# Technical Papers

## Birefringent Stepgauge

Katharine B. Blodgett

*General Electric Research Laboratory, Schenectady, New York*

The barium stearate stepgauge[1] has demonstrated the usefulness of a gauge that measures the thickness of films a few microinches thick by means of the interference colors that they reflect. It consists of a plate of special glass on which monolayers of barium stearate have been built up in a series of steps having thicknesses 2, 3, 4, . . . 16 microinches.

A new type of stepgauge has been made which makes use of the principle that a birefringent material, placed between two properly oriented polarizing films, transmits light which, in general, exhibits interference colors.

Many plastics that are commercially available in thin sheet form are birefringent. Ordinary cellophane is a familiar example. A small square piece cut from a new sheet of Dupont waterproof cellophane with its edges parallel to the edges of the sheet transmitted light of a blue color when placed between two parallel polarizing films, and yellow between two crossed polarizing films. In each case the piece was oriented with its four edges making an angle of 45° with the direction of the polarizers. This phenomenon has been commonly employed for demonstrating some of the properties of birefringent materials.

The birefringent stepgauge consists of a set of small pieces of a birefringent plastic, cut and stacked together so as to form a flight of steps. Each step differs from the next by a constant thickness, which is usually the thickness of one layer of plastic. A series of 10 steps having a convenient size can be made by cutting a strip of plastic 1½″ wide from a sheet, and then cutting it into 10 pieces having the successive lengths 3″, 2¾″, . . . ¾″. These are stacked together and bound with Scotch tape around the edge.

When the birefringent stepgauge is sandwiched between polarizing films with the direction of the stepgauge making an angle of 45° with the direction of the polarizers, bright colors are seen by transmitted light. The colors vary from step to step. They are interference colors which occur because the light is split into two rays that travel through the plastic with different velocities and therefore emerge from the plastic with a phase difference. The light that passes through the second, or "analyzing," polarizer is the resultant of two rays having a phase difference. The light, therefore, exhibits interference colors that are identical with those seen in the light reflected by very thin films of transparent substances.

Interference colors ordinarily belong to one or the other of two different series. The color exhibited by one series for any given path difference of the two interfering rays is complementary to that of the other series for the same path difference. The new stepgauge exhibits the two series. The colors seen with the polaroids parallel are the same as those reflected by a thin film when $n_0 < n_1 < n_2$, where $n_1$ is the refractive index of the film, and $n_0$ and $n_2$ of the media on either side of the film. The colors seen with crossed polaroids are the same as those exhibited by a thin film for the cases $n_0 < n_1 > n_2$ and $n_0 > n_1 < n_2$.

The interference minima for monochromatic light occur as follows:

*a*) *Parallel polarizers.* Minima occur at an "effective path difference," $\Delta l$, given by

$$\Delta l = \lambda/2, 3\lambda/2, \ldots \text{ etc.},$$

where "effective" refers to the path difference in air that corresponds to the phase difference of the two rays.

*b*) *Crossed polarizers.* Minima occur at

$$\Delta l = 0, \lambda, 2\lambda, \ldots \text{ etc.}$$

The new stepgauge can be used to measure accurately the thickness of films a few microinches thick, in the same way that measurements are made with the barium stearate stepgauge, by matching the color of the film that is to be measured to that of one of the steps on the gauge. The birefringent gauge must first be calibrated. This can be done by viewing a source of monochromatic light, such as a sodium lamp, through the stepgauge and polarizers.

As an example, a stepgauge was made of 12 steps of Kodapak[2] 0.015″ thick. The first minimum for perpendicular sodium light seen with crossed polarizers was found to occur at step 9, and the first minimum with parallel polarizers at step 4.5 (interpolated between 4 and 5). Therefore, the calibration for the gauge is

$$\Delta l_g = \lambda/9 \text{ per step for sodium light,}$$

where the subscript $g$ refers to the gauge.

In the case of perpendicular light reflected by a thin film, the lag between the two rays due to distance retardation is given by

$$\Delta l_f = 2nt,$$

where $n$ and $t$ are the refractive index and thickness, respectively, of the thin film. Therefore, one step of the gauge produces the same lag as a thickness $\lambda/18n$, which is 218 A for a material for which $n = 1.5$.

The steps of the barium stearate stepgauge are commonly made with a steprise 244 A, which is nearly 1 microinch. When the colors of the birefringent stepgauge which has just been described are compared with those of a barium stearate stepgauge, they are found to differ by the small amount predicted by the calibration.

The amount of lag per step is determined by the

[1] Barium Stearate Stepgauge, General Electric Company Instruction Manual.

[2] Manufactured by Eastman Kodak Company, Rochester, N. Y.

product $Nt\Delta n$, where $N$ is the number of layers in a step, $t$ the thickness per layer, and $\Delta n$ the difference in refractive index for the two polarized rays. Since many different plastics having a wide variety of birefringence and thickness are commercially available, a variety of stepgauges can be made having different "steepness" for the flight of steps. Ordinary cellophane was found to have more birefringence than was desirable for a stepgauge. A flight of steps made of cellophane had too great optical steepness to be generally useful as a measuring instrument.

The steps of a birefringent stepgauge are commonly cut out of a sheet of plastic with all the steps in the same direction of the sheet. In this case the thicknesses add. If a step is cut out of the sheet in a direction at right angles to the direction of the rest of the steps, its thickness will subtract from that of the series.

The birefringent stepgauge is not yet commercially available.

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## An Observation on the Infrared Absorption Spectrum of Dextran


### Stanley C. Burket and Eugene H. Melvin

***Northern Regional Research Laboratory,*[1]**
***Peoria, Illinois***


In an extensive study of the physical characterization of dextran, we have examined the infrared absorption spectra of dried films of a wide variety of undegraded and degraded dextrans produced by different organisms under different conditions. The instrument used was a Perkin-Elmer Model 21 infrared spectrophotometer.[2] Throughout most of the spectral region 3 μ–15 μ, these spectra resemble each other quite closely, but some significant differences have been found. The largest variations occur in the spectral neighborhood of 12.6 μ, and a few examples of particular interest are shown in Fig. 1. It will be noted that, of the commercial dextrans, the nondomestic show marked differences from the domestic in the amount of absorption at 12.6 μ. Samples of dextran produced by *Leuconostoc mesenteroides* NRRL B-512 do not show appreciable absorption at 12.6 μ; NRRL B-512 and the organism that produces the domestic dextran stem from the same original culture. Dextrans produced by other organisms in the NRRL culture collection show varying amounts of absorption at 12.6 μ. One dextran we have studied in particular is produced by *L. mesenteroides* NRRL B-742. Undegraded dextran from this latter source has been fractionated by alcohol precipitation from water. Two fractions, labeled in Fig. 1 as B-742, Type I, and B-742, Type II, have been obtained. The physical characterization of these materials will be discussed later by others, but we can say that the molecular weights of the two fractions as determined by light scattering are approximately the same. The spectra of

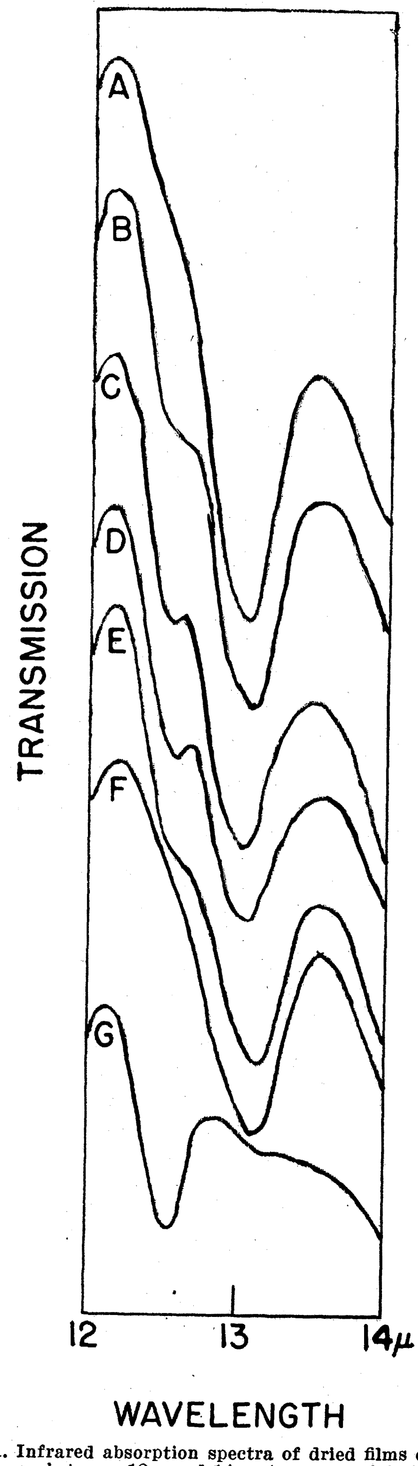


**Fig. 1.** Infrared absorption spectra of dried films of different dextrans between 12 μ and 14 μ. *A*, commercial, domestic; *B*, *C*, and *D*, commercial, nondomestic; *E*, unfractionated B-742; *F*, B-742, Type I; *G*, B-742, Type II.

[1] One of the laboratories of the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, United States Department of Agriculture.

[2] Mention of the instrument used does not constitute an endorsement by the U. S. Department of Agriculture.