of polymers and biopolymers (**tRNA**, **ferritin**). The measurements permit drawing conclusions on the shape, conformation, dynamics and interactions of biomacromolecules in solution, *in vivo* and *in vitro.*

NATURAL BIREFRINGENCE

The natural birefringence is the optical phenomenon observed in a transparent medium (gases, liquids, crystals), manifested as the medium ability to show double light refraction or a light beam splitting. The substances for which this phenomenon is observed are called birefringent. The natural birefringence illustrated in the figure beside was discovered in 1669 in the crystal of calcite ($CaCO_3$) by the Danish scientist Rasmus Bartholin and it was explained after the English physicists Thomas Young propounded the wave theory of light, in 1801. The Dutch scientist **Christiaan Huygens** observed that the two rays appearing in the crystal are linearly polarized in the mutually orthogonal planes.

The double image seen through the birefringent crystal of calcite..



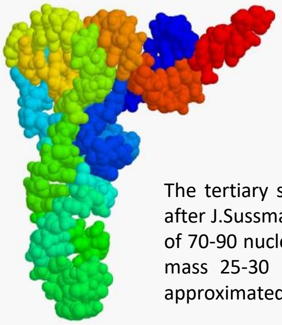
The unpolarized light beam ***p*** passing through the birefringent medium is split into the **extraordinary ray *e*** and **ordinary one *o*** .

In the beginning of the 19th century, the French physicist **Augustin J. Fresnel** explained this phenomenon as follows: "In a birefringent crystal light has two different velocities depending on the orientation of the oscillation plane (polarization)". A measure of birefringence Δn is the difference between the light refraction indices of the extraordinary ray, n_e, and the ordinary one, n_o: $\Delta n = n_e - n_o$, which depends on the microscopic properties of the birefringent medium. A birefringent crystal has an optical axis, it is such a direction along which light does not split into two rays because its velocity does not depend on the direction of polarization. The presence of the optical axis in a birefringent crystal follows from the regular and identical arrangement of its elongated molecules, it is the symmetry axis of these molecules.

INDUCED BIREFRINGENCE

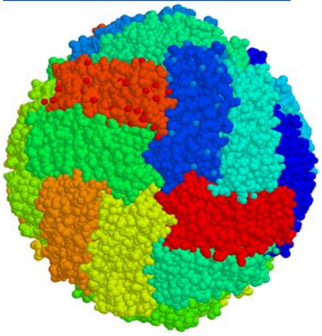
Birefringence can appear under the effect of external factors such as electric field ***E*** (**electro optical Kerr effect**), including the electric field of photons (optical Kerr effect) and by magnetic field ***H***(**Faraday effect, Cotton-Mouton effect)**. The explanation is that the anisotropic molecules of a given substance may not be regularly arranged and can have charges at their ends so can be electric dipoles or magnetic dipoles. Then under the effect of the external field ***E*** or ***H*** they assume the most beneficial energy positions so align their dipoles along the direction of the field. The disordered molecules can also be ordered by mechanical impact, under the effect of compression or stretching of a given material (like threads that get straighten up when stretched).

OKE STUDIES OF tRNA



The tertiary structure of tRNA, resembling the letter L, after J.Sussman (1976). Specific tRNA molecules are built of 70-90 nucleotides and are characterized by molecular mass 25-30 kD and the shape of their molecules is approximated by a spheroid of parameters 50Å× 20Å.

CME STUDIES OF FERRITINE



The model of ferritin molecule. It is built of 24 identical peptide subunits arranged into a shell surrounding a central cavity. The core in the central cavity can capacitate a few thousand iron ions. The balls represent atoms of the radius approximated by the van der Waals radius.

APPLICATIONS

The phenomenon of birefringence is applied in polarizing objects (e.g. in **Nicola prisms, half-wave and quarter-wave plates**) and in LCD screens. This phenomenon is particularly important in nonlinear optics when it is induced by light of high intensity. It is also employed in birefringent fiber-optic cables, in sensors of **stress**, **bend**, **pressure** and **temperature, used** in telecommunication and fiber-optic monitoring.

The birefringence of minerals has substantial effect (along with the sample thickness) on their interference colors observed in the so-called thin plates, used by geologists and petrologists. The interference colors and material birefringence allow identification of minerals.

QR kod do zaktualizowania