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Optical Phenomena in Diatoms

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(ozark) was clear, spring-fed and alkaline with a steep gradient. Big Creek (deltaic) was turbid, low in alkalinity, with slight gradient and low stream velocity. Mean standing crop for Janes Creek was 265 organisms/M². One hundred taxa were identified, snails dominating. Big Creek supported a mean standing crop of 726 organisms/M². Only 55 taxa were identified, oligochaetes and chironomids dominating. These streams exhibited two distinct habitats due to differences in substrate, watershed and land use.

Optical Phenomena in Diatoms

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ABSTRACT

Diatoms are unicellular algae which fabricate siliceous shells that are frequently marked with intricate ornamentations and patterns. The nature and characteristics of the siliceous shells provide a basis for diatom taxonomy and give rise to a number of interesting and colorful optical phenomena. This paper presents the results of investigations of diffraction phenomena, complementary color behavior, Rayleigh scattering and optical activity in diatoms.

1. INTRODUCTION

Diatoms are a distinct group of unicellular algae belonging to the phylum Chrysophyta and the family Bacillariophyceae. All diatoms characteristically encase themselves in cell walls (frustules) composed of extremely pure hydrated amorphous silica (i.e., silicic acid as a polymer). Chemical analysis of the frustules of marine planktonic diatoms indicated 96.5% SiO_2 and approximately 1.5% of Al_2O_3 and 1.5% Fe_2O_3.[1] Diatom shells have a refractive index of 1.43.

The diatom shell is constructed of two overlapping valves (resembling a hat box). As the diatom grows, these two valves can slide apart, thereby permitting some expansion of this otherwise rigid quartz structure. The two diatom valves are frequently connected by a girdle-like band (intercalary band). When viewed from the top (valve view), the shape of the diatom varies widely; when viewed from the side (girdle view), diatoms are generally rectangular. Diatoms are usually divided into two orders; the Centrales comprising the radially symmetric diatoms and the Pennales comprising bilaterally symmetric and asymmetric diatoms, as seen in valve view. Many of the Pennate diatoms possess a V-shaped groove (raphe) in the valve wall. By exuding cytoplasm along this raphe, and collecting it again at a central or polar nodule, the diatom can propel itself through the water[2,3]. Only diatoms with a true raphe have the power of locomotion; all others are either free floating or attached to aquatic plants or other underwater objects.

The surfaces of diatom shells or frustules often exhibit complex and intricate ornamentations. These usually consist of thickened ribs arranged in a fairly definite pattern, hyaline areas, spikes, alveoli, costae and fine

(1) "Silicification" by Joyce C. Lewin in **Physiology and Biochemistry of Algae,** Academic Press, New York, New York (1962), p. 448.

(2) Cornelius Onderdonk, **The Microscope,** August, 1890.

(3) Ruth Patrick and Charles W. Reimer, **The Diatoms of The United States,** Vol. 1., Academy of Natural Sciences of Philadelphia, 1966, pp. 22-23.

lines or striae. The nature and characteristics of these ornamentations and the structure of the siliceous shell provide a basis for diatom taxonomy. They also give rise to a number of interesting and colorful optical phenomena.[4] Many of these effects are well understood, while others await explanation.

II. DIFFRACTION PHENOMENA IN DIATOMS

Beautiful diffraction colors may be observed by illuminating a spray of diatoms which possess straight parallel striae (e.g., Navicula, Nitzschia, Pinnularia, etc.) with an intense unidirectional white light source. The diatoms oriented such that these striae are perpendicular to the direction of the light will behave as small diffraction gratings and produce brilliant colors.[5] The entire range of the spectrum is obtainable and the hue will change markedly with small variations in the angle of illumination. These colors disappear in uniform light and are not visible with a large aperture objective or with a wide illuminating cone.

Diffraction colors are only observable if the illuminating beam is in the proper azimuth and are best seen against a dark background. The colors will disappear if the system is rendered optically homogeneous by using a mounting medium of the same refractive index as the diatoms.

III. RAYLEIGH SCATTERING

Many diatoms contain pores, poroids or fissures in the cell wall which are so small that they may not be seen directly with the visible light microscope. However, their presence may be detected by observing the diatom in dark field illumination. If the transparent particles or pores of the diatom are larger than 1 micron diameter, the diatom will appear white under dark field illumination. Diatoms belonging to the Genus Triceratium, Coscinodiscus, Synedra, Pinnularia, Melosira, Stictodiscus, Hyalodiscus, Fragillaria and many others behave in this way.

If the diatom contains transparent pores which are approximately 0.3 microns in diameter, the scattered light will be a brilliant Tyndall blue and the transmitted light is turbid orange or yellow.[6] This occurs because the pores are large enough to scatter the short wavelengths but too small to deviate the longer waves which are consequently transmitted. Due to Rayleigh scattering, Heliopelta appear bright blue with a bronze maltese cross in the center surrounded by a crown of golden spikes.[7]

This technique has been used to detect the presence of subwavelength diameter pores in Navicula, Nitzschia, Pleurosigma, Gyrosigma, Stauroneis, Pleurostauron, Actionoptychus, and Actinocyclus, etc. It is a valuable tool because it provides useful information about the microstructure of the cell wall.

IV. OPTICAL ACTIVITY IN DIATOMS

Since the diatom cell wall is hydrated amorphous silica, it is generally assumed that diatoms would have no effect on the state of polarization of visible light. During this work, over a thousand species of diatoms were examined and only a few were found to have any effect on the state of polarization of visible light.

These include:

1. A specimen Aulacodiscus Oregonus from Santa Maria, California which glows a brilliant yellow when viewed through crossed polarizers.[8]

2. Pleurosigma Angulatum from the United States as well as from Hawksbury, Australia, has been found to exhibit bright blue colors under crossed polarizers. Where two specimens overlap, a color shift may occur and shades of red and pink have been observed and photographed. This may be caused by organic material remaining in the specimen.[9]

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(4) During this research, several thousand color photomicrographs were produced, which clearly illustrate these phenomena. Many of these photographs have already appeared in full color in a wide variety of publications. These will be referenced to permit the reader to observe these interesting color phenomena.

(5) Diffraction colors are illustrated in the spray of diatoms from Pensacola, Fla., which will appear in the color plate "Diatoms," to be published in the McGraw-Hill Encyclopedia of Science and Technology, 1971 Edition. The diagonally oriented Navicula lyra and Nitzschia sp. are a brilliant yellow whereas those oriented horizontally are a deep reddish orange (Photograph b).

(6) The photograph of Actinoptychus heliopelta published in **Physics Today,** p. 24, December 1970, shows the brilliant Tyndall blue arising from Rayleigh scattering at small pores in the diatom frustule. The unscattered radiation forms a gold maltese cross in the center of the diatom and a golden periphery.

(7) The Tyndall blue can also be seen in the spray of Heliopelta, McGraw-Hill Encyclopedia of Science and Technology, 1971 Edition, (Photograph g). (The subtle colorations of the central cross and spikes cannot be seen in this reproduction.) The actual pores forming the striae can be seen in the oil immersion photomicrograph of Actinocyclus Ellipticus (McGraw-Hill Encyclopedia of Science and Technology - Photograph i).

(8) Photomicrographs showing optical activity in this diatom have been published in color by the Dicalite Division of Grefco, Inc. Some of the publications in which this photograph may be found include: **Chemical Week,** May 6, 1970, p. 20; **Chemical and Engineering News,** May 11, 1970; **Filtration Engineering,** May 1970; **Chemical Engineering Deskbook,** April 27, 1970.

(9) A photomicrograph of a spray of Pleurosigma (produced by another researcher) appears on the cover of the September issue of **Saturday Review.**

3. Melosira Numuloides and Grammataphora have also been observed to rotate the plane of polarization of visible light.

4. Some specimens of Triceratium favus, Nitzschia sp. and Coscinodiscus sp. from Pensacola, Florida, and St. Andrews Bay, Florida, have also exhibited optical activity.[10] The reasons why these diatoms affect the plane of polarization of visible light is not yet thoroughly understood.

V. COMPLEMENTARY COLOR PHENOMENA IN ACTINOCYCLUS

An interesting effect has also been observed in diatoms of the Genus Actinocyclus. An unusual diatom, which appeared green in bright field illumination, was first observed in a spray of diatoms from Apalachicola, Florida. This diatom, Actinocyclus Ehrenbergii, changed to brilliant red as the microscope condenser was moved from dark field illumination. Several other diatoms of this species from Pensacola, Florida, also exhibited the same property. The diatom, Actinocyclus ellipticus, from Richmond, Virginia, was found to have the same ability to switch from one color distribution to the complementary one as the mode of illumination was changed from bright field to dark field. A beautiful spray of multicolored diatoms (of the Genus Actinocyclus) which exhibit this interesting property has also been found on a slide from Walvis Bay, South Africa.

The reason for this interesting behavior, which seems to be restricted to the Genus Actinocyclus, is not fully understood. These diatoms do not affect the state of polarization of visible light.

(10) McGraw-Hill "Encyclopedia of Science and Technology," 1971 Edition (photograph j).

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An Undergraduate Research Program In Chemistry At Philander Smith College

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Introduction

Philander Smith College is a predominantly Negro institution located in the heart of Little Rock, Arkansas. It is supported by the United Methodist Church. The school has an enrollment of approximately 750 students and is accredited by the North Central Association of Colleges and Secondary Schools. Baccalaureate degrees are granted in arts and sciences and teacher education.

Philander Smith College maintains an integrated faculty and strives to serve the undereducated and the underprivileged student. The college offers special opportunities and support for students who:

(1) Need assistance in the development of college level skills in reading, writing, listening, organizing, and interpreting information and mathematics;

(2) Show evidence of ability to achieve academically in a small, individually oriented college curriculum.

The Chemistry Department is part of the Division of Natural Sciences. The chemistry faculty consists of a full-time Ph.D., two part-time M.S. level instructors and a part-time Ph.D. At times, other part time people are used to teach special topics. There are 3-6 junior and senior chemistry majors at any time with 10-20 junior and senior minors.

The chemistry program has been developed in the