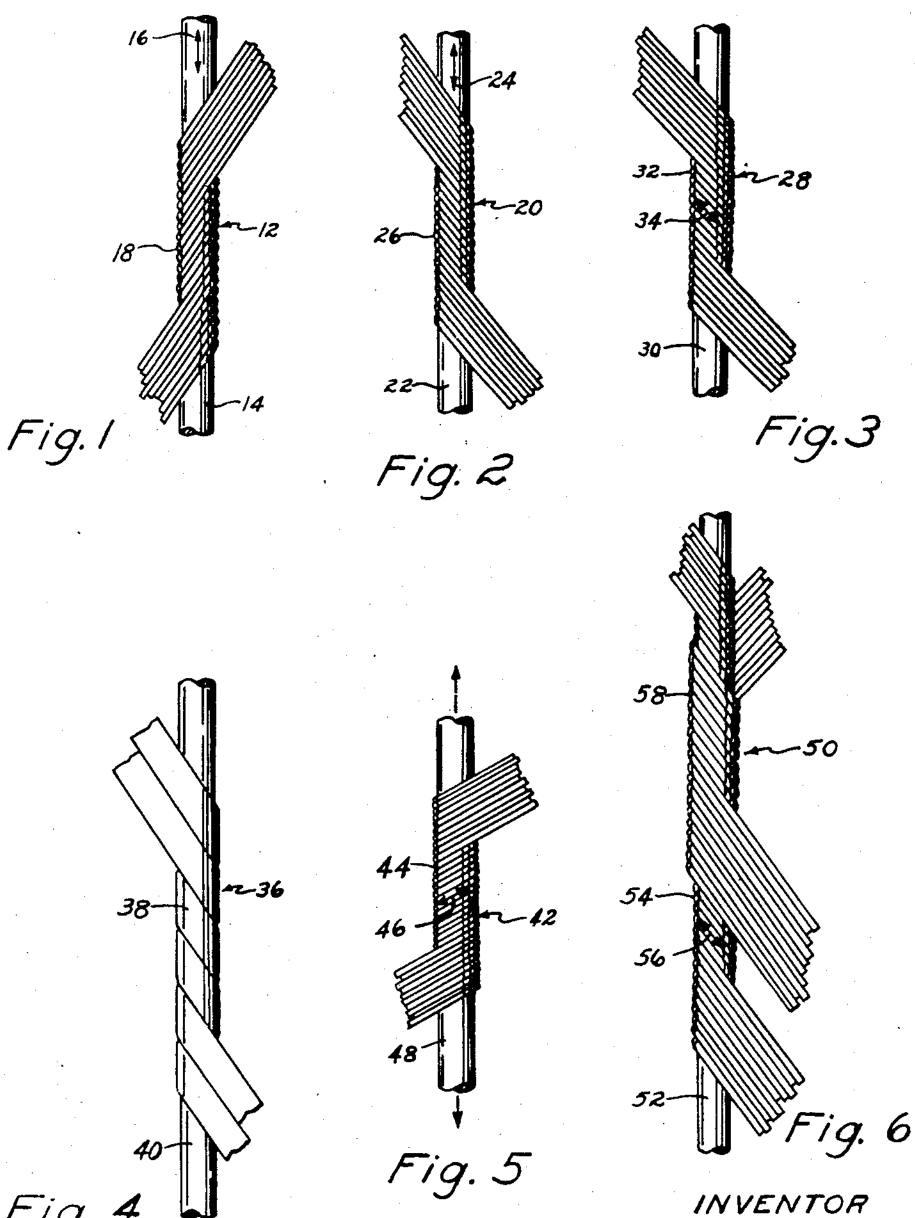
Aug. 31, 1954 P. BOONE 2,687,673

TEXTILE MATERIAL HAVING ORIENTED FIBERS

Filed April 4, 1949 6 Sheets-Sheet 1

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TEXTILE MATERIAL HAVING ORIENTED FIBERS

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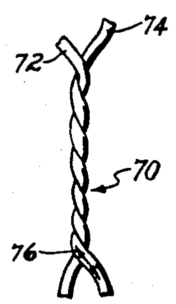


Fig. 8

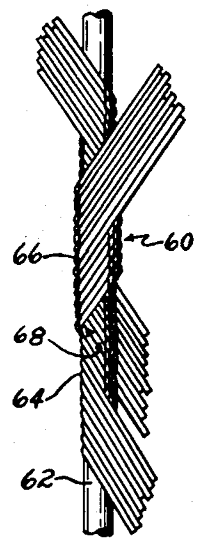


Fig. 7

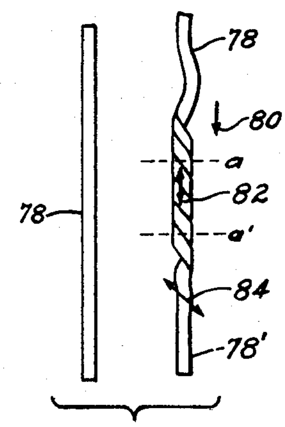


Fig. 9

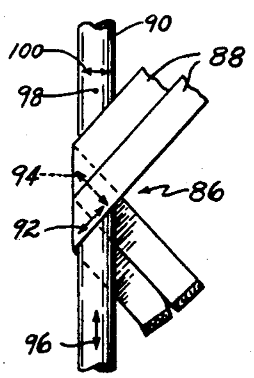


Fig. 10

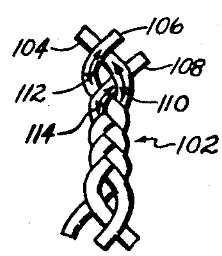


Fig. 11

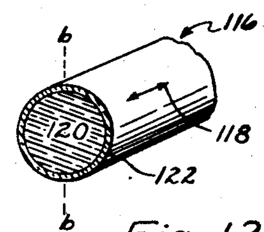


Fig. 12

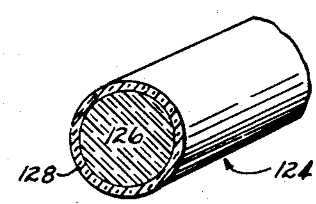


Fig. 13

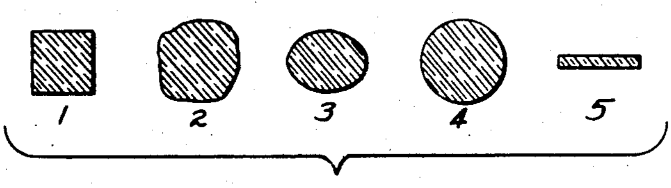


Fig. 14

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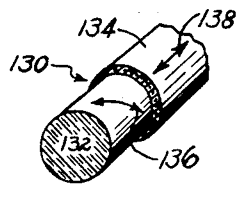


Fig. 15

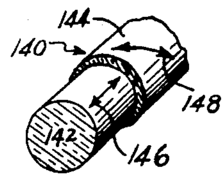


Fig. 16

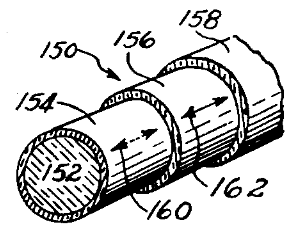


Fig. 17

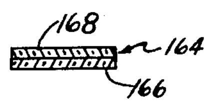


Fig. 18

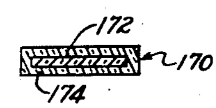


Fig. 19

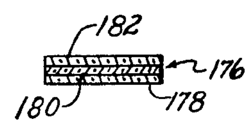


Fig. 20

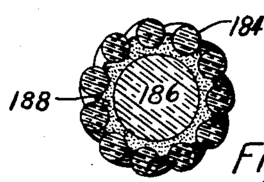


Fig. 21

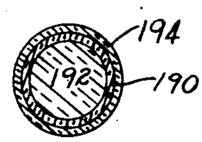


Fig. 22

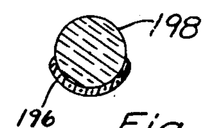


Fig. 23

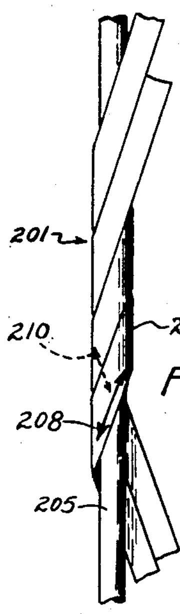


Fig. 25

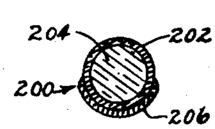


Fig. 24

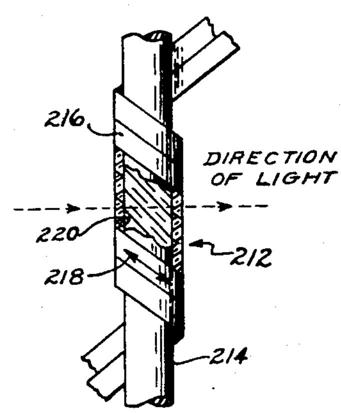


Fig. 26

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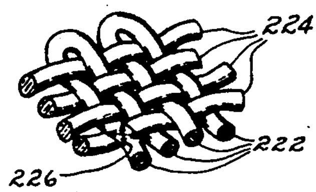


Fig. 27

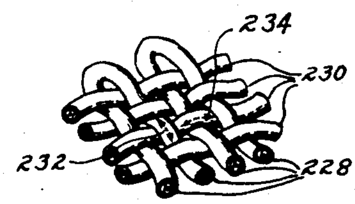


Fig. 28

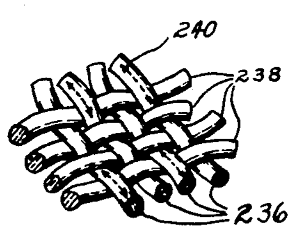


Fig. 29

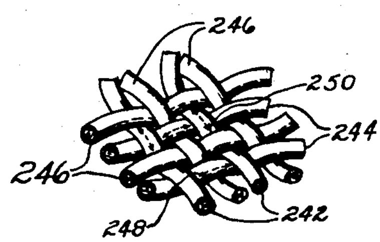


Fig. 30

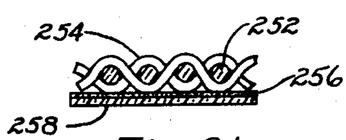


Fig. 31

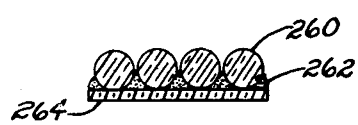


Fig. 32

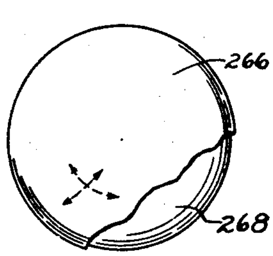


Fig. 33

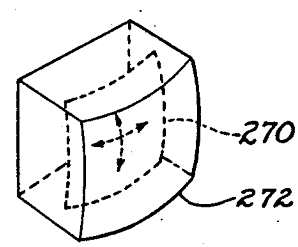


Fig. 34

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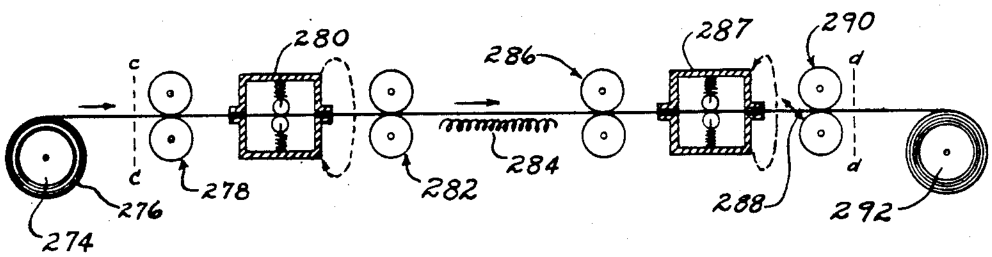


Fig. 35

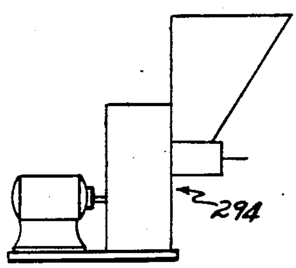


Fig. 36

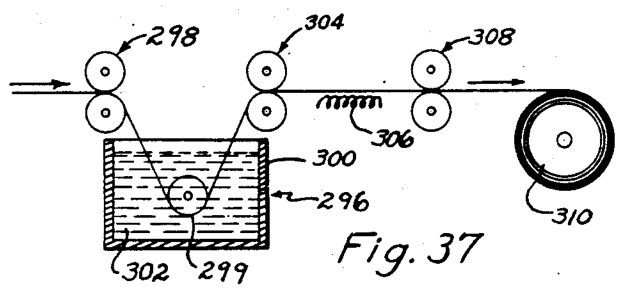


Fig. 37

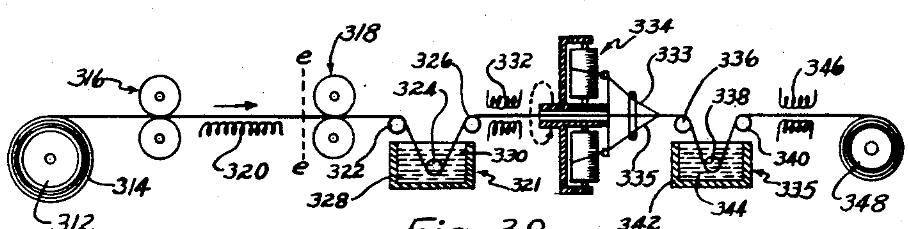


Fig. 38

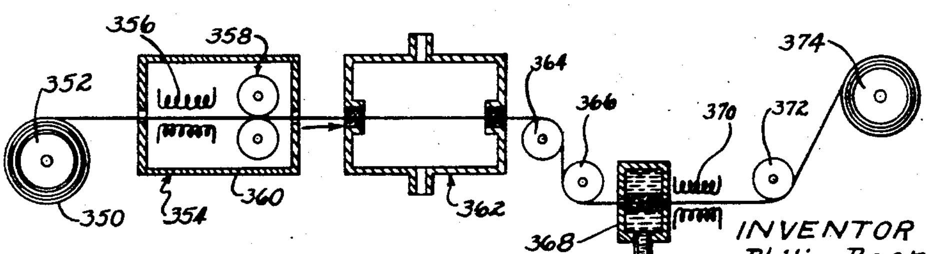


Fig. 39

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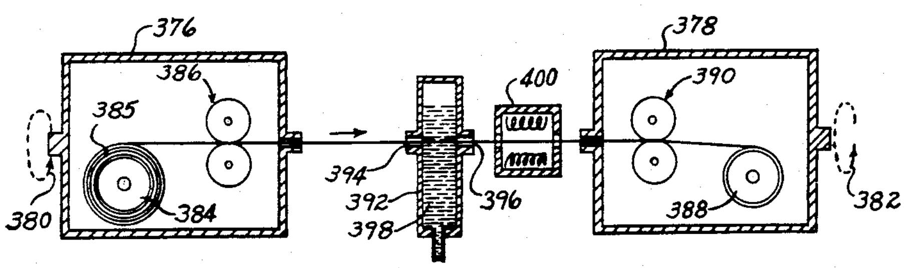


Fig. 40

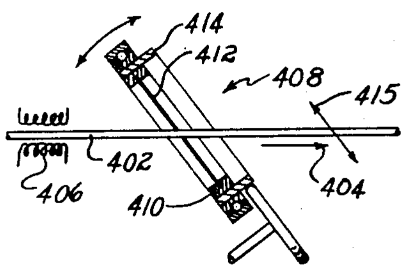


Fig. 41

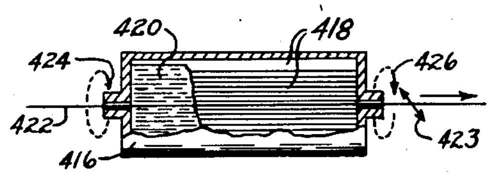


Fig. 42

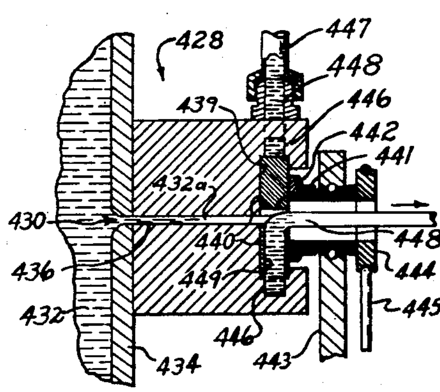


Fig. 43

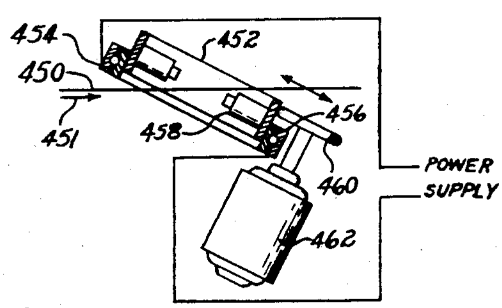


Fig. 44

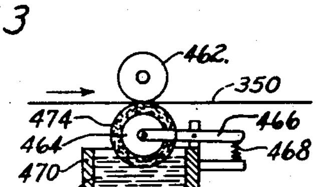


Fig. 45

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Patented Aug. 31, 1954 2,687,673

# UNITED STATES PATENT OFFICE

2,687,673

## TEXTILE MATERIAL HAVING ORIENTED FIBERS

Philip Boone, Winchester, Mass.

Application April 4, 1949, Serial No. 85,377

5 Claims. (Cl. 88—65)

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This invention relates to light-altering materials and more particularly to light-modifying bodies, areas, filaments, fabrics or the like for producing various color and other effects.

It is well known that birefringent or doubly-refracting substances or components in conjunction with light-polarizing means may be employed to resolve a mixture of light into its color components or to produce other visual effects. It is also known that rotatory-polarizing or optically active substances or elements may be employed with light-polarizing means for a generally related objective. The present invention contemplates the adaptation of the phenomenons of light polarization, double refraction and optical activity to the textile and related arts and the provision of filaments, fibers, yarns, fabrics and other areas of material capable of producing unusual and attractive color, pattern, luster and variable effects heretofore unknown thereto. Components of the invention may be extruded, twisted, folded, spun, coated, interlaced, interwoven, bonded, embedded or otherwise arranged in functional relation to provide various interference colors and other qualities. Filaments and yarns of the type to be described herein may readily be formed and woven together into fabrics and may also be interwoven with conventional filaments and yarns. In certain of the constructions, the interference colors and other effects may be produced by each body or filament alone, and in other constructions they may be produced through the coaction of a plurality of such bodies or filaments as, for example, through their cooperation in a fabric. Thus, a construction of the invention may broadly be considered as constituting a self-sufficient, relatively small body or a plurality of coacting bodies forming a larger body or area.

A wide range of uses for materials of the invention is contemplated inasmuch as their attractiveness and utility are unique, their manufacturing cost should not exceed that of known quality textile materials, and they may be produced by methods generally related to known methods or by the various methods set forth herein. While certain embodiments of the materials are adapted to produce interference effects through reflection of light, it is presently indicated that those forms which produce interference colors and other effects through transmittal of light will have greater acceptance and, accordingly, constructions of the latter type are in the preponderance among those described herein. Both reflection and transmittal of light for the

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above-mentioned and other functions may also be performed by various of the examples as will presently be described. In other forms of the materials, reinforcing or supplementary color effects may be obtained by combining known materials such as conventional fibers and dyes therewith.

Among principal contemplated decorative and utilitarian uses for the materials are draperies, curtains, lamp shades, screens, wall panels, window shades, theatrical costumes and properties, and clothing portions and accessories. While the propensities of light-polarizing and doubly-refracting or optically active substances to coact for producing interference colors, and the unusual beauty of said colors have long been recognized, substantially no method has been developed heretofore for making the same available for widespread artistic and utilitarian uses. A principal application has been in the field of microscopy where doubly-refracting objects are examined under polarized light to provide interference color contrast of various regions of the object. Other applications such as may have occurred in the field of optics or elsewhere have been restricted to extremely narrow usage or have possessed limitations which have resulted in their finding little or no acceptance. The marked differences therefrom of products and methods of the invention in such considerations as form, performance and adaptability to significant esthetic and utilitarian uses of the general public are believed to substantiate an inventive concept which is inherently broad in scope.

Inasmuch as variation of orientation of components of the invention produces a variety of visual effects, it will be seen that their embodiment in the form of bodies such as filaments and fabrics offers a multiplicity of directions of orientation not similarly obtainable in other structures. For example, the width of materials of the invention may be as extensive as that of any presently known fabric, which is to say that it is limited only by the capacity of current or to-be-developed textile machinery. Continuous lengths of the materials may be formed similarly to other known filaments and fabrics. Functional arrangement of the components to obtain predetermined relative orientations thereof may be adapted to, or facilitated by known procedures of twisting, spinning, coating and stretching filaments and by substantially any type of weaving, knitting, braiding, netting or other known methods. The materials may be formed to show qualities of drape and stretch in the manner of conventional textile materials and, accordingly, they may be in the form of assemblies capable of being deformed simultaneously in substantially all directions, curved as well as planar, without appreciably affecting inherent or relative orientation of the components.

With reference to the showing of light-polarizing birefringent and optically active components in the drawings, the vibration directions of the light-polarizing components are indicated therein while principal axes of birefringent and optically active components are generally intentionally omitted because they could be operatively represented in several directions depending upon the characteristics of the components. A principal axis of a birefringent or optically active component, relative to the drawings, may generally be considered, for purposes of illustration, as extending either transversely or longitudinally, or in both directions of said component unless otherwise indicated for producing a predetermined color or other effect, said direction or direction or directions providing a given angle of orientation thereof relative to a light-polarizing component or components which provides an operative assembly. It is to be understood, however, that modifications of said relative orientation may exist and moreover that various crystalline aggregations forming structural patterns or a random disposition of anisotropic particles or the like may be bonded to or incorporated in the component or material to provide a plurality of optic axes extending in a plurality of functional directions.

It is an object of the present invention to provide novel materials having attractiveness and utility wherein a wide range of color and other effects are obtainable through means providing controlled interference of components of light.

Another object of the invention is to provide textile materials such as filaments, yarns, fabrics or the like wherein a wide and novel range of color and other effects may be obtained.

A further object of the invention is to provide components adapted to the production of interference colors and other effects either through their combination in bodies such as filaments or the like or in fabrics, or in both.

Still another object of the invention is to provide materials such as bodies, areas, filaments and fabrics or the like wherein light-polarizing and anisotropic or optically active components are combined in a predetermined manner for providing interference colors and other effects.

A still further object of the invention is to provide novel light-modifying bodies capable of contributing to or providing, of themselves, interference colors and other effects.

Another object of the invention is to provide light-modifying components of the character described which are generally adapted to employment in textile materials or the like.

A further object of the invention is to provide materials and components of the character described which may readily be manufactured at reasonable cost and which may have wide esthetic and utilitarian appeal and, accordingly, many new and significant uses.

Still another object of the invention is to provide materials of the charatcer described which are capable of producing interference colors and other effects through portions thereof enabling either transmittal or reflection of light, or both.

A still further object of the invention is to provide novel light-polarizing and birefringent materials, and components of the same, which possess new and useful properties.



Another object of the invention is to provide novel materials and components of the character described which are capable of producing variable interference colors and other effects.

A further object of the invention is to provide various means for producing products of the invention.

Still another object of the invention is to provide general improvements in the construction of textile materials such as filaments, yarns, fabrics or the like to the end that appearance of such materials may be enhanced.

These and other objects of the invention will be apparent from the following description taken in connection with the accompanying drawings wherein like reference characters refer to like parts throughout the several views of which:

Figures 1 through 11 are side elevation views of different light-modifying bodies or filaments of the invention;

Fig. 12 is a perspective view of a light-modifying body or filament of the invention;

Fig. 13 is a perspective view of another light-modifying body or filament of the invention;

Fig. 14 is a cross-sectional view of various forms of light-modifying bodies or filaments of the invention;

Figs. 15 through 17 are perspective views of various other light-modifying bodies or filaments of the invention;

Figs. 18 through 24 are cross-sectional views of various other light-modifying bodies or filaments of the invention;

Fig. 25 is a side elevation view of another light-modifying body or filament of the invention;

Fig. 26 is a side elevation view, partly in cross-section and with parts broken away, of a light-modifying body or filament of the invention which illustrates the direction or directions of a light ray relative thereto;

Figs. 27 through 30 are perspective views of various swatches of light-modifying fabrics of the invention;

Figs. 31 and 32 are cross-sectional views of light-modifying materials of the invention comprising combinations of film and other components;

Figs. 33 and 34 are perspective views of light-modifying fabrics of the invention which are, respectively, laminated to a curved or spherical surface and embedded in a molded product;

Fig. 35 is a diagrammatic representation of apparatus for producing a product of the invention;

Fig. 36 is a diagrammatic repersentation of a modification of elements of Figs. 35 and 38;

Fig. 37 is a diagrammatic representation of a modification of elements of Fig. 35; and

Figs. 38 through 45 are diagrammatic representations of various apparatus for producing products of the invention.

For a fuller understanding of the constructions of the present invention and their function, a preliminary consideration of certain of the basic optics involved is presented herein, with particular reference to the coacting properties of a plurality of light-polarizing elements; to the cooperation of birefringent and light-polarizing components; and to the interrelation of rotatory polarizing or optically active elements or substances and other light-polarizing means. It is intended that the theory or examples presented in conjunction therewith, which must necessarily be limited, shall not be regarded as in any sense defining the scope of the invention, said theory and examples being merely for the purposes of illustration and for furthering an understanding of operation of constructions of the invention, presently to be described.

As one example related to the invention, let it be assumed that a pair of light-polarizing elements such as a pair of Nicol prisms or dichroic foils is arranged in optical alignment and that one of said elements may be rotated with respect to the other, the pair constituting a polarizer and an analyzer. It is well known that when the vibration directions (vibration planes, polarizing directions or axes) of such elements are crossed at right angles, components of light transmitted by the polarizer are removed or extinguished by the analyzer, and that when the vibration directions of both elements are otherwise mutually disposed as, for example, parallel, components of light are transmitted by both elements, varying degrees of transmittal being obtainable between said parallel and crossed positions. Let it next be assumed that a birefringent component such as a crystal, a suitable foil, or the like, is positioned between the polarizer and analyzer, with its crystallographic or optic axis predeterminedly angularly disposed relative to the vibration directions of said polarizer and analyzer. A ray of light passing through the polarizer is plane polarized and thereby enters the birefringent component vibrating in a given direction. Upon entering the birefringent component, it is divided into two rays, an extraordinary ray and an ordinary ray, each of which vibrates in a direction substantially at right angles to the other and traverses the birefringent component with a different index of refraction and velocity, a different distance being traversed thereby and a phase difference being introduced therebetween.

Upon emergence from the birefringent component, both of the rays proceed substantially along a direct path to the analyzer, while continuing to vibrate at right angles. The direction of vibration of the rays depends primarily upon the angular relation existing between the polarizing (vibration) direction of the polarizer and the optic axis of the birefringent component. Upon entering the analyzer, the extraordinary ray may be said to be broken into two components vibrating substantially at right angles, one of which may be considered as an ordinary component which is absorbed or deviated to one side so as to no further be utilized and the other of which is transmitted as an extraordinary component vibrating in a given direction. The ordinary ray, emanating from the birefringent element is resolved by the analyzer into an ordinary component which is absorbed or deviated to render the same no longer functional, and an extraordinary component, vibrating in a direction similar to that of the first-named extraordinary component, which is also transmitted by the analyzer.

Thus, it may be said that two extraordinary components are "selected" and transmitted by the analyzer, vibrating in the same direction but with a phase difference therebetween because one derives from the ordinary ray and the other derives from the extraordinary ray between which a phase difference has been produced, as above described. In consequence, the two extraordinary components are adapted to interfere and the resultant of their interference may be transmitted light of a given intensity, extinction of light, one or more interference colors or other effects depending upon their phase relation or, in other words, depending substantially upon whether reinforcing or destructive interference occurs and to what extent.

The nature of the interference produced may be due to several factors or variables. Bearing in mind that the phase difference depends in general upon the difference between the velocities of the ordinary and extraordinary rays in the birefringent component, and that this difference varies for light of different wave lengths (of different colors) of the spectrum, it will be seen that a resultant interference color, or its diminution or extinction, relates to such variables as the nature of the light source, the retardation properties of the birefringent component, and the relative orientation of the optic axis of the latter with respect to the polarizing axes or directions of the polarizing components. It will be understood that the polarizing axes or vibration directions of polarizing components may have some other angular relation than 90° and may indeed be parallel, provided the optic axis of the birefringent component forms some suitable angle therewith, to produce interference colors.

The relative retardation of the ordinary and extraordinary rays may be altered throughout a wide range where the type of birefringent material employed permits variation of its thickness, where internal structural orientation thereof may be varied, and where the relation between the optic axis thereof and the directions of polarization of the polarizing components may be varied. If a choice of birefringent materials is possible a further variable is provided. Birefringent components of the invention may be varied in all of the above respects.

Where $\Delta$ equals the retardation of one ray with respect to the other (expressed in millimicrons or $m\mu$); where $t$ equals the thickness of the birefringent element or substance; and where $n_1$ and $n_2$ equal the lesser and greater indices of refraction, respectively, of the two rays emergent from the birefringent element, we have the equation:

$$\Delta = t(n_2 - n_1)$$

The aforesaid two emergent rays have a difference in phase which may be termed P. This difference equals the retardation divided by the wave length, or

$$P = \frac{\Delta}{\lambda}$$

Substituting the equivalent for $\Delta$, as determined above, it follows that

$$P = \frac{t(n_2 - n_1)}{\lambda}$$

When the retardation is some whole multiple of a wave length, the components of light emerging from the analyzer are equal and opposite in phase and nullify one another. When the retardation consists of half wave length odd multiples, said components of light are equal and on the same side of the line of transmission and, therefore, are of a reinforcing nature. The resultant equals the sum of the two components and the transmitted light is of maximum intensity.

Various birefringent substances or materials are known, some of which are classified as uniaxial and others as biaxial, both being termed anisotropic. In addition, other substances are designated as rotatory polarizing or optically active. The latter substances will also be considered as anisotropic herein, as components of light are rotated in opposite directions thereby and at different velocities. Materials or substances of each category may be employed in products of the invention, the choice depending upon constructional requirements and optical properties desired. Different forms of light polarization such as circular or elliptical polarization will not be treated upon at length herein since, although they occur in various stages of light modification involved in the invention, exhaustive consideration thereof is in no sense essential to an understanding of the optical interrelation of elements or the interference results obtainable.

In general, with other variables constant, it may be said that a uniaxial birefringent material in conjunction with light-polarizing means permits extinction of light or the obtaining of complementary colors through alteration of the axial relationship of said material and means, while a combination of an optically active substance and polarizing means permits continuous color changes throughout the range of the spectrum by changing the axial relationship therebetween, even though other variables are held constant, the colors being rotated by different amounts. As employed herein, birefringent materials may be considered as substances, components, elements or the like, wherein a phase difference is produced in the general manner described in examples hereinbefore given, and optically active materials may be regarded as substances, elements, components or the like, wherein light is divided into two circularly polarized components thereof, the light vectors of which rotate at different velocities in opposite directions, light of different wave lengths being thus rotated by different amounts, and a resultant vibration plane being provided.

An extensive number of substances and materials are adapted to be employed in forming the bodies, areas, filaments, fabrics or the like of the invention, said substances and materials being of various degrees of suitability according to their properties and according to specific requirements. Among anisotropic materials which may be utilized in forming one or another of the components are the majority of vegetable fibers, animal fibers, mineral fibers and synthetic fibers. Glass and other fibers of a generally isotropic nature may also be combined therewith for such purposes as providing a support, an interconnection, an additional optical property or some other function. Among the vegetable fibers contemplated are cotton, flax, sisal and other of the seed hair, bast and structural groups. Animal fibers which may be employed comprise various hairs, furs, wool and silk. The mineral fiber asbestos may also be utilized. Synthetic materials comprising cellulosic, protein and polymer types may be employed to particular advantage and further materials either existing or to be developed, having birefringent, optically active, light-polarizing, fluorescent or other contributory properties may be incorporated in constructions of the invention. Substantially transparent rubber, latex or a synthetic as, for example, Butacite, manufactured by the E. I. du Pont de Nemours Company, Plastics Division, Arlington, New Jersey, may be employed for special uses involving elasticity, or elasticity combined with variable birefringence. Certain of the above materials may be employed functionally of themselves while others may coact to produce various effects or serve as carriers for various functional substances.



Wherein filaments and fibers are employed, long continuous types constitute a preferred embodiment as will be apparent from the constructions shown and described, although short staple fibers and small bodies may serve special functions. Thus, synthetic materials of the cellulosic and polymer types may be considered as particularly adapted to employment for forming filament and fabric components of the invention as well as for coatings or the like which may be applied thereto, as will presently be described.

Among the synthetic materials contemplated for various specific uses are viscose and acetate rayons, regenerated cellulose, nitrocellulose, ethyl cellulose, cellulose acetate, vinyl acetate, nylon, vinyl chloride, vinylidene chloride, polyethylene, polyvinyl acetal, polyvinyl alcohol and other materials, said materials being treated or modified as may be required to provide special characteristics. Certain of these materials are known as adapted to be formed into birefringent and light-polarizing elements through various treatments involving their subjection to stretching operations, applications of fields of force, stain, dye, acid and heat treatments or the like. For example, ethyl cellulose, regenerated cellulose, and polyvinyl alcohol may be stretched, under suitable conditions of temperature or in conjunction with softening agents, and preferably set to provide birefringent materials as, for example, to provide a material wherein a high degree of substantially uniform crystalline or molecular orientation is accomplished throughout the material, said material having, generally, an optic axis consistently extending in a predetermined direction.

Various controls may be employed for obtaining predetermined diameters or thicknesses of filaments or other components of the invention. For example, in extrusion processes it is known that the rate of delivering materials to a spinneret, the rate of drawing materials away therefrom, and the amount of stretch applied thereto may all be controlled to regulate diameters of filaments. If, for example, a filament is drawn to four times its original length, it may be reduced to substantially one-half its original diameter. Certain of the materials may be cold drawn and others may be stretched in a softened condition, as provided by applications of heat or softening agents. Various forms of spinnerets or extrusion orifices relating to diameter and contour of extruded filaments are well known.

Materials of the above-mentioned type, which may readily be stretched and elongated and thereby have their thicknesses and internal structure oriented as, for example, to acquire a certain birefringence, are adapted to be formed into bodies or filaments, or to be employed as coatings therefor of the type contemplated herein. After such bodies or filaments are formed, they may readily be joined with other components such as light-polarizing bodies or filaments through constructions of the invention to provide a predetermined relation of optic and light-polarizing axes. It will be understood that in addition to providing predetermined characteristics of birefringence in filament components of the invention, such qualities as tensile strength, flexibility, durability, resistance to shrinkage or the like may be varied therein, the stretching process generally improving tensile strength and flexibility and increasing birefringence.

The properties of birefringent materials relating to the obtaining of various predetermined colors will now be considered more specifically, and, for purposes of illustration, one of the aforementioned general types of such materials which may be embodied in constructions of the invention will be utilized. Accordingly, let it be assumed that a plurality of such bodies, as, for example, monofilaments or coagulated multifilaments, uniformly stretched (of constant birefringence), but of predeterminedly different thicknesses are arranged in progressive order of thickness, side by side, between any suitable light polarizers crossed at 90°. Let it also be assumed that the optic axes of the filaments are all disposed at a predetermined angle relative to the vibration directions of the light polarizers, for example, at 45°, that white light is employed and that the filaments and polarizers are fixed as to axial relation.

The relation of retardation, phase difference and wave length has been described hereinbefore. In accordance therewith, the field of view surrounding the filaments will appear dark and, assuming certain thicknesses of the filaments, the thinnest filament may, for example, appear blue-gray and other filaments, in order of increased thickness, may appear, respectively, white, yellow, orange, orange-red, deep red, violet, indigo, blue, blue-green, green, et cetera. The relationship between interference colors due to monochromatic light and white light should be considered. If monochromatic light is substituted for the white light source, that filament which is of such thickness as to provide a retardation of $\lambda$ will cause the vibration components to be equal and opposite and cancel one another out, the filament appearing as a dark band. All filaments which provide a retardation which is a whole multiple of $\lambda$ cause a similar operation. Conversely, if the filaments provide retardations at odd multiples of $\frac{1}{2}\lambda$, maximum intensity will occur because the vibration components are equal and in the same phase.

Interference colors due to white light are a subtraction of all of the various wave lengths of the spectrum from white. Assuming, in view of the foregoing, that monochromatic light produces dark bands for different thicknesses of birefringent materials and maximum intensities at intervals intermediate thereof, the difference between the wave lengths at the opposite ends of the spectrum is such that the first dark band for violet occurs almost in the first position of maximum intensity for red. For violet, the band is approximately 410 m$\mu$. As the wave length for red is approximately 700 m$\mu$, the maximum intensity for red occurs at 350 m$\mu$ or $\frac{1}{2}\lambda$. When the thickness and double refraction provide a retardation of 410 m$\mu$, no violet is present in the interference color. Since the maximum intensity for red occurs at $\frac{1}{2}\lambda$ or 350 m$\mu$, the percentage intensity at 410 m$\mu$ would be:

$$\frac{2(\lambda r-\lambda v)}{\lambda r}\times 100=\frac{2(700-410)}{700}\times 100=83 \text{ percent}$$

If the wave lengths are known, the percentage of any given monochromatic light present in an interference color of a given retardation may be computed.

The maximum birefringence (the greatest difference between $n_1$ and $n_2$) may be considered as substantially constant for any given anisotropic substance wherein orientation, as obtained for example through stretch, is held uniform. If this constant is substituted in the equation

$$\Delta=t(n_2-n_1)$$

a straight line curve is the result in an interference color chart. If various thicknesses are assumed, the corresponding retardation $\Delta$ may be determined directly. If the normal sequence of colors is known, it is possible either to predict the color of the substance of a given thickness or to ascertain the thickness of the substance having a given interference color, provided the axial relation of the substance is such that $n_2-n_1$ is a maximum.

In an interference color chart, interference colors with $\Delta$ less than 550 m$\mu$ are said to belong to the first order. Violet ($\Delta$=550 m$\mu$) belongs at the boundary of the first order. From violet $\Delta$=550 m$\mu$ to violet $\Delta$=1128 m$\mu$, the colors belong to the second order. From violet $\Delta$=1128 m$\mu$ to violet $\Delta$=1652 m$\mu$, the colors belong to the third order. Above the fourth order, colors are not easily separated. The colors at the end of the first order and at the beginning of the second order are the most striking and brilliant. At the end of the fourth order they merge into one another, forming tints of green and pink tending toward grayish white. These colors are distinct from the blue gray, white and yellowish white of the lower first order. Identification of the order of a given color may be determined by using a mica plate or the like capable of increasing or decreasing retardation of an area by about $\frac{1}{4}\lambda$ (sodium light). Such an increase or decrease in the lower first or second orders produces a set of colors entirely different from that occasioned by a similar change in higher orders. For example, in the case of a first-order yellow $\Delta$=400 m$\mu$, an increase of 175 m$\mu$ will result in violet $\Delta$=575 m$\mu$, and a decrease of the same amount will produce white $\Delta$=225 m$\mu$. The same increase or decrease in retardation above the fourth order would produce little perceptible change.

It will be understood that stretching of a filament of the type considered herein, or micellular orientation as obtained through extrusion of a filament from a die or orifice, or both, may be employed to provide a filament having a predetermined birefringence. It will further be understood that increases in stretch produce increases of birefringence and decreases in thickness, said increases of birefringence generally exceeding accompanying decreases in thickness so that resultant increases in retardation properties of the filament occur and the interference colors capable of being produced when the filament is positioned between crossed polarizers may commence in the first order and proceed through second and third orders, et cetera. The exact characteristics for any material may readily be ascertained and the birefringence and retardation properties thereof be charted. For example, a filament of polyvinyl alcohol of .003'' thickness may be stretched and set under suitable conditions of heat so as to acquire a birefringence of approximately 0.013 and a reduced thickness of approximately .002''. When formed into a composite structure such as that shown in Fig. 3, namely, when positioned between light-polarizing components so that a principal axis of the birefringent filament is disposed at 45° relative to polarizing directions crossed at 90°, a second order blue may be provided. A second filament of similar initial thickness may be stretched to acquire a birefringence of approximately 0.029 and a reduced thickness of approximately .0015'' and, when similarly employed with polarizing components, may provide a second order reddish-purple. Lesser and greater stretches of said filament could be employed to provide, respectively, first or third and higher order interference colors. The interference color obtained through a given amount of stretching depends upon the birefringence per unit thickness produced in a given material and, accordingly, different materials may be differently elongated to obtain a given interference color.

Light-polarizing components of the nature contemplated herein may be of any type having properties which contribute satisfactorily to the functional qualities required thereof in a given construction of the invention. Such qualities involve the production of colors and other effects and the adaptability of the constructions to be employed in or to constitute products of the type contemplated as, for example, a filament, fabric or other area of material. Several known light-polarizing treatments or substances, such as those identified with various synthetic plastic materials may appropriately be employed or modified for use in forming light-polarizing components or portions of structures of the invention. A list of such light-polarizing materials is presented hereinafter. Presently-known polarizing materials are suitable for employment in constructions of the invention but it is also considered that the invention comprehends the development of other polarizing materials insofar as they are employed in similar constructions or serve in similar functional capacities.

Polarizing components of the type comprehended herein are considered as possessing such light-polarizing characteristics or properties that they are capable of coacting to produce interference colors or the like when employed with substantially any birefringent or optically active component or substance having retardation or other properties adapted to coact with polarizing means for producing perceptible interference colors or the like. Thus the weakest partial polarizing means which can be employed may be said to be that which, when crossed at 90°, is capable of coacting with a birefringent or optically active substance or component to produce a perceptible color or colors substantially at the end of the first order and at the beginning of the second order of spectra. The strongest or most complete type of polarizing means which may so be employed is that which, when polarizing axes thereof are crossed at 90°, produces extinction of light. The most complete type of polarizer, when employed with anisotropic materials, is particularly adapted to provide the most brilliant interference colors. Partial polarizers and polarizers providing more than 99% extinction, formed of synthetic plastic materials are well known. Thus effective light-polarizing substances and components of the type contemplated herein may be considered as comprising a range extending from a relatively weak partial polarizer which transmits components of light vibrating in a plurality of directions, although preferentially in a given direction, to a polarizer which may substantially absorb all components of light excepting those vibrating in a given direction. It will be apparent that polarizers intermediate of said extremes may be employed. The well-known Judd unit of color difference may be employed in determining the weakest perceptible color obtainable with a partial polarizer, as above described, and may also be used in determining different interference colors produced.

While, in general, the more completely light-polarizing components may constitute a preferred embodiment, certain constructions of the invention may advantageously employ so-called partially light-polarizing components or a plurality of such partially light-polarizing components in superposed or optically aligned relation to provide more fully light-polarizing components. It is believed that certain light-polarizing aspects of the invention are such as to involve novel processes and products which will presently be described. It will be understood that partial polarizers may be employed to provide "dilute" colors through their property of transmitting unpolarized as well as polarized components of light. In general, it may be said that polarizing components of the invention are of types possessing such light-polarizing properties, form and arrangement in the constructions as to contribute effectively to the production of interference colors and other effects of acceptable quality relative to the uses intended.

Light-polarizing components of the type contemplated herein may appropriately be formed of substances providing a neutral polarization of light, that is, they may polarize light substantially impartially throughout the spectrum of, for example, white light, or they may be formed of substances providing light-polarization throughout a predetermined restricted band or bands of wave lengths. It is contemplated that certain of the light-polarizing components may employ light-polarizing, or light polarizing and other substances, enabling their transmittal of polarized light predominantly of certain wave lengths. For example, a polarizing treatment may provide a red, a blue or some other color in the polarizing component whereby the polarizer transmits vibrations of said color preferentially. Or, some tint, dye or the like may be added to the polarizing component or be provided in a coating or in another component associated therewith to provide a predominant color characteristic in a light-modifying body or filament of the invention. Where coacting light-polarizing and birefringent or optically active components are employed for producing interference colors of given characteristics, said provision of a dye, tint or the like may be utilized to provide, in effect, a blend with interference colors or a reinforcement of the same. Where said coacting light-polarizing and anisotropic components produce substantially white light said provision of a dye, tint or the like may be utilized for providing a dominant color while the interference resultant is employed for producing a high luster effect. It will be understood that fabrics or other materials comprising polarizing components and such tints or dyes may be formed so that light emanating therefrom will predominantly be colored light as provided by said tints or dyes. It is further to be understood that fabrics or other materials comprising polarizing and birefringent or optically active components and such tints or dyes may be formed so that light emanating therefrom will predominantly be colored light as provided by said tints or dyes, or some blend thereof with interference colors, if so desired.

Referring to the drawings, Fig. 1 illustrates a composite light-modifying body 12, such as a fragmentary portion of a composite filament comprising a light-polarizing core component 14, of any suitable cross-sectional shape as, for example substantially cylindrical, having a direction of polarization or vibration direction generally indicated by double-headed arrow 16, and a Z twist or spiral of one or more birefringent filament components 18, of a suitable cross-sectional shape, such as substantially round or flat, formed around the core. It may be assumed that the structural orientation of the birefringent filament components 18 is substantially longitudinal of said components and that the direction or plane of a principal axis of said filament components forms a predetermined angle with said polarizing direction 16 of the core as, for example, an angle of 45°.

It will be noted that the thickness of core 14 is appreciably greater than that of each filament 18, and, accordingly, because filaments 18 provide a relatively thin layer around the core, a functional superposition of birefringent twist and light-polarizing core is presented substantially throughout the composite body when it is viewed from any position radially thereof. It is to be assumed that core 16 is of a predetermined diameter and has predetermined light-polarizing properties. It is also to be understood that birefringent components 18 have predetermined diameters and preferably similar internal structural orientation and are of such thickness as to provide a predetermined retardation and phase difference between ordinary and extraordinary rays transmitted thereby.

Wherever a twist of components is shown herein, the number and thickness of said components are contingent upon the relative thickness of the core and the angle at which the twist is to be wound around the core. Unless otherwise specified, either an S or a Z twist may be employed. Light incident twist 18 passes through the same to core 14. It is plane polarized by core 14 and the transmitted components again enter twist 18, at a side remote from the area of incidence, and a difference of index of refraction between said components occurs in the manner hereinbefore described. Composite filament 12 is adapted to be employed with other filaments of similar or other characteristics in an assembly such as a fabric. In said fabric, filament 12 may serve as a cooperative or coacting body with another light-polarizing means in the production of interference colors or other effects. Core component 14 may appropriately be formed as a monofilament or a multifilament of extruded, coagulated substantially parallel strands of a suitable synthetic plastic material which has been treated to serve as a light polarizer.

Filament components 18 may be formed of any suitable birefringent material such as one of the materials hereinbefore described. It is to be assumed that the materials employed in composite body or filament 12 and in all of the constructions herein are suitably treated to provide satisfactory characteristics of tensile strength, resistance to shrinkage and other qualities which may be required of a fabric or other area of material of a type contemplated.

Fig. 2 represents a composite filament 20 of the same general type as that of Fig. 1 comprising core component 22, having a light-polarizing axis or direction 24 and an external layer of birefringent filament components 26. Composite filament 20 differs from filament 12, however, in that birefringent layer 26 is formed of an S twist. The composite filaments of Figs. 1 and 2 may advantageously be combined in a fabric as, for example, one filament serving as the warp and the other as the weft or filling, said arrangement enabling, for instance, crossed polarizing components and parallel birefringent components, as provided by said warp and filling. It will thus be seen that filaments of the warp and filling coact to produce interference colors or the like.

Fig. 3 shows a composite light-modifying body or filament 28 comprising a birefringent core component 30 formed of one or a plurality of coagulated filaments of the type hereinbefore described, the structural orientation of said core preferably being substantially longitudinal thereof and a predetermined generally uniform direction of the optic axis thus being established throughout said core component. A twist or spiral of one or more light-polarizing filament components 32, having a direction of polarization or vibration direction indicated by double-headed arrow 34, is formed around core component 30. Core 30 may preferably be substantially cylindrical in shape and twist components 32 may preferably be generally cylindrical or flat in shape although other shapes may be employed. It will again be observed that core component 30 is of considerably greater diameter than twist components 32 and thus provides a superposed functional relation of components when viewed from any position generally radially of the core. The angle at which twist components 32 are formed around core 30 provides a predetermined angular relation between polarizing direction 34 and the optic axis of core component 30. It may be assumed that core 30 comprises a predetermined thickness of birefringent material contributing to a given retardation and phase difference between transmitted light components. From a radial viewing position and looking through composite filament 28, it will be apparent that portions of polarizing twist 32 which are located generally diametrically opposite one another, on opposite sides of the core, are crossed at angles depending upon the angle of twist, and that when crossed at 90°, as generally indicated in Fig. 3, one of the preferred angular relationships therebetween exists. It will further be apparent that a birefringent component is provided in the form of core 30 having its internal orientation, and accordingly its optic axis, angularly disposed relative to said crossed polarizing directions, said angular relation being generally indicated as 45°, which constitutes one of the preferred angular relationships between the optic axis and polarizing axes. Light rays incident any given surface portion of twist 32 are plane polarized in passing through the same, are resolved into ordinary and extraordinary rays having a phase difference by core 30, and are transformed into components vibrating in a given plane by the opposite portion of twist 32 whereby an interference color is produced. Composite body or filament 28, accordingly, is a self-sufficient unit for producing interference colors and other effects and may be employed in a fabric as, for example, the warp, substantially conventional transparent filaments being suitably employed as filling or vice versa.

Fig. 4 illustrates a composite light-modifying body or filament 36 having a twist of substantially flat, ribbon-like components 38 formed around a core component 40. The twist may consist of light-polarizing components and the core comprise a birefringent component, or the twist may be formed of birefringent components and the core consist of a light-polarizing component. Composite filament **36** may thus function either in the manner of the filaments of Figs. 1 and 2, or similarly to that of Fig. 3. It will be apparent that use of ribbon-like component **38** permits a decrease in the angle of twist without a proportional increase in the diameter of filament **36**. If desired, the twist could be overlapped to provide different thicknesses of a birefringent layer.

In Fig. 5, a composite light-modifying body or filament **42** which may be altered dimensionally to vary interference colors or the like is shown. As a preferred embodiment, composite filament **42** may be regarded as generally similar to that of Fig. 3 as to the relation of components, with a twist of light-polarizing filament components **44** having vibration directions **46** formed around a birefringent core component **48**. However, core component **48** is formed of a suitable elastic material, such as a transparent rubber, latex or a synthetic elastic material of the type above-described so that, upon stretching said core component as indicated by the arrows, its thickness may be altered and different retardation properties may, accordingly, be acquired thereby. In a modified form, core **48** could serve as an elastic light-polarizing component and twist **44** could be in the form of elastic birefringent components, preferably bonded to the core whereby, upon stretching filament **42**, and thus probably rendering the core slightly less efficient as a polarizer, twist **44** would be stretched obliquely with respect to its axis and both thickness and direction of internal orientation thereof would be altered, thus affecting its properties relating to the production of interference colors as hereinbefore described. In a less preferred modification of the first-named elastic embodiment, the twist may also be bonded to the core, provided a suitable elastic polarizing material is used. The first-named embodiment, which is preferred, provides a self-sufficient unit for variably producing interference colors and, accordingly, it may be combined with substantially transparent conventional elastic or essentially nonelastic filaments to form a stretchable fabric wherein the color and light transmission may be varied by stretching and relaxing the same. The second-named or less preferred embodiment would require combination with another light-polarizing means.

The composite body or filament **50** of Fig. 6 may be considered as illustrating any of the light-modifying bodies of Figs. 1 through 5 with an additional layer or twist formed thereabout. For example, it may consist of a birefringent core component **52**, a twist of light-polarizing filament components **54** having a polarizing direction **56** formed around the core, and a twist of substantially transparent surfacing components **58** formed around components **54**. Surfacing twist **58** may, for example, be colorless and contribute to an appearance of whiteness of a fabric in which the filaments are woven when light is reflected from the fabric. Or, twist **58** may comprise a transparent dye or tint for providing reflection of colored light and for coacting with core **52** and twist **54** so that interference colors produced by the latter will be modified by the color of twist **58** and a different resultant color will be obtained. Where core **52** and twist **54** produce a substantially white interference color, twist **58** may be employed to provide some other color which is dominant. Twist **58** may also be utilized to furnish a desired surface texture and, accordingly, may be twisted more irregularly than shown. Furthermore, twist **58** may be of a material adapted to receive a desired surfacing treatment which, for example, may be applied to a fabric in which the filament is incorporated.

Twist layers **54** and **58** may, however, each consist of partial polarizers, preferably superposed so that their polarizing directions extend similarly, the two layers reinforcing one another to provide more complete polarization of light. If twist components **54** and **58**, as partial polarizers, serve said cumulative function, it will be apparent that certain materials which are capable of producing only partial polarization of light but which have other advantages such as availability, low cost and adaptability to textile uses may be employed for the purpose. If, alternatively, composite body or filament **50** is considered as comprising a light-polarizing core **52** and a birefringent layer or twist **54** formed therearound such as shown in Figs. 1 or 4, double-headed arrow **56** may be regarded as a direction of internal orientation of the birefringent layer and external twist **58** may be considered as a surfacing layer of the general type above described, and either isotropic or predeterminedly anisotropic for providing some desired retardation in conjunction with birefringent layer **54**. In constructions of the invention involving twists, spins, plies, braids or the like, bonding or fusing of inner superposed surface portions of the components may be desirable to reduce a loss of transmitted light by reflection at said inner surfaces.

Fig. 7 shows a composite light-modifying body or filament **60** having a core component **62**, an S twist **64** formed around the core, and a Z twist **66** formed around twist **64**. Filament **60** may comprise at least any of the constructions described relative to Fig. 6 and illustrates an external reverse twist **66** formed on an underlying twist. Certain structural advantages of combinations of S and Z twists are well known in the textile art. In addition, it will be seen that different angles of twist of layers **64** and **66** may be used for different interference effects if said layers are both birefringent. Double-headed arrow **68** may be regarded as indicating either a polarizing direction of a light-polarizing layer or a direction of internal orientation of a birefringent layer, according to the interpretation of the construction.

Fig. 8 represents a light-modifying body or filament **70** comprising components **72** and **74** which are twisted together. Component **72** may suitably have light-polarizing properties, a polarizing direction thereof being indicated by double-headed arrow **76**, and component **74** may be composed of a suitable birefringent material having a predetermined optic axis. The angle at which said components are twisted together is predetermined as, for example at 45°. Superposed portions of the components provide a combination of light-polarizing and birefringent materials such that filament **70** may be employed in a fabric, in conjunction with other polarizing means, to produce interference colors. Fig. 8 may also be considered as representing a ply of filaments as, for example a ply of any of the filaments described herein with a preferably transparent filament whereby the desirable features of a ply construction which are known in the textile art may be achieved. It will be understood, however, that where the light-modifying filament of said ply is of a type for coacting with another light-modifying filament in a fabric (i. e. warp and filling) that an oblique orientation of said ply filament exists which must be considered with respect to the orientation of the coacting filament. Fig. 8 could also advantageously represent a ply wherein both of the filaments comprise a polarizing core and at least one of the filaments comprises a birefrigent covering as, for example, a ply of the filament of Figs. 1 and 2. Said ply would provide a self-sufficient structure for producing interference colors.

Fig. 9 illustrates a fragment of an orientable body **78**, suitable for conversion into an oriented body portion **78'** which may be employed as, or, in turn, converted into a birefringent component or a light-polarizing component or entity. Body portions **78** and **78'** may, for example, be in the form of a substantially flat ribbon or strip, or a substantially round or other form of filament. Said portions may, appropriately, be composed of a suitable plastic material such as polyvinyl alcohol, regenerated cellulose or some other material of the type hereinbefore described. Body portion **78** may be considered as in a generally unoriented condition or to be partially oriented as, for example, in a direction longitudinally of its long axis. To achieve a modified orientation in portion **78'**, body portion **78** is twisted at a predetermined angle with respect to its long axis, and is then stretched longitudinally under suitable conditions of environment, preferably while undergoing movement in the direction of arrow **80**, stretch occurring in a predetermined twisted or folded portion thereof generally represented as between $a$ and $a'$. Said stretching of the twisted portion provides an overall orientation therein substantially in the direction of double-headed arrow **82**. After leaving the zone $a$, $a'$, wherein the stretching occurs, the body is untwisted or unfolded and the untwisted portion **78'** possesses an oblique orientation in a direction such as that represented by double-headed arrow **84**. It will be apparent that the direction **84** is primarily dependent upon the angle at which body **78** is twisted or folded although other factors may be involved.

Two or more bodies of the type of body **78** may be twisted together and a similar procedure to that above described may be utilized to provide oblique orientation therein, it being apparent that the method of stretch employed should be such as not to permanently bond the bodies together. Body portion **78'** may subsequently be treated as, for example, while held taut, to remove any fold marks therein. Furthermore, assuming the above-described stretch of the material to have been less than said material is adapted to undergo, a further longitudinal stretch may be applied to portion **78'** without appreciably disrupting the oblique structural orientation therein, it being apparent that the primary oblique orientation is well established in the material. Treatments of heat or other suitable softening agents may be applied to the material in conjunction with the above-described methods to facilitate the same. Subsequent treatments for hardening, insolubilizing, coating or otherwise treating the material may be applied thereto such as applications of heat, boric acid or coatings hereinafter described.

In its condition of oblique orientation, body **78'** may be employed in any of various capacities where a birefringent material having said oblique orientation would prove useful. For example, it may be utilized as a birefringent component in various of the constructions described herein. Assuming body **78** to have such composition or characteristics that when it is stretched it acquires light-polarizing properties, or may subsequently be treated to acquire said properties, it will be seen that a polarizing body having a predetermined oblique light-polarizing direction may thus be formed. In the form of a polarizer, body **78'** may also be employed as a polarizing component of the present invention having oblique orientation of its polarizing direction. It will be evident that the plurality of oblique orientation angles which may be provided in birefringent and polarizing components, as above described, when added to longitudinal directions of orientation obtainable by known methods of stretch or other processes, and reverse directions of twist hereinbefore described, offer substantially any relative disposition of optic axes and light-polarizing directions. Other constructions and methods relating to orientation of components will also be described herein. It is to be understood that the above language relative to twisting body **78** is also intended to cover the coiling, folding, spinning or otherwise shaping of the same to achieve a substantially similar arrangement thereof during the stretching process. Alternatively, said twisting or the like may be performed, simultaneously within the portion undergoing stretch.

Fig. 10 illustrates a light-modifying body **86** comprising a twist of light-polarizing components **88** formed around a birefringent core component **90**. While said twist is shown as composed of generally flat, ribbon-like components, said components may be substantially round or of some other shape. Fig. 10 is primarily intended to illustrate a possible relation of various axes which may exist in a body or filament of the invention. For example, diametrically opposed light-polarizing portions are shown as having polarizing directions **92** and **94** which are crossed at 90° with respect to one another. Birefringent core component **90** is represented as having a direction of structural orientation **96** and principal axes **98** and **100** which are disposed substantially at 45° with respect to the polarizing directions **92** and **94**.

Fig. 11 illustrates a light-modifying body **102** comprising a plurality of braided components **104**, **106**, and **108**, any two of which may appropriately be formed of a light-polarizing core having a layer of oriented birefringent material formed thereabout. The third of said components may suitably have merely light-polarizing properties although a birefringent layer of predetermined orientation could also be formed thereupon. Assuming but two birefringent layers, as above described, one of said layers would appropriately be of an **S** type and the other of a **Z** type. The double-headed arrows **110**, **112** and **114** indicate the polarizing directions of said components **104**, **106** and **108**. Accordingly, braided body **102** comprises a plurality of superposed functional light-polarizing and birefringent areas for producing interference colors wherein are comprised light-polarizing portions and interposed birefringent portions of alternately different thickness having suitable axial directions for coacting with one another. In accordance with the above-described construction, the principal axes of superposed birefringent portions may extend in a similar direction. As shown in Fig. 9 and presently to be amplified, birefringent components having a different relation therebetween may be employed. Where the third component also has a birefringent layer formed thereabout, it will be apparent that the above-described alternately different thickness of interposed birefringent portions may not necessarily exist. The construction of Fig. 11 may also be employed for other obvious purposes as, for example, whenever it is desired to provide an angular relation of one or more components with respect to the longitudinal direction of a body.

Fig. 12 shows a light-modifying component 116 which is adapted to polarize light passing therethrough and which may have a light-polarizing direction 118 or some other light-polarizing direction or directions. Component 116 is adapted to polarize light which passes therethrough, substantially impartially in any direction. The component 116 may be formed of a suitable transparent material 120 having portions 122 adjacent the surface thereof which may be rendered light-polarizing by any suitable means, or 120 may represent a substantially isotropic core material or a non-functionally oriented material which is not adapted to be rendered light polarizing and 122 may represent a light-polarizing layer formed around said core. Polarizing portion or layer 122 may appropriately be composed of a partial polarizer whereby light passing through component 116 may be polarized to a desired degree by passing through substantially opposite areas of layer 122 and be "doubly" partially polarized to achieve a more complete polarization. If deisred, portion 120 may be light-polarizing throughout, it being obvious that physically thicker synthetic polarizers should, in general, have less density to equal the performance of thinner polarizers.

In another construction relating to Fig. 12 component 116 may comprise a light-polarizing portion having a direction of polarization extending differently from that of double-headed arrow 118 as, for example, portion 120 may be formed as described relative to Fig. 9 and any predetermined oblique orientation may be provided therein. In said construction, portion 122 may represent either a polarizing portion of 120 adjacent the surface or a protective coating for an underlying polarizing portion. It is to be understood that a protective coating may be applied to a surface of any of the components described herein or to layers formed thereupon.

In another modification of Fig. 12, component 116 may comprise an isotropic or a non-functionally oriented transparent core 120 and a light-polarizing coating 122 formed around only a part of its circumference as, for example to one side of dotted lines *b*, *b*, said partial coating being provided after incorporation of component 116 in a fabric, as will presently be described. In still another modification, component 116 may comprise an isotropic or non-functionally oriented core 120 and a layer 122 composed of an optically active substance comprising, for example, suitable oriented minute crystals of a rotatory, polarizing type, for example, sulphate of strychnia, sulphate of aethylendiamin, sodium chlorate, or a suitable rotatory polarizing amorphous solid such as may be formed from an optically active solution, for example, tartaric acid. An additional protective coating (not shown) or a stabilizing treatment of the optically active layer 122 would probably be required in the last-named modification. Although component 116 is represented as of cylindrical shape, it may have some other shape, as hereinbefore described. Light-polarizing properties of component 116 may be provided by any of the well known methods involving stretching, applying predetermined fields of force thereto, rubbing, treating with a stain, a gas or an acid, applying heat thereto, or by some other method.

Fig. 13 illustrates a light-modifying component 124 which is adapted to serve in a birefringent capacity and which may comprise a birefringent core 126 and a protective coating 128 or a substantially isotropic core 126 and a birefringent coating 128. The last-named form would permit a relatively thin birefringent portion relative to the overall thickness of the component. Many suitable birefringent materials would, however, permit their use as filament components without a protective coating thereon. Although component 124 is represented as round in cross-section, it could be of some other shape as, previously described. A birefringent component could also be formed as a hollow rod or tube to reduce the thickness of the material while providing a relatively large outside diameter, said thickness contributing to a predetermined phase difference between transmitted components of light when employed with polarizing means.

Fig. 14 illustrates a plurality of cross-sectional shapes in which various constructions of the invention, such as light-polarizing and birefringent components, may be formed. Choice of the same depends upon the interference effects and other characteristics desired in the fabric or other material. Type 4 constitutes a preferred embodiment for general use in the constructions described herein because it is radially uniform and provides consistency, as between components, of one of the variables, namely, that of thickness which relates to the production of interference colors. Type 5 has already been described as particularly adapted to use as a form of twist. Other forms may be employed where a predetermined selection of other variables, hereinbefore described, permits slight alterations of thickness of birefringent components without appreciably varying the interference colors produced. Where functional components are in the form of coatings, it will be understood that said coatings may be substantially uniformly distributed over irregular or other carriers therefor such as types 1, 2 and 3. Similar considerations are pertinent relative to polarizing components. Forms of components represented by types 1, 2 and 3 may also be employed where unevenness of interference effects and/or texture are desired. It will be understood that shapes other than those shown may also be employed.

Figs. 15, 16 and 17 illustrate various forms of composite light-modifying bodies or filaments comprising core components and surrounding layers coated thereupon. Subcoats therefor may also be employed, as required. Functionally, said bodies are substantially similar to bodies and filaments previously described, having a twist formed around a core.

In Fig. 15, a composite light-modifying body or filament 130 is shown comprising a core component 132 and a coating component 134 surrounding said core. Core 132 may appropriately represent a light-polarizing component having a predetermined polarizing direction such as 136, and coating 134 may be formed of a suitable birefringent or optically active material having a predetermined direction of orientation such as 138 which provides a suitable angular relation of its principal axis relative to polarizing direction 136, or, if preferred, comprising a random disposition of birefringent or optically active particles. The oblique direction 136 may be obtained as through employment of a light-polarizing element of the type described with respect to Fig. 9 as a core, or by a method presently to be described. Coating 134 may then be applied and orientation thereof achieved by stretching the composite body or by applying a field of force to said coating as, for example, while applying the coating or thereafter. The functional optical relation of polarizing and birefringent components having a relative disposition of their axes similar to that above-described has been described hereinbefore. Accordingly, body or filament 130 may be employed in conjunction with a similar filament, as in a fabric, whereby said filaments are capable of coacting to produce interference colors. Or, body or filament 130 may be employed with any suitable polarizing means for providing interference colors.

Filament 130 of Fig. 15 may also represent a light-polarizing layer 134 having a polarizing direction 138 surrounding a birefringent core 132 having a direction of orientation 136. Light, in passing through the filament is intercepted by two polarizing portions having parallel directions of polarization and by a birefringent portion having an optic axis angularly disposed relative thereto, interposed between the polarizing portions, an arrangement adapted to produce interference colors. Alternatively, core 132 may comprise optically active rather than birefringent properties.

In Fig. 16, a composite light-modifying body or filament 140 comprising a core component 142 and a coating component 144 surrounding said core is shown. Core 142 may comprise a light-polarizing material having a polarizing direction 146 and coating 144 may suitably be formed of a birefringent material having a direction of orientation 148, or, alternatively, coating 144 may comprise an optically active material. As a modification, core 142 may comprise a birefringent material having a direction of orientation 146 and coating 144 may comprise a spirally oriented coating having a polarizing direction 148. As described relative to a twist, a spiral orientation formed around a core provides crossed polarizing axes transversely of the core. The significance of said arrangement of components relative to production of interference colors has been described hereinbefore.

Fig. 17 shows a composite light-modifying body or filament 150 comprising a core component 152, a coating component 154 surrounding said core, a second coating component 156 surrounding coating 154, and a third coating component 158 surrounding coating 156. Core 152 comprises light-polarizing material having a polarizing direction such as 160. Coating 154 comprises an optically active substance which is preferably predeterminedly oriented with respect to polarizing direction 160, but which may consist of areas or particles disposed at random. Coating 156 comprises light-polarizing material having a polarizing direction 162, and coating 158 represents a protective surfacing material. Composite filament 150 is adapted, of itself, to produce interference colors in a manner hereinbefore described. Filaments of Figs. 15, 16 and 17 could comprise both cores and coatings which are elastic to produce effects generally similar to those described with respect to Fig. 5.

Fig. 18 represents, in cross-section, a composite light-modifying body 164 of substantially flat or ribbon-like form comprising a light-polarizing layer 166 having a predetermined polarizing direction, and a superposed layer 168 formed thereupon or bonded thereto comprising an optically active substance. At least portions of the optically active substance are so oriented with respect to said polarizing direction as to coact with light-polarizing layer 166 and to rotate components of plane polarized light entering the optically active substance from the polarizing layer. Plane polarized light incident layer 168 from an external source (not shown) may be rotatorily polarized by the optically active substance and resolved into interference colors by polarizing layer 166.

Fig. 19 illustrates, in cross section, a composite light-modifying body 170 of substantially flat or ribbon-like form comprising a light transmitting layer or core 172 and a surrounding layer or coating 174. Core 172 may comprise an optically active substance and coating 174 may comprise a light-polarizing material having a predetermined light-polarizing direction. At least portions of said substance are so oriented with respect to said polarizing direction as to coact with the light-polarizing material and to rotate components of plane polarized light entering core 172 from coating 174. In turn, a substantially opposite portion of coating 174 serves as an analyzer for the rotated components to provide interference colors. Alternatively, core 172 may comprise light-polarizing material and coating 174 may comprise an optically active substance, the optical properties of such a construction being similar to those of Fig. 18 excepting that rotatory polarization occurs for light passing through the body from a source either above or below the same, as positioned in the drawing.

Fig. 20 shows, in cross-section, a composite light-modifying body 176 of substantially flat or ribbon-like form comprising three functional layers 178, 180 and 182. Said layers may be effectively bonded to one another or may consist of a central layer 180 having coatings 178 and 182 applied to both sides, or a central layer 180 having a coating 178 applied to one side and a layer 182 bonded to the other side. The central layer may comprise light-polarizing material and the superposed layers may, accordingly, comprise an optically active substance or substances or, alternatively, the central layer may comprise an optically active substance and the superposed layers may, accordingly, comprise light-polarizing material. At least portions of the optically active substance are so oriented with respect to a polarizing direction of the polarizing material as to produce interference colors. The optical properties of the two constructions are generally similar to those of Fig. 19.

Fig. 21 illustrates, in cross-section, a twist of transparent filament components 184 bonded to a transparent core 186 by a transparent bonding substance 188 such as vinyl acetate or methyl methacrylate. The bonding substance 188 may serve several functions. For example, it may be adapted to prevent slippage of the layer of filaments around the core during a twisting process and/or after incorporation in a fabric. Or, it may serve as a barrier to prevent a dye, stain or the like, from penetrating to underlying portions of the filaments 184 or to the surface of core 186. The first-named function applies to any of the twist constructions shown herein, and the second-named function would apply when twist 184 is a light-polarizing component. A twist adapted to be treated to become light-polarizing could thus be stained, dyed or the like upon exposed portions only, thereby reducing the polarizing portions through which light would pass. A slight diffusing property of bonding substance 188 could be provided therein, in special instances where a small diffusion of interference colors is desired. Relative to the general subject of selectively treating certain components of composite products of the invention with a dichroic fluid, a conventional dye or another substance, the construction of Fig. 21 serving as an example, it will be understood that twist 184 could be fused, coagulated or otherwise bonded to core 186, or that said core could, for example, be of a material nonreceptive to the fluid, or selectively receptive to the dye, et cetera.

Fig. 22 illustrates, in cross-section, the employment of a suitable transparent subcoat 190 between surfaces of a composite light-modifying body of the invention as, for example, between a core 192 and a coating 194. The subcoat may serve as a bonding agent or provide an intervening substance of predetermined refractive index to improve transmission or reflection of light rays relative to said body.

Fig. 23 shows, in cross-section, a light diffusing coating 196 applied to a surface portion of a light-modifying body 198 of the invention, said coating being applied, for example, similarly to a method, presently to be described, of applying a light-polarizing fluid to a fabric.

Fig. 24 shows, in cross-section, a composite light-modifying body or filament 200 comprising a spirally oriented coating or twist of filament components 202 formed around a preferably isotropic core 204, said coating or twist being birefringent and potentially light-polarizing and providing a predetermined crossed orientation of transversely opposite portions thereof. A protective coating 206 is formed upon a portion of twist or coating 202, it being assumed that said protective coating has been thus formed after filament 200 has been incorporated in a fabric. Coating 206 may be either temporary or permanent and, if the latter, it is transparent. If temporary, it is adapted to be dissolved by a suitable organic or inorganic substance. Coating 206 is impermeable to a light-polarizing treatment such as a dye or stain. Upon application of a light-polarizing treatment to the fabric, exposed portions of coating or twist 202 are rendered light-polarizing while portions thereof covered by protective coating 206 are unaffected by said treatment. After the light-polarizing treatment, protective coating 206 may be dissolved if adapted thereto, as above described. A construction providing a light-polarizing portion and birefringent portion radially superposed therewith is thus formed, the optic axis of the birefringent portion being predeterminedly angularly disposed relative to the light-polarizing direction.

Alternatively, coating 206 may be a permanent reflecting or semi-reflecting coating so that at least part of the light entering the polarizing and birefringent portions is reflected substantially reversely along its path. In a construction where light passes through polarizing and birefringent layers to a reflecting surface and is thus reflected, the birefringent layer serves functionally twice, and the polarizing layer serves both as a polarizer and analyzer. Core 204 may also have predetermined anisotropic properties for coacting with said birefringent portions of coating or twist 202. In another modification, core 204 may be omitted entirely and layer 202 may then consist of a twist of one or more components, or a spin of a plurality of components. Where layer 202 is in the form of a coating, several methods of providing an oblique or spiral orientation thereof will presently be described.

Fig. 25 represents a side view of a composite light-modifying body or filament 201 of a type described with respect to Fig. 24 and comprises a preferably substantially isotropic core 205 and a twist of birefringent components 203 formed around the core, said twist being adapted to become light-polarizing when suitably treated. A transparent bonding substance, impervious to a light-polarizing treatment such as a stain or dye, may suitably exist between the core and twist, or the twist may be shrunk tightly upon the core. Directions of orientation of portions of the twist at opposite sides of the core are generally indicated by double-headed arrows 208 and 210. Core 205 may have predetermined anisotropic properties as stated with respect to Fig. 24. Filament 201 is adapted to be employed in a fabric as, for example the warp, with a similar filament forming the filling. A plurality of filaments 201 may thus be incorporated in a fabric prior to a polarizing treatment thereof. After the fabric is formed, it may be treated with a coating substance for providing a protective coating over inner facing surfaces of warp and filling in the manner described relative to Fig. 24. Or, inner facing surfaces may be temporarily or permanently bonded together so as to be shielded from a light-polarizing treatment. The polarizing treatment, accordingly, affects exposed surfaces of the filaments only and birefringent portions are provided, interposed therebetween. The relation between optic axes of the birefringent portions and polarizing directions of polarizing portions is adapted to produce interference colors. The relation between birefringent and light-polarizing axes may be altered by varying the twist angles of warp and filling filaments and by use of S and Z twists. Use of filaments having an oblique orientation such as that described relative to Fig. 9 may also be employed for further varying the relation of axes, or a combination of said variables may be employed.

Further referring to the above, a twisted monofilament or multifilament or a plurality of twisted filaments, as shown in Fig. 8, could similarly be incorporated in a fabric and subjected to a light-polarizing treatment thereafter, provided the filament or filaments are birefringent and adapted to become light-polarizing when treated therefor. Light-polarizing treatments of a fabric, which obviate the necessity of coating or bonding inner surfaces of filaments such as those set forth relative to Figs. 8 and 25, will presently be described. Self-sufficient bodies or filaments of the type hereinbefore described for producing interference colors may also be treated for providing their light-polarizing properties after incorporation in a fabric, provided transparent filaments crossed therewith in the fabric are substantially nonreceptive to the polarizing treatment.

Fig. 26 shows a composite light-modifying body or filament 212, partly in cross-section and with parts broken away. The filament is of a type previously described and may thus comprise a birefringent core 214 and a twist of light-polarizing components 216, having a direction of polarization 218, formed thereabout. Fig. 26 illustrates the transmittal of light relative to a filament of the invention wherein, for example, may exist an assembly of components having similar refractive indices or a core with a slightly higher refractive index than the twist. Where desired, adjacent surfaces may be bonded, fused or coagulated together, as at **220**, to insure optical contact of said surfaces, a bonding substance preferably having a similar refractive index to that of twist and/or core components, for maximum transmittal of light. For providing reflection of light at various surfaces, materials of different refractive index may be employed as, for example, a core having a lower refractive index than the twist. Bonding substances of appropriate refractive index may also be employed for the purpose as well as semi-reflecting coatings or the like.

Fig. 27 illustrates a swatch of a light-modifying fabric of the invention wherein self-sufficient filaments **222** for producing interference colors are employed with preferably transparent filaments **224** of any desired type. Filaments **222** may be of any of the forms described hereinbefore which are capable, of themselves, of producing interference colors and other effects and are shown having crossed polarizing axes **226**, although such a relation of axes is merely illustrative. Filaments **224** may have various optical properties for coacting with filaments **222** or for otherwise contributing to the overall appearance of the fabric as, for example, they may be tinted, strongly reflecting, fluorescent or have some other functional characteristic. Moreover, they may provide some other desired characteristic of the fabric such as a texture effect, fire resistance, stability, strength or the like.

Fig. 28 represents a swatch of a light-modifying fabric of the invention wherein filaments **228** and **230** are of a type previously described which coact, as warp and filling, to produce interference colors and other effects. Accordingly, said filaments may comprise a light-polarizing core and a birefringent layer formed thereabout. Double-headed arrows **232** and **234** generally indicate the polarizing directions of warp and filling, respectively.

Fig. 29 illustrates a swatch of a light-modifying fabric wherein filaments **236** may appropriately be of the type shown in Fig. 28. Filaments **236** may, for example, be employed as warp in which event the filling **238** may suitably be composed of substantially transparent filaments such as filaments **224** of Fig. 27, previously described. A fabric of this type may be employed with an external source of polarized light for producing interference colors. If filling **238** is birefringent, alternate crossings of the filaments will provide portions having different retardation properties which will produce different interference colors from other portions. Two fabrics of the type shown in Fig. 29 could be bonded together, with either a parallel or angular relation of the polarizing directions thereof, to provide a composite fabric for producing interference colors. Filaments **236** may have polarizing directions **240** or another direction, as hereinbefore described.

Fig. 30 shows a swatch of a light-modifying fabric with warp and filling comprising coacting filaments **242** and **244** having light-polarizing cores and birefringent surrounding layers for producing interference colors. The warp and/or filling also comprise preferably transparent elastic filaments **246**. When the fabric is stretched as, for example, on the bias, the axial relation between filaments **242** and **244** is altered, providing different interference color effects and different transmission of light according to differences in the angular relation of said axes. Alternatively, filaments **242** and **244** may be light-polarizing, without birefringent coatings, for altering light transmission only, in which instance a tint or dye may be incorporated therewith for providing a constant color to light of variable intensity. It will be apparent that elastic filaments **246** may also thus be tinted or dyed. Elastic light-modifying filaments of the type described relative to Fig. 5 may also be employed in the fabric of Fig. 30 in place of either filaments **244** or **246**, or both.

Figs. 31 and 32 illustrate light-modifying bodies or filaments of types described herein, which are associated with a film or other component or components to form composite structures. In Fig. 31, a plurality of said light-modifying bodies **252**, capable of producing interference colors, are formed into a fabric or the like with a plurality of preferably transparent filaments **254** and said fabric is bonded by a transparent adhesive substance **256** to a film component **258**. Film component **258** may be of a relatively nondeformable type or may have pronounced qualities of drape. Said film component may be transparent, translucent, diffusing, dyed or have some other quality according to the intended use of the structure. Alternatively, film **258** may be in the form of a fabric or some other material having generally similar optical qualities to those described relative to the film. In another modification filaments **252** and **254** may be of the type, above described, which coact to provide interference colors In a further modification, at least one of filaments **252** and **254** may comprise a light-polarizing core and a layer of birefringent or optically active material and film **258** may comprise light-polarizing properties, the polarizing axes of the filaments and film being suitably oriented. In still another modification, film **258** could comprise both light-polarizing and birefringent or optically active properties while at least one of filaments **252** and **254** could be light polarizing. Other modifications will readily be apparent in view of various constructions described herein. The fabric may be embedded in a transparent film or laminated between film components. In the last named form, the light-modifying bodies could be self-sufficient for producing interference colors or could be merely birefringent or optically active bodies, the film components being at least light-polarizing.

Fig. 32 shows a plurality of light-modifying bodies **260**, having self-sufficient or coacting properties of the type described herein, bonded by a transparent substance **262** to a film component **264**. Said bodies may be oriented, as generally indicated, or may be disposed at random on the surface of the film. Substantially all of the modifications described relative to Fig. 31, omitting those requiring filaments **254**, are applicable to the construction of Fig. 32. It will be apparent that filaments of the present invention may be severed to form short staple fibers or abbreviated bodies for use in conjunction with a fabric, film or other material, in the general manner above described. Accordingly, they may be bonded to or embedded in various materials for many purposes where the production of interference colors is an objective. It is also to be understood that other fabric constructions comprising filament components of the invention may be incorporated with film materials. The invention also contemplates the provision of an artificial fabric formed of a film-like material comprising light-polarizing and birefringent or optically active components having principal and polarizing axes suitably disposed relative to one another for producing interference colors in the manner described herein. Said material could be formed of thin laminae or could readily be formed by the method described relative to Figs. 9 and 35. The artificial fabric could comprise an embossed, etched, printed, flocked or otherwise treated surface to generally resemble a fabric, or it might have a laminated or embedded netting or the like, or other internal structure for providing a substantially similar resultant. The interference colors, which would generally be visible, could be extinguished wherein such constructions provided opaque lines of demarcation, or could be differently visible, due to diffraction or other effects, where transparent or translucent lines of demarcation were provided. The artificial fabric could have pronounced qualities of drape or be relatively nondeformable, according to desired characteristics thereof.

Figs. 33 and 34 illustrate the adaptability of light-modifying fabrics of the type described herein to be draped in various contours substantially without affecting the orientation of their light-modifying components. Fig. 33 represents such a fabric **266** laminated to a spherical surface **268**. Fig. 34 illustrates a draped fabric **270** of said type embedded in a molded transparent plastic body **272** or the like. The double-headed arrows indicate the presence of vibration directions of light-polarizing materials rather than any specified direction thereof. Where the fabrics are draped, so that curved areas thereof are formed, various merging interference effects will be visible to an observer while viewing said areas from any position, said effects relating to gradations of color and luster and being unobtainable in any conventional fabric. As employed in Fig. 34, a fabric of the invention may be deformed according to the requirements of a molded product for producing interference colors therein. The fabric may also serve to strengthen the product in a known manner.

Fig. 35 is a diagrammatic representation of apparatus for forming a light-modifying body of the type shown in Fig. 9. Means such as a spool **274** releasably holds a supply of a filament, strip or ribbon of orientable transparent plastic material **276**. The material **276** is of a type adapted to be rendered birefringent after undergoing stretch, or to be converted into a polarizer when stretched. Or, material **276** could be of a preliminarily treated type which is adapted to be converted into a polarizer by a stretching process. The material is drawn between preferably freely rotatable pressure rollers **278** and is then twisted or folded in a given direction and to a predetermined degree as by twisting or folding means **280**. It then passes, in twisted or folded form between powered pressure rollers **282** and is subjected to softening means, as required, such as heat-applying means **284**. Thereafter, it passes between powered pressure rollers **286**, which rotate at a predeterminedly greater speed than rollers **282**, so that the twisted or folded material is predeterminedly stretched in the area between rollers **282** and **286**, internal orientation being longitudinal of the twisted material as a whole, as shown in Fig. 9. After leaving rollers **286**, the material is untwisted or unfolded by untwisting or unfolding means **287** and an oblique orientation, as indicated by double-headed arrow **288**, is provided therein. The material is then drawn between pressure rollers **290**, which may appropriately be powered to rotate at a more rapid speed than rollers **286**, to take up the slack of material **276** produced by untwisting the same. The material is then taken up by means such as powered spool **292**. Instead of being drawn from spool **274**, the material may be supplied from an extruder **294**, shown diagrammatically in Fig. 36, said extruder being suitably positioned to the left of dotted line *c—c* (Fig. 35). Alternatively to passing from rollers **290** to take-up spool **292**, the material may be directed to a coating device **296** (Fig. 37), said device being suitably positioned to the right of dotted line *d—d* (Fig. 35). Element **296** may appropriately comprise guide rollers **298** and **299** and a container **300**, holding a suitable coating substance **302** which, after its application to material **276**, is adapted to be rendered birefringent by stretching means **304**, **306**, and **308**, which are similar in function to means **282**, **284**, and **286** but which may apply a different stretch to the coated material as, for example, a lesser stretch. The material is then taken up by means **310**. It will be understood that if material **276**, as supplied to coating device **296**, is of a form whereby the first stretching procedure performed by elements **282**, **284** and **286**, or said procedure plus a light-polarizing treatment, render the material polarizing, that the coating and stretching means of Fig. 37 complete a continuous process of forming a body, such as a strip or filament, comprising a light-polarizing component having an oblique orientation, with a birefringent layer having, for example, longitudinal orientation, coated upon the light-polarizing component. Said light-polarizing treatment could be provided by means **362** of Fig. 39, presently to be described.

Further relative to Fig. 35, if a body such as a strip or filament comprising an obliquely oriented central portion or core with a polarizing layer having a different orientation formed thereupon is desired, a modification of Fig. 35 for forming the same is as follows. Material **276** is rendered birefringent with an oblique orientation by twisting and stretching means of Fig. 35, already described. Means of Fig. 37, inserted at *d-d* of Fig. 35, may be assumed to provide a coating of potentially light-polarizing substance **302** upon material **276**, which is hardened sufficiently for stretching upon leaving tank **300**. The coated body is stretched by means **304**, **306**, and **308** to a degree which does not disrupt the oblique orientation of material **276** but which provides a generally longitudinal orientation of coating **302**. Polarizing treatment means, such as means **362** of Fig. 39, may then be employed prior to taking up the body upon means **310**. Alternatively, material **276** may be supplied to coating device **296** either after said oblique orientation has been provided therein or without having been subjected to the twisting and untwisting means, namely, with means **280** and **287** removed from the apparatus, in which latter instance material **276** would have a longitudinal orientation. Coating **302** could consist of either of the aforesaid types of orientable material which are adapted to be oriented when hardened and stretched. By spreading the position of the elements, twisting and untwisting means **280** and **287** could, respectively, be repositioned before and after stretching means **304**, **306** and **308**. Accordingly, material **276** would be provided with a given orientation, as above described, and the coating thereupon would be provided with a predetermined oblique orientation. Where cold drawing of the materials is possible, it will be obvious that softening means of the apparatus may be omitted.

Further referring to Fig. 35, if material **276** is in the form of a relatively wide strip or ribbon, supplementary means such as guide means, folding means, coiling means or the like may be employed instead of the device **280** which is merely a diagrammatic representation. Other similarly functional means could also be employed in place of untwisting element **287**. A means for preliminarily treating the material **276**, for rendering the same more easily twisted or folded, such as means for softening the material or rendering the same elastic, could also be introduced. The spacing of the stretching means, namely, the spacing between elements **282** and **286**, could be varied and, where a relatively wide strip is undergoing treatment, said means could be spaced sufficiently adjacent one another to grip a single oblique twist or fold of the material. It will be apparent that if material **276** is in the form of a flat strip, means for laminating thereto other strips of similar width having different orientations could be introduced. Accordingly, where material **276** is supplied in the form of a strip, a further modification of Fig. 35 plus Fig. 37 is as follows: Heater **306** is removed and fluid **302** is a suitable laminating fluid. A strip of suitable transparent plastic material is introduced at one or both sides of strip **276**, at pressure rollers **308**, and is laminated thereto by said rollers to form structures similar to those shown in Figs. 18 and 20 but using birefringent strips in place of the optically active layers thereof. In said modification, the material **276** may be either birefringent or light-polarizing. Accordingly, the laminated strip or strips would, respectively, be light-polarizing or birefringent. The above modification would permit the formation of said structures by a continuous process. Other modifications of the apparatus of Fig. 35 will readily be apparent.

In Fig. 38, apparatus is shown diagrammatically for forming light-modifying composite bodies or filaments of the invention wherein a twist or spiral of a component or components is formed around a core component. Means such as spool **312** releasably holds a supply of orientable transparent filament material **314**. Said material is, for example, of a type adapted to be rendered birefringent when stretched, or to be converted into a polarizer when stretched, or both. Alternatively material **314** may have light-polarizing properties initially, in which event stretching means of Fig. 38 may not be required. Material **314** serves as a core component of the light-modifying filament. Supposing material **314** to be of either of the first two types, above named, it is drawn between powered pressure rollers **316** and **318**, the second pair of which rotates more rapidly than the first. Softening means, such as heater **320**, is positioned between rollers **316** and **318**, as required, to facilitate the stretching action of the rollers. After stretching and, accordingly, longitudinal orientation, of material **314** has been performed, it may, as required, be introduced to a coating means **321** comprising, for example, guide rollers **322**, **324** and **326** and a tank **328** which contains a fluid **330**. Fluid **330** may serve as a binder for preventing slippage of the twist or twists to be formed about filament or core **314**. Alternatively, fluid **330** may facilitate shrinkage of the twist upon the core to provide optical contact therebetween, or may serve another function to be described. After filament **314** is withdrawn from coating means **321**, the coating formed thereon may be partially hardened, as by heater means **332**. The filament **314** is then introduced to a suitable means such as element **334** for supplying and forming a twist of one or more filament components thereabout, such as components **333** and **335**. Assuming filament or core **314** to be birefringent, the twist components may be considered as either light-polarizing or adapted to be treated therefor, or, assuming the core to be light-polarizing, the twist components may be considered as birefringent or adapted to be treated therefor, in accordance with products of the invention, above described. The number and thickness of twist components employed depend, generally, upon the predetermined relative thickness of the core, the relative diameters of core and twist and the speed of longitudinal movement of the core, said variables having been predetermined in accordance with a desired twist angle. After leaving means **334**, the composite filament may, as required, be subjected to a further coating means **335** comprising, for example, guide rollers **336**, **338** and **340** and a tank **342** which contains a coating fluid **344**. Said fluid may appropriately provide a protective coating for the composite filament. The filament may then be drawn past drying means, such as heater **346**, and be taken up, as by spool **348**.

Further relative to Fig. 38, means for treating either the core or the twist to render the same light-polarizing may be introduced as a part of the apparatus. For example, means **321** could be employed to form a protective coating of the type shown in Fig. 21, where the twist is to be rendered light polarizing. Accordingly, a light-polarizing treatment device, such as element **362** of Fig. 39, presently to be described, could be introduced, as between means **334** and roller **336** of Fig. 38. Or, if material **314** is adapted to be treated to become light-polarizing, such a light-polarizing treatment device could be introduced, as between rollers **318** and element **321**. It will be understood that only one of the core and twist components would be rendered light-polarizing in any product thus produced. If the material **314** is adapted to be cold drawn, softening means such as means **320** could be dispensed with, and where protective or other coatings are not required, means for applying the same such as means **321** and **335** would be omitted. Extrusion means, as represented by extruder **294** (Fig. 36), could be substituted for certain elements of Fig. 38 as, for example, those positioned to the left of line *e—e*. It will be apparent that a plurality of elements such as means **334** could be provided for superposing other twists upon a primary twist, as shown in Figs. 6 and 7.

Where material **314** is supplied in the form of a strip, a further modification of Fig. 38 would eliminate elements **334**, **341** and **346** therefrom, and substitute therefor a pair of preferably powered pressure rollers, such as rollers **308** of Fig. 37. Fluid **330** (Fig. 38) would be in the form of a suitable laminating fluid. A strip of material as, for example, produced by apparatus of Fig. 35, exclusive of takeup means **292** thereof, would be introduced to one or both sides of strip **314** at said pressure rollers and would be laminated thereto to form composite structures which could be represented by those shown in Figs. 18 and 20, with birefringent strips substituted for the optically active layers thereof. In said modification, the strip **314** could be either birefringent or polarizing. Accordingly, the laminated strip or strips would, respectively, be either polarizing or birefringent. The above modification would enable the formation of said structure by a continuous process.

Fig. 39 is a diagrammatic representation of apparatus for providing light-polarizing properties in predetermined portions of a fabric of the invention. Among filaments which may suitably be incorporated in such a fabric are those forms shown in Figs. 8 and 25, it being understood that no polarizing properties exist therein when so incorporated. Said filaments comprise a twist or spin which is birefringent and which is adapted to become light-polarizing when treated for the purpose. A supply of said fabric **350** is releasably carried by a supply means such as a spool **352**. From spool **352**, the fabric is directed to a means **354** for at least temporarily bonding together inner facing surfaces of the fabric, such as inner facing surfaces of warp and filling. Means **354** comprises suitable components for effecting a bond or heat seal between said surfaces, such as heating means **356** and pressure rollers **358**, enclosed in a chamber **360**. The fabric is then led to a polarizing treatment chamber **362** where it is subjected to some suitable treatment to render exposed surfaces of the fabric light-polarizing. Said treatment may involve application of a dichroic dye or stain, an acid, a gas, heat or other conditioning means to the material or a combination of such means, the type of treatment generally depending upon the material and the nature of the orientation existing therein. It will be understood that an orientation exists in the filaments which, in conjunction with the polarizing treatment, provides a predetermined direction of polarization. After leaving chamber **362**, the fabric may be subjected to means for fracturing the sealed inner surfaces such as rollers **364** and **366**. A protective coating may then be applied to the fabric, as required, means for the purpose being shown as a fluid applicator **368** and a hardening means **370**. The fabric is then guided by a roller **372** to a take-up means such as spool **374**. Rollers **358**, **364**, **366** and **372** may, appropriately, be powered. Alternate means to means **354** for protecting inner facing surfaces of the filaments during a polarizing treatment could appropriately consist of a tank containing a coating fluid of a type impermeable to a polarizing treatment such as element **296** of Fig. 37. The fabric could be immersed therein and coated, then withdrawn, and the coating could be removed from outer surfaces by means (not shown), whereupon the fabric could be subjected to a polarizing treatment. Subsequently the coating between the inner surfaces could be removed.

Fig. 45 shows a device which may be substituted for elements **354** and **362** in apparatus of Fig. 39 to provide a light-polarizing treatment of predetermined portions of fabric **350**. The device of Fig. 45 is adapted to apply a liquid, such as a polarizing dye, stain or the like, for example, a polyiodide or a direct cotton dye, to said fabric in such a manner that the liquid does not reach the inner facing surfaces of the filaments, thus eliminating the need to seal or otherwise protect said surfaces. Means of Fig. 45 comprise a roller **462** and a roller **464**, the latter preferably being bodily movable with respect to roller **462** and, as shown, being mounted on a pivotal arm **466** which is predeterminedly loaded as, for example, by a



spring **468** so that roller **464** is biased toward roller **462**. Tank **470** contains a supply of a polarizing dye, stain or the like **472** within which roller **464** is partially immersed. The rollers may advantageously be synchronously powered. Roller **464** may have a yielding, liquid-retaining surface portion **474** or may be hard surfaced. The liquid is applied to the under surface of fabric **350** in controlled or measured amounts as determined by the bias applied to roller **464**, said amounts being insufficient to reach inner facing surfaces of filaments thereof. Various alternative means for mounting the rollers will be apparent. For example, roller **464** may be bodily fixed or it may be limited in its movement toward roller **462** by a limit stop. Furthermore, roller **464** may be adjustably movable to fixed positions relative to roller **462** for accommodating to various thicknesses of fabrics. If desired, roller **462** could have a yielding surface and roller **464** could be engraved for printing a design, it being understood that dichroic fluid **472** is of a suitable paste-like consistency for the purpose and that suitable elements known to the printing art are included in the apparatus. It will be apparent that other known printing methods also have special significance relative to the invention when dichroic fluids are employed.

Further referring to Fig. 45, it will be understood that the fabric **350** may be reversed in direction and similarly treated on its other side. It will also be apparent that means could be provided for simultaneously applying the liquid to both sides of the fabric. Various means may be provided for restricting flow of the liquid, once applied to the fabric. Such means could comprise forced air and/or heat-applying devices positioned adjacent the rollers for rapidly drying the liquid. A somewhat viscous form of liquid could also be employed to reduce its flow tendencies. Various other methods for rendering outer surfaces of the fabric polarizing and inner facing surfaces of the fabric nonpolarizing will be apparent. One such method contemplates applying a polarizing fluid to all surfaces of the fabric; coating outer surfaces, only, of the fabric with a substance impervious to a bleaching liquid; immersing the fabric in the bleaching liquid to remove the polarizing fluid from said inner facing surfaces; and, lastly, removing the coating substance from the outer surfaces. Another method involves treating outer surfaces of a fabric, which is initially nonreceptive to a polarizing dye or the like, with a mordant which renders said outer surfaces receptive thereto and then, for example, immersing the fabric in said polarizing dye.

Figs. 40 through 44 illustrate, diagrammatically, various forms of apparatus for providing oblique or spiral orientation to at least surface portions of filament components of a type contemplated herein. Fig. 40 shows a pair of synchronously rotatable mounting member **376** and **378**, their directions of rotation being indicated by arrows **380** and **382**. Any suitable means may be employed for rotating members **376** and **378**. A means, such as spool **384**, for releasably carrying a supply of a transparent plastic filament **385** is mounted upon member **376**. Filament **385** is appropriately birefringent, has a preferably longitudinal orientation and is adapted to receive a coating which is differently oriented. A pair of pressure rollers **386** is also mounted upon member **376**. A take-up spool **388** and a pair of preferably powered pressure rollers **390** are mounted upon member 378. Suitable means for mounting said elements in members 376 and 378 will be apparent and, therefore, are omitted. A chamber 392 having suitable entrance and exit orifices 394 and 396 is positioned between members 376 and 378, said chamber containing an orientable coating fluid 398 as, for example a viscous fluid, adapted to adhere to filament 385. An oven 400 is positioned between chamber 392 and member 378 for applying heat to the coated filament. The filament 385 is drawn, respectively, between pressure rollers 386, through coating chamber 392 and oven 400, between powered pressure rollers 390, and is then taken up by spool 388. While undergoing longitudinal movement, the filament is rotated in the direction of arrows 380 and 382, the relative speeds of said longitudinal and rotational movements being predetermined. In passing through chamber 382, a substantially spirally oriented layer of fluid 398 is formed around the filament, the orientation being provided by the combined longitudinal and rotational movement of the filament and by properties of the filament and fluid encouraging adhesion of the latter to the former. The predetermined relative speeds of longitudinal and rotational movement of the filament together with the viscosity and adhesion properties of the fluid provide a predetermined angle of orientation of the coating. Fluid 398 may be preliminarily oriented as to molecular or crystalline direction in chamber 392, as desired and feasible, by electrical or other means, not shown. Assuming fluid 398 to be of a type which becomes light-polarizing when oriented and hardened or which becomes light-polarizing when subsequently treated after hardening, the above-described method provides a composite filament having a birefringent core and a light-polarizing coating with relative axes angularly disposed.

Further referring to Fig. 40, various modifications of the apparatus and alternatives as to materials employed in forming the filament will readily be apparent. For example, if the core is birefringent and has an oblique orientation, such as may be provided by apparatus of Fig. 35, a light-polarizing coating may be applied by apparatus of Fig. 40 having some other oblique orientation or, indeed, a longitudinal orientation if members 376 and 378 are held fixed. Alternatively, in Fig. 40, the filament 385 may be light-polarizing, having a longitudinal or oblique orientation and the coating 398 may be applied so as to have any orientation above-described relative to a birefringent coating. It will be understood that chamber 392 and entrance and exit orifices 394 and 396 are shown diagrammatically and that suitable constructions are provided for introducing and removing filament 385 relative to fluid 398, so that orientation of the coating is not disrupted at the exit orifice 396 said constructions being readily apparent. Either the coating 398 or core 385 could also be of an optically active character.

Fig. 41 represents, diagrammatically, a device for applying an oblique field of force to a filament which is undergoing longitudinal movement to provide a structural orientation adjacent the surface of the filament which differs from that in central portions thereof. A filament 402, undergoing movement in the direction of arrow 404, is preferably, although not necessarily, slightly softened, as by heating means 406, or, alternatively it may be introduced with a coating thereupon which is preferably not completely hardened. Said filament or coating is composed of a material adapted to become oriented in a given direction when a field of force is applied thereto and may thus be said to be initially orientable. In the same sense, materials hereinbefore described which may be oriented by stretching are also termed initially orientable. An orienting means 408 comprising a rim 410 mounting a plurality of inwardly extending bristle-like members 412, appropriately formed of a spring steel or a suitable plastic material, is rigidly connected to a circular rotatable support 414. Means 408 is positioned obliquely with respect to the longitudinal direction of filament 402 and, preferably, may be adjusted so as to be inclined at various angles relative thereto. Means (not shown) are provided for rotating support 414 at a predetermined speed, the field of force applied by members 412 providing an oblique orientation of at least surface portions of the filament or the coating formed thereon, as indicated by double-headed arrow 415. Alternatively, means 408 may comprise merely a sector of bristle-like members 412, whereby predetermined relative speeds of longitudinal movement of filament 402 and rotational movement of orienting means 408 provide a spiral orientation of the filament or coating portions. It is to be understood that the filament is held in a taut condition during the aforesaid treatment and means (not shown) for guiding and holding the filament may be placed immediately contiguous the area of contact of members 412. The oriented filament may be employed, respectively, as a birefringent, an optically active or a light-polarizing body or component of the invention, or a combination thereof, depending upon its initial characteristics, the characteristics induced by orienting means 408, and subsequent treatment which may be necessary, such as a polarizing treatment of a type hereinbefore described.

Fig. 42 illustrates a device for applying a spirally oriented coating around a filament. A rotatable circular chamber 416, comprising a plurality of inwardly extending vanes 418, contains a preferably viscous orientable coating substance 420. Any suitable means (not shown) may be employed for rotating chamber 416 at a predetermined speed, as in the direction of arrows 424 and 426. Filament 422 is to be understood as undergoing longitudinal movement through chamber 416 at a predetermined speed. A coating of substance 420 is formed around the filament, it being understood that the adhesion properties of the filament and fluid, relative to one another, as well as the viscosity of the fluid are predetermined. A predetermined relative speed of rotation of chamber 416 and of longitudinal movement of filament 422 provides a substantially spirally oriented coating of substance 420 around the filament, said coating being oriented at a predetermined angle. Adjustment of the individual speeds of movement permits other relative speeds therebetween and other angles of orientation. The coated filament may constitute a body or component of the invention generally similar to any of those described relative to Fig. 41.

Fig. 43 represents, in cross-section, elements of an extrusion device 428, adapted to provide differential orientation of portions of an extruded filament, said elements being positioned adjacent an outlet orifice 430 of the device. A quantity of an orientable plastic mix **432** adapted, for example, to form a birefringent plastic material having micellular orientation when extruded, is releasably contained in a chamber **434**. Mix **432** is extruded through orifice **430** as, for example, while subjected to heat and pressure, means for applying the same not being shown. The mix **432** is at least partially hardened and oriented substantially longitudinally after entering bore **436** of extruder head or nozzle **438** as indicated at **432***a*. A circular indentation **439** is formed within the front of head **438**, said indentation being adapted to receive a circular fluid-dispensing member **440** having a central bore **441**. Member **440** is rigidly connected to a hollow shaft **442**, said shaft being rotatabaly mounted in a supporting member **443**. Circular member **440** may be caused to rotate at a predetermined speed by any suitable means as, for example, by a pulley **444**, rigidly attached to shaft **442**, and a belt **445**, the latter being driven by a motor having a suitable speed control, not shown. A circular groove **446** is formed within circular portions of head **438** defined by indentation **439**. An inlet **447** is adapted to supply an orientable fluid plastic substance **448** to groove **446**. A preferably thin rectangularly shaped channel **449** is formed inwardly of member **440** so as to provide a passage for conducting fluid substance **448**, in ribbon-like form, from groove **446** to bore **441** at any rotational position of member **440**. Channel **449** may extend radially within member **440** or may, advantageously be directed slightly to the side of the axis of bore **441**. Orientable fluid substance **448** is introduced, respectively, through inlet **447**, groove **446** and channel **449**, as by heat and pressure means, not shown, said substance being oriented substantially longitudinally of channel **449** before being applied to a core of hardened mix **432***a*. It will be understood that fluid substance **448** is adapted to adhere to said core. The relative rates of extrusion of mix **432** and substance **448** and the rotational speed of circular member **440** relative to said rates are predetermined to provide exertion of a generally oblique field of force upon substance **448**. Accordingly, substance **448**, in a hardened form **448***a*, is superposed around said hardened core as a substantially spirally oriented coating. The composite filament, thus formed, is drawn to take-up means, not shown, and is subjected to such intermediate processing means as may be required. The oriented core may thus serve as an anisotropic component and the oriented coating may possess the properties of a light-polarizing layer, or subsequently be treated therefor. Alternatively, the core may have light-polarizing properties and the coating may be anisotropic. If mix **432** is of a type suitable for use in forming either a birefringent component or, when hardened and treated, a light-polarizing component, it would be possible to have inlet **447** also lead from chamber **434**, although a means for applying to the core a subcoat impervious to said mix would preferably be introduced prior to formation of the coating.

Fig. 44 represents a transparent filament **450**, moving at a predetermined speed in the direction of arrow **451**, said filament being adapted to acquire a structural orientation of at least portions thereof when subjected to an electromagnetic or an electrostatic force. Means for the purpose are diagrammatically shown for providing an electromagnetic force in an oblique direction relative to the direction of movement of the filament. An annular rotatable member **452**, supported in bearings represented by **454** and **456** and comprising a plurality of electromagnets **458** extending inwardly therefrom, is provided for the purpose. Annular member **452** is rotated by frictional driving element **460** which bears against peripheral portions thereof, the element **460** being driven at a predetermined speed by a motor **462**. Series connection of electromagnets and commutator means are to be understood as included. Alternatively to the electromagnetic means shown, a suitable dielectric means could be mounted within annular member **452** to provide application of an obliquely directed electrostatic force to the filament. Any of the devices of Figs. 41, 42 and 44 could be introduced into apparatus of the invention, or modifications thereof, wherein a filament is advanced from a supply means to a take-up means and where a substantially oblique or spiral orientation of the filament or of a coating applied thereto is desired.

Various types of light-modifying bodies, filaments, fabrics and other areas of material have been shown and described herein, together with apparatus and methods for producing the same. It will be apparent that many other forms of materials and constructions, and methods for producing said forms, which are too numerous for specific coverage herein, are within the scope of the invention. Materials and products of the invention are adapted, in varying degree, to be employed in substantially any known method of forming a fabric. Although only a plain weave has been shown herein to illustrate the function of components of the invention, other types of woven, knitted or differently formed fabrics may have special advantages as, for example, for admitting or directing light to predetermined components. In general, it is indicated that the purity of colors obtainable in filaments and fabrics of the invention excels that of conventional textile filaments and fabrics. A single given dye, stain or other treatment may be employed in constructions of the invention for providing an entire range of colors of the spectrum. The various retardation effects, such as those of highlights and luster, provided by the different optical paths of light rays passing through filaments and fabrics of the invention contribute appreciably to the appearance thereof and may be considered as a principal meaning of "effects" other than those of color, to which reference is made herein.

Among general considerations relating to constructions of the invention, a preliminary twisting of various components may be performed to a predetermined degree prior to their assembly into composite structures, without appreciably affecting their relative orientation in the composite structures, provided such preliminary twisting is not sufficient to affect internal orientation of the components or to significantly change the directions of portions of a component from an overall longitudinal direction. This type of twisting is not generally recommended, however, because it may add an unnecessary complication to methods of determining exact characteristics and relations of axes of the components. The degree to which a component may be preliminarily twisted without perceptibly altering its optical qualities may readily be ascertained for given materials. A small twist should neither appreciably affect the planes of principal axes of birefringent components nor the vibration directions of polarizing components. A considerable twist will alter said planes and if carried to an extreme will provide overlapping, angularly-disposed directions of orientation within the component. Alteration of said planes of birefringent and polarizing components through preliminary twisting may be employed to achieve further relationships of axes in composite structures. An overlapping of directions of orientation in a birefringent component may also be employed for providing a desired alteration of its properties, but said overlapping would be undesirable in a polarizing component. It will be apparent that an appreciable number of the constructions shown and described herein may be modified as to the relative orientation of their components where preliminary twisting of said components for the last-named purpose is performed. However, the altered directions of orientation may readily be ascertained and merely require the employment of an additional list of orientation values in forming the composite structures, to obtain an ultimate predetermined relative orientation of the components. The above considerations do not refer to twisting a component prior to stretching the same because it has been seen, relative to Figs. 9 and 35, that overall longitudinal orientation may be achieved in a twisted filament through a stretching process, provided the filament is maintained in a twisted condition. Said considerations are thus applicable to a filament which is substantially completed as to internal structural orientation and which may serve as a core, twist, spin, braid or other component. It is well known that a preliminary twist may provide improved characteristics of strength in certain types of filaments.

Such known filaments, as glass filaments, may be interwoven with filaments of the invention to enhance the fire resistance of a fabric formed thereof. Various other known treatments for improving the fire resistance of synthetic materials may also be employed such as applying a solution of borax and boric acid thereto. In some instances as, for example, where twists or spins are employed in forming composite filaments, it may be desirable to shrink the components into close contact with one another as, for example, to provide optical contact thereof, or a seal therebetween which is impermeable to a subsequent treatment. The components may, accordingly, be formed together while possessing a moisture content, the moisture thereafter being released to provide a contraction of the components. Components formed of polyvinyl alcohol may be utilized in a hygroscopic condition for such a purpose and, thereafter, may be insolubilized, hardened, coated or the like.

Although transparent materials are generally specified in constructions of the invention, it is to be understood that said constructions may appear translucent or opaque rather than transparent because of reflection, diffusion, diffraction or other effects exhibited thereby. However, various embodiments may be provided in substantially fully transparent form where functionally desirable. In certain of the constructions, light-diffusing materials may be employed to counteract transparency. The structures shown in Figs. 19 and 20, and a modification of Fig. 20 described relative to Fig. 35, might advantageously include a light diffusing layer bonded to or formed upon one of the major surfaces thereof. For example, a suitable diffusing substance could be printed thereon by apparatus similar to that shown in Fig. 45 as a step in a continuous process of forming said structure. In use, the structure would be positioned with the diffusing layer nearest a light source. In general, it may be said that the relatively small size of components described herein, as well as the forms thereof, prevent the perception of any small blemishes which may exist in said components. Accordingly, such blemishes may be present to a limited degree without adversely affecting the overall appearance of a construction embodying said components.

In addition to employing a plurality of superposed twists of partial polarizers, as described hereinbefore relative to Fig. 6, to obtain a cumulative polarization of light, a generally similar result through a coating method is contemplated. In such a method, a transparent body or filament having partially polarizing properties, or adapted to be treated therefor, would be subjected to successive coatings, again having partially polarizing properties or adapted to be treated therefor. The cumulative effect of a plurality of said coatings would be to provide a substantially complete polarizer. As required, subcoats could be formed between each of the polarizing layers. The partially polarizing layers would functionally be required to have a substantially uniform direction of polarization. A preferred method for forming a "cumulative polarizer" of the aforesaid type comprises: employment of a core and layers formed therearound which are receptive to a polarizing treatment and which may be oriented uniformly by ultimately stretching the body or filament; treatment of the core as by a suitable polarizing dye stain, acid, heat or other treatment; similarly treating each layer when sufficiently hardened; applying subcoats between the core and the first layer and between subsequent layers as required; stretching the body or filament, either in twisted or folded form as shown in Figs. 9 and 35 to provide an oblique direction of polarization therein, or in untwisted form to provide a longitudinal direction of polarization therein. An alternative method would comprise providing a core which would serve as a transparent carrier and which could either be partially polarizing or not, as desired, and applying successive light-polarizing layers thereupon by any known method of forming such layers, subcoats being applied to the core and between the layers, as required. Apparatus for producing a cumulative polarizer by the above-described preferred method could appropriately consist of a plurality of coating, hardening and polarizing treatment units through which the body or filament would be drawn in succession. Such units are generally represented herein by element **296** of Fig. 37, element **400** of Fig. 40, and element **362** of Fig. 39 respectively, appropriate supply and take-up means for use therewith being shown in either of Figs. 35 or 38. Construction of such a "cumulative polarizer" would permit the use of a material such as regenerated cellulose, which, as a singly treated layer, may be said to provide only an "indifferent" polarizer. Polarizing elements of a type wherein certain components of incident light are polarized and other components are transmitted in diffused, scattered or other form may possibly be employed to advantage where coaction thereof with other elements of a construction may provide special effects, or where a greater overall transmittal of the incident light may be obtained. With reference to providing uniformity of polarizing components, it is to be noted, relative to Fig. 12, that a polarizing filament component having exactly similar polarizing properties, substantially in all directions radially of its longitudinal axis, is shown.

Products of the invention may be subjected to various known processes and derive special advantages therefrom. For example, bodies or filaments of the invention may be differentially stretched, as by intermittently actuated stretching means, or may be differentially compressed, as by intermittently actuated compressing means, to provide variations of their thickness throughout their length. Said variations of thickness may be employed to produce various retardation properties in a given filament. Where improved transmission properties of bodies or filaments are desired they may be treated for reducing surface reflection by any known method. Depending upon the materials and constructions employed, fabrics of the invention may be pressed, beetled or calendered to provide embossed, moire or other surface effects which may also be contributive to producing phase differences between color components by altering thicknesses of anisotropic elements. Where outer fabric areas are of light-polarizing material, portions thereof may be selectively treated for increasing or diminishing their polarizing properties as, for example, by applying, respectively, additional polarizing treatments or bleaching treatments thereto, as by a printing method, to form designs capable of differently transmitting interference colors, or of transmitting light of other characteristics. Suitable apparatus therefor is described relative to Fig. 45.

Short transparent fibers may be fused or flocked upon the surfaces of products of the invention, or external twists of transparent continuous or short staple fibers may be applied to filaments for adding various characteristics. Such materials and methods should be applied with discretion, however, so that the transmittal of interference colors is not appreciably diminished.

The wide range of novel color effects, luster effects, pattern effects and variable qualities thereof, obtainable through products of the invention, may be said to present a vast new fund of resources for use in the textile art. Possible variations of filament and fabric structure are so numerous as to render their complete listing beyond the realm of the present description. However, each color or other effect to which a filament is capable of contributing may be predetermined by charting the characteristics of the filament in terms of the variables hereinbefore described.

Where birefringent or optically active substances or materials are mentioned herein, it is to be understood that in addition to those above-described, various other forms of such substances and materials might be employed. For example, materials comprising relatively small birefringent or optically active particles might be utilized as components of the invention. Said particles could be bonded to carrying materials or embedded therein and could either be oriented, as by one of the methods described herein, or dispersed at random.

Where filaments of the invention have substantially identical optical properties, irrespective of fineness, the denier system or another known system may be applied thereto. Where their optical properties are varied functionally with variations



of fineness, it will be apparent that such a system would be inadequate. Any system which designates the optical properties of the filament in terms of the variables described herein as well as the physical properties, such as the number of unit weights per standard length, could be employed.

The present invention is not limited to any particular type of light-polarizing material or treatment relative to forming polarizing components thereof. Accordingly, a resume of several materials which may be employed for the purpose, in known or modified form follows. It is to be understood, however, that while various methods and constructions relating to orientation and form of polarizing components of the invention have been described herein and are believed to be within the scope of the invention and to apply to any suitable materials so treated and formed, the following materials and methods, as presented, in no sense constitute a part of the invention nor are they so to be construed. Among examples of such light-polarizing materials are: cellophane which, prior to being completely hardened, has been stretched to a maximum and treated with a suitable aqueous solution of a dichroic stain such as iodine; polyvinyl alcohol which has been immersed for approximately 5 minutes in an aqueous solution containing 5% of boric acid at 90° C., stretched, dried, and treated with a 5% aqueous solution of potassium polyiodide; polyvinyl alcohol which has been heated to a suitable temperature such as 175° C. and stretched; polyvinyl alcohol which has been treated with a suitable solution of an acid in methanol such as a solution of 1% hydrochloric acid, or hydrobromic acid, or hydriodic acid, or sulphuric acid in methanol, heated to approximately 150° C. and stretched; polyvinyl alcohol which has been treated with a solution of 1% of one of the foregoing acids in 60% methanol and 40% water, heated to approximately 150° and stretched; polyvinyl alcohol which has been stretched, baked for 10 to 15 minutes at about 145° C., stained with a dichroic stain comprising iodine, dried, treated with boric acid, and washed in water or acetone; completely hydrolized unsoftened polyvinyl alcohol which has been swollen in an aqueous solution of 5 parts of boric acid, 0.25 part of potassium iodide and 0.13 part of iodine in approximately 95 parts of water, stretched while swollen and dried while held in a stretched condition. As stated, the foregoing list of light-polarizing materials is presented merely as a general reference to known materials which may be of advantage in forming products of the invention. Said materials, as set forth, constitute no part of the invention, nor are they to be interpreted either as a limitation with respect to light-polarizing materials which might be employed in forming products of the invention or as in any sense referring to orientation or defining the form of said products. In general, it may be said that light- polarizing materials such as those described in the present paragraph would be rendered more suitable for purposes of the present invention by applying protective coatings thereto. Coatings of the type contemplated comprise fluid forms of cellulose acetate, vinyl acetate, methyl methacrylate, cellulose acetate butyrate, various known lacquers or the like. Subcoats and bonding agents could also be formed of said materials.

The term "filament," as employed herein, is intended to comprise a monofilament, a multifilament, a yarn or substantially any form of attenuated body. Materials of the invention which are considered as falling within the term "birefringent" comprise those wherein different atomic spacings exist in different directions of a crystal lattice, as well as those wherein an anisotropic arrangement exists of isotropic structural units whose dimensions are less than the wave length of light. The term "layer" is intended to embrace a twist, a spin, a lamina, a coating or some other superposed base or surrounding material or component. The term "core" is used to refer to any central portion of a body as distinguished from surrounding portions. A light-modifying "body," "structure," "unit," "assembly," "product" or "material," as employed herein, may refer to a filament, a fabric, or some other construction of the invention unless qualified by a more specific designation. The above terminology is given in the interests of clarity and is not to be considered as defining the scope of the terminology which may be employed.

Since certain changes in the constructions and methods set forth herein could be made without departing from the scope of the invention, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A process for providing a composite transparent plastic material having an oblique structural orientation throughout a core portion, and a longitudinal structural orientation throughout a layer formed about the core, which comprises the steps of continuously supplying a length of orientable plastic material for forming the core, twisting the core at a predetermined angle, stretching the core while it is twisted, untwisting the core, applying a transparent orientable coating to the core, hardening the coating, and stretching the coated core, the core being moved continuously in a longitudinal direction.

2. A process for providing a composite transparent plastic material having a longitudinal structural orientation throughout a core portion, and an oblique structural orientation throughout a layer formed about the core, which comprises the steps of continuously supplying a length of orientable plastic material for forming the core, stretching the core longitudinally, applying a transparent orientable coating to the core, hardening the coating, twisting the coated core at a predetermined angle, stretching the coated core while it is twisted, and untwisting the coated core, the core being moved continuously in a longitudinal direction.

3. A process for providing a transparent coating having an oblique structural orientation around a transparent core of an orientable plastic material having another structural orientation comprising the steps of continuously longitudinally moving a length of a core material having a given established structural orientation, applying a transparent orientable coating to the core, hardening the coating, twisting the coated core at a predetermined angle, stretching the coated core, and untwisting the coated core.

4. A process for providing a transparent coating having an oblique structural orientation around a transparent core of an orientable plastic material having another structural orientation comprising the steps of continuously longitudinally moving a length of a core material having a given established structural orientation, applying a transparent orientable coating to the core, hardening the coating, twisting the coated core at a predetermined angle, stretching the coated core, and untwisting the coated core, one of the core and coating materials being at least potentially light-polarizing and the other of said materials being birefringent.

5. A composite substantially cylindrical filament comprising an oriented transparent birefringent elongated inner core portion having a given direction of its optic axis, and an oriented light-polarizing layer surrounding said core portion and having a polarizing axis extending in at least another given direction from that of said axis of the birefringent core portion, said surrounding layer having twisted filament components and being so structurally formed around said inner core portion as both to enclose said inner core portion and to provide said relative difference of axes directions between said inner core portion and said surrounding layer portion.

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