

Aug. 2, 1955

K. E. PRINDLE ET AL

2,714,569

LAMINATED THREAD

Filed Jan. 18, 1952

2 Sheets-Sheet 1

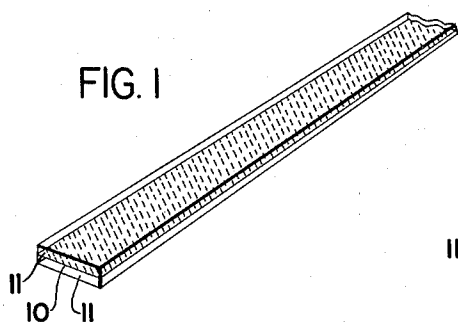
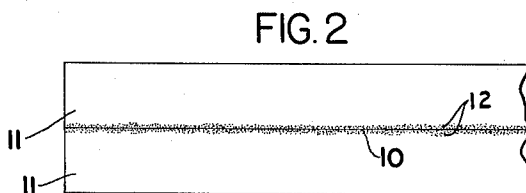
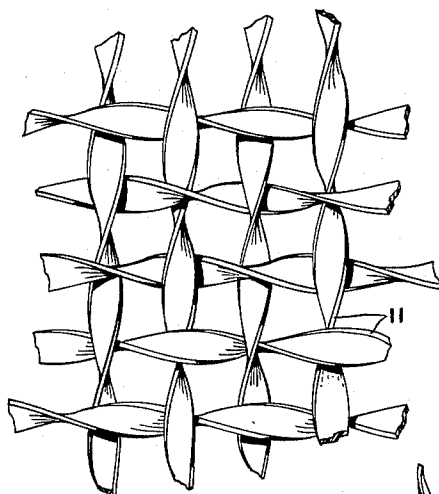
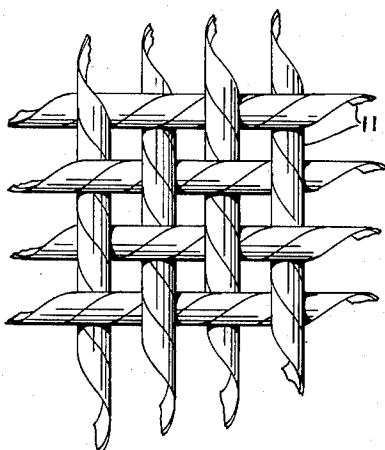


FIG. 4

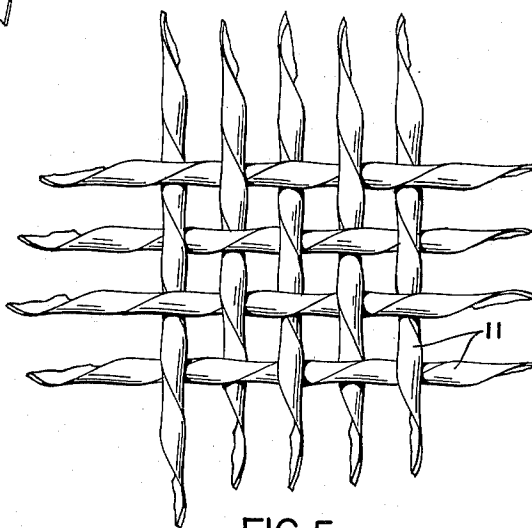


FIG. 5

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2 Sheets-Sheet 2

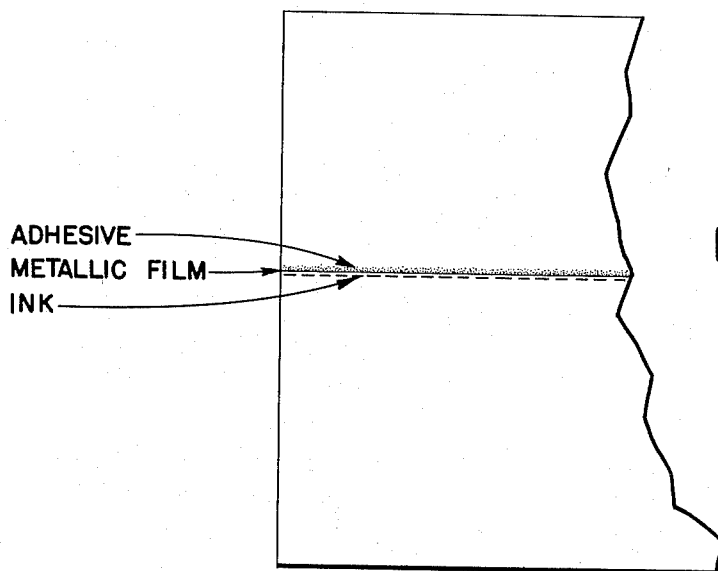


FIG. 6

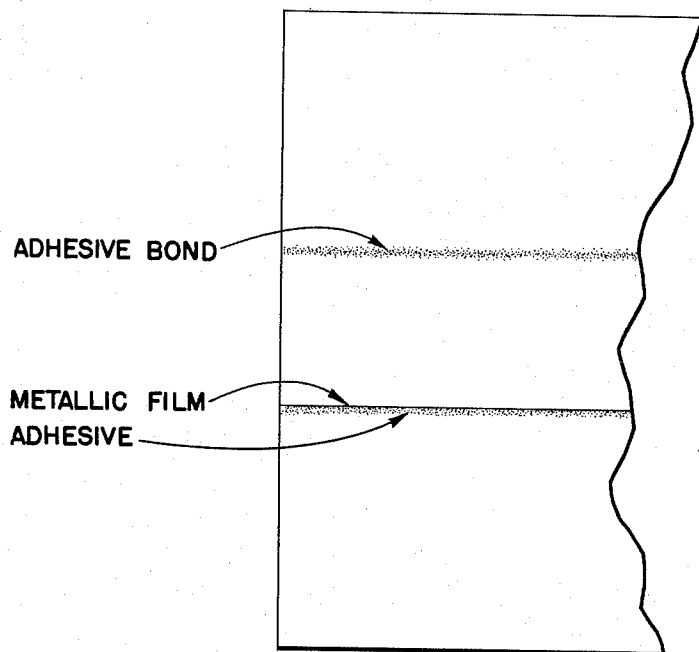


FIG. 7

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LAMINATED THREAD

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15 Claims. (Cl. 154—53.6)

The present invention relates to textiles and more particularly to a highly decorative, permanently bright, shock resistant thread of specular metallic appearance adapted to a wide variety of weaving, embroidering, plaiting, braiding, knitting, gimping, or similar operations.

In the past, threads of metallic appearance have been provided comprising a metal foil strip laminated on both sides with transparent strips of cellulosic material. Threads of this type have been widely used in the manufacture of various textiles, trims and patterned goods but have not been fully satisfactory for several reasons. In the first place, in the process of producing the foil, the necessary rolling and working of the metal effects a crystalline disorientation and distortion and a dulling of the foil surface detracting from the brightness and specularity of the final laminated product. Furthermore, the thin edges of foil strips embodied in the laminated product comprise cut surfaces which cannot be feasibly finished or smoothed and which, therefore, are characteristically dull. The thinnest foils which may be finished on both sides so as to be usable in the laminated thread have a thickness in the order of .0004 inch. In an $\frac{1}{60}$ inch (.0125 inch) thread this edge thickness comprises several percent of the visible foil surface, so that its dullness significantly detracts from the brightness of the thread as a whole. This lack of brightness is particularly emphasized when the thread is twisted or otherwise incorporated in a weave or braid in a manner to present the thread surface to an observer at oblique angles, rather than to expose a flat top or bottom surface normal to the line of sight. Rather than presenting a mirror-like appearance, the thread when viewed obliquely reflects a flat lustreless or hazy color or combination of colors roughly equivalent in hue to the brighter metallic colors exhibited by the top and bottom of the thread. In some woven patterns this side effect is not a serious drawback because the thread, employed either as a warp or filler, is woven perfectly flat to give a sequin-like appearance. However, in the majority of textile applications, the side effect detracts from the decorative effectiveness of the thread. For example, threads containing aluminum foil (intended to exhibit a bright silver color) have the appearance of a dull white thread when incorporated in twisted thread embroidery on a background of colored fabric.

A second disadvantage of laminated foil thread has been its relatively low shock strength. Resistance to wear is impaired by this characteristic of previous thread but more serious is the frequency of failure of the thread in fabrication operations. Related to the low shock strength of the laminated foil thread is its inability to withstand elongation without failure. Even a degree of elongation of this thread insufficient to cause failure will result in rupturing or drawing of the foil within the transparent lamination, largely destroying the specular effect of the thread. These characteristics of the thread limit the speed and intricacy of fabricating operations

and complicate the problem of adapting textile machinery to handle metallic weaves or patterns.

Another disadvantage of metal foil threads, particularly in respect to fabrication of textiles, has been their relative stiffness or, negatively stated, their lack of flexibility.

As mentioned above, what has been termed a side effect characterized by the subjective dulling and negation of any metallic appearance to the eyes of an observer looking sidewise at the thread occurs in the laminated metal foil threads. The nature of this side effect is not fully understood although it has been hazarded that it is the manifestation of diffusion phenomena related in some way to the distorted and fragmentary crystalline structure of the foil surface which has been subjected to calendering, beating or other severe mechanical working, coupled with the dulling effect of the non-specular cut edges of the thread.

The mechanical, chemical and optical characteristics of metallic thin films as opposed to massive metal (into which latter category fall those foils produced by calendering or beating) has been and is currently the object of research and experimentation. Considerable differences in the properties of thin film metals and massive metals have been observed. For example, thin films have a degree of transparency and behave optically in a different way than do massive metals. With increasing film thickness the reflectivity increases and the refractive index decreases, until, on reaching a certain thickness which is critical for each metal, the constants approximate to the values which apply to the massive metal. The thinnest attainable calendered or beaten foils have a mean thickness in the order of 10^{-3} mm. or 10,000 Angstrom units. Although the thickness of metallic films which justify the designation of "thin films" distinguishable from massive metal by anomalous physical properties has been believed to be in the order of 100 Angstrom units or less, nevertheless empirical data and formulated theory in this field have remained incomplete and questionable, particularly with regard to the mechanical properties of the thin metals. Complete expositions of the mechanical properties of metal films too thin to be obtained by rolling, calendering or beating but thick enough to have a reflectivity comparable with that of the massive metal are unavailable. Even whether thin films are initially amorphous or crystalline in structure is not clear, nor is the inevitability of crystal growth in these thin films established. In this connection, the control of crystal growth and the orientation or non-orientation of the crystal formation and its effect on mechanical properties has not been explored sufficiently to yield quantitative data of any practical utility.

We have discovered that a narrow strip of metal vapor coated or cathode sputtered transparent lamina of suitable plasticity is, under practical conditions, capable of being elongated by more than 25 percent of its initial length before failure. Its elongation at failure is about double that of previous laminated foil threads and under ideal controlled conditions it will elongate by more than 40 percent of its initial length before failure. Initially, and even when elongated to its maximum amount, such a thread does not exhibit the side effect encountered in laminar metallic threads. Most striking, however, is our discovery that to the eye of the observer the smooth mirror-like surface of the metal film remains undisturbed by any ridges or apparent dulling or diffusion throughout the entire process of elongation, and no ruptures occur in the metal film until the thread itself fails.

We have further discovered that it is possible to maintain thread brightness and produce even narrower widths of metallic thread than those which may be cut by deliberately elongating the thread and also, preferably re-

3

setting the thread by heat treatment after elongation has occurred. The thread is preferably elongated in this operation to less than its full limit of elongation. Contrary to expectation, but as set forth above, the metallic film retains its brightness and continuity in the elongated state and, moreover, has the capacity for still further ruptureless elongation.

The purpose of the present invention is to provide a thread of bright metallic appearance which overcomes all of the disadvantages of laminated foil threads. We have provided a thread which is bright and specular when viewed from oblique angles as well as directly from the top or bottom. The thread is flexible and will elongate to more than 25 percent of its initial length before failing. At no time before failure is there rupturing or ridging or appreciable diminution of brightness of the metallic film. Furthermore, the present thread can be more readily cut in widths of $\frac{1}{80}$ of an inch or less without tearing or failure of the thread. Finer patterns and lighter fabrics may be decorated with the thread of the present invention than has been possible in the past with laminated foil threads.

Another object of the present invention is to provide, by plastic or semi-plastic elongation, a metallic thread in even narrower widths than those to which the thread can be cut, as more fully set out below.

Further objects and advantages of the invention will become apparent from an examination of the following description and accompanying drawings in which:

Figure 1 illustrates an enlarged perspective view of the subject of the invention.

Figure 2 is a view in transverse cross section, necessarily partially schematic, of a thread made according to the invention.

Figure 3 is an enlarged plan view of a woven piece of material fabricated from twisted lengths of the thread illustrated in Figure 1.

Figures 4 and 5 are views similar to Figure 3 showing threads having other degrees of twist.

Figures 6 and 7 are greatly enlarged schematic cross-sections of alternate forms of the invention.

An enlarged view of a segment of thread made according to our invention is illustrated in Figure 1. A narrow film of metal 10 is sandwiched between two plies or strips of co-extensive normally transparent material 11. The material preferably employed is cellulose acetate butyrate although strips of other cellulosic materials preferably containing suitable plasticizers may be used (e. g., cellulose acetate, cellulose acetate propionate). Other non-cellulosic lamina may also be employed, as for example, longitudinally and transversely oriented films of polymerized ethylene glycol terephthalate.

To produce the illustrated thread, a sheet of metal-coated material 11 is first obtained by known thermal evaporation or cathodic sputtering methods. In the preferable thermal evaporation method, a sheet of the material 11 is placed in or passed through a high-vacuum chamber in apposition to a grid, coil, powder, sheeting or other form of the metal to be employed in the coating. The metal is then heated by suitable heating grids, trays, coils or other heating apparatus to volatilize the metal whereby the metal will condense on the material 11. Preferably, the atoms of the volatilized metal should pass directly from the source to the surface of the metal to be coated without encountering molecules of the residual atmosphere in the evacuated chamber and, consequently, evacuation of the chamber should be high enough so that the mean free path of the metal-vapor atoms exceeds the distance from the source to the surface of the material 11. Temperatures of the metal source which greatly exceed the volatilization temperature should be avoided since they may result in too high a vapor density of the gaseous metal giving rise to a pulverulent deposit, although it has been found that specular adherent coatings

4

may be obtained even for high metal-vapor densities by ionizing the gaseous metal by means of auxiliary high potential electrodes, all as is known in the metal coating art.

After receiving its metal coating, the sheet of material 11 is then laminated to a second sheet of the same material in the usual manner under heat and pressure with the second sheet in contiguous relation with the metal film to produce a relatively wide web of metallic appearance. The web is then cut or slit into narrow threads of the desired width. It should be noted, however, that due to the mechanical characteristics of the transparent sheet material, thread widths of $\frac{1}{80}$ of an inch or less are difficult to obtain in any continuous operation.

To provide a firmer bonding between the metal film 10 and the material 11 and to secure a stronger lamination, the metal receiving side of the piece of material 11 which receives the metal film and/or the contiguous side of the remaining piece of material 11 may be coated with a suitable thermoplastic flexible adhesive 12 prior to any other operations. Natural or synthetic resins of a sufficient degree of tackiness or with a plasticizer added may be employed for this purpose. Cellulose derivatives such as nitrocellulose, cellulose acetate or cellulose ethers may be used together with a resin with or without additional modifying ingredients. To enable ready application of the adhesive to the material, a volatile solvent may be included to reduce the viscosity of the adhesive. The solvent is then removed after application of the adhesive and before the coating and laminating operations.

It is to be noted that in commercial production it is impractical to pre-coat with adhesive the metal-receiving surface of a sheet of the material 11 on which metal is to be deposited. The sheet material 11 can only be economically handled in rolls, but cannot be rolled up after receiving an adhesive coating. On the other hand, to attempt to make the operations of adhesive coating and metal depositing continuous and successive is prohibitively expensive. In practice, thread comprising a metal film deposited on one layer of material 11 and bonded to the other with an adhesive has been found to give more than sufficiently firm bonding of the thread layers.

Figures 3 to 5 represent fragments of pieces of simple weave fabricated from variously twisted lengths of thread, the illustrated twists being of varying degrees of tightness. As may be seen in these illustrations, the majority of the thread surface in applications of twisted thread is viewed at oblique angles; indeed, about half of the observed thread surface area is viewed by the observer at angles varying by more than 45 degrees from the perpendiculars to the viewed surface portions. In these embodiments, then, and in any embodiments where twisted metallic thread is woven into or combined with conventional threads or yarns, our thread is particularly advantageous because of the absence of the side effect mentioned above. Regardless of the oblique observation of the thread, its appearance remains sharply metallic in all the various patterns and fabrics in which it may be employed.

The metal preferably used in the present thread is aluminum, the aluminum film giving the thread the appearance of silver. Gold metal may also be successfully deposited on the transparent material in a thin film, the extreme thinness of the film so minimizing the amount of gold used that the cost of the thread is not prohibitive.

Threads employing aluminum metal may be colored to give metallic color effects other than silver. In fact, suitably colored thread containing aluminum (examples of which are given below) has the appearance of gold and is preferable to thread which actually contains gold metal. Still other metallic color effects may be obtained by including dyestuffs or pigments in the adhesive. For instance, Tartrazine yellow or Tungstateo Victoria green will give a yellow or a green color respectively. However, as has been pointed out above, it is impractical to manu-

facture a thread in which both sides of the metallic film are bounded by the adhesive. Modifications in the thread structure are therefore required when using dyes or pigments to provide a thread colored on both sides.

We have illustrated in Figures 6 and 7 two thread structures which are varied somewhat from the structure illustrated in Figures 1 and 2 in order to adapt the thread to the rendition of color effects other than silver. The thread illustrated in Figure 6 is similar to the thread illustrated in Figure 1 in that it comprises two layers of transparent material 11. However, before receiving a metallic film deposit, the top surface of the transparent sheet material from which a first layer 11 is cut is initially printed with a colored transparent ink. The metallic film is then deposited on the ink. The second layer 11 is then laminated to the first layer and bonded thereto by a suitable colored transparent adhesive whose color is chosen to match the transparent color of the ink. The laminated layers are then cut or slit into narrow strips exhibiting the same metallic color on both sides. A practical thickness for each layer of sheet material 11 in the embodiment illustrated in Figure 6 is .0016 inch, giving an approximate thread thickness of .0032 inch.

Several problems are encountered in the commercial production of the thread illustrated in Figure 6. The colored ink may be affected by the heat incident to the metal depositing and laminating operations. The ink also interferes with firm adhesion between the deposited metallic film and the layer 11 upon which the film is deposited. Moreover, it is difficult to maintain an exact match of color between large mixes of ink on the one hand and adhesive on the other.

The thread illustrated in Figure 7 eliminates the above problems by using colored adhesive as the sole means for coloring both sides of the thread. In this thread, three layers of transparent material 11 are utilized. The metal film is deposited on a first side of the center layer. An outer layer is then coated with a colored adhesive and laminated to the metal coated first side of the center layer. Also, the outer layer is coated with the same colored adhesive and is laminated to the second side of the center layer. Subjectively, both sides of the finished thread appear to be colored identically. A thickness of .0011 inch has been found suitable for each of the three layers of transparent material 11 in the embodiment schematically illustrated in Figure 7, giving an approximate thread thickness of .0033 inch. However, the thickness of each layer of transparent material 11 is not critical, and it may be advantageous (as actually illustrated) to make the center layer thinner than the two outside layers, or to otherwise vary the thicknesses of the individual layers. A total thickness of about .0032 or .0033 inch has been found preferable because this thickness is economical and also results in a thread of sufficient body and strength.

Specific colored adhesive and ink weight formulae are set forth below on the basis of 100 pound lots. The pigments recited give a very satisfactory gold color, though it will be understood that other pigments may obviously be substituted to give alternate colors. An exhaustive listing of possible formulations would be impractical, but the following examples will obviously suggest variations to those skilled in the art:

Example 1.—Gold colored transparent adhesive

	Pounds
Tartrazine yellow.....	1.5
Thioindigo maroon.....	.3
Coconut oil alkyl resin.....	16.0
R. S.—½ sec. nitrocellulose.....	9.6
Textile spirits.....	30.0
Isopropyl acetate.....	33.6
Tricresyl phosphate.....	9.0

100.0

Example 2.—Gold colored transparent adhesive

	Pounds
Tartrazine yellow.....	1.5
Thioindigo maroon.....	.3
Polyvinyl acetate resin.....	20.0
Tricresyl phosphate.....	10.0
Toluol.....	40.0
Isopropyl acetate.....	28.2

100.0

Example 3.—Transparent gold ink

	Pounds
Tartrazine yellow.....	4.0
Thioindigo maroon.....	.8
R. S.—½ sec. nitrocellulose.....	2.0
18–25 centipoise nitrocellulose.....	15.0
Maleic modified ester gum.....	8.0
Tricresyl phosphate.....	13.0
Toluol.....	28.0
Ethyl acetate.....	29.2

100.0

Elimination of the pigments in Examples 1 and 2 above will leave formulations for clear adhesives which are fully satisfactory for use in manufacturing a silver colored thread containing a film of aluminum or a gold colored thread containing a metallic gold film.

As stated above, metallic foil thread widths of $\frac{1}{80}$ of an inch or less have been difficult to produce. The high margin of permissible elongation in the present thread makes possible the production of threads reduced in width from the smallest dimensions heretofore attainable. The thread may be elongated by simply winding it from one spool to another under a closely controlled tensile load. This operation may also be performed as a part of the thread cutting or severing operation by suitably increasing the tensile load on the thread between the cutting station and the thread receiving spools on which the severed thread is wound. Torque responsive speed controls or controlled tension drives, well known in the laminating art, may be used to control the thread tension in these operations. If desired, after elongation, the thread may be subjected to heat to reset the thermoplastic material 11 and adhesive 12. In some applications it may be advantageous to elongate the lamination before it is severed into threads although this procedure will not reduce the ultimate thread width. Here again a reeling operation with a controlled tension drive may be utilized. Also, if desired, the elongated lamination may be subjected to heat and may be passed between cooperating pressure rolls.

The specific embodiments of our invention set forth above will suggest variations to those familiar with the manufacture of laminated threads. Accordingly, the scope of the invention is not to be limited to the disclosed embodiment but is to be defined solely by the following claims.

What is claimed is:

1. A continuous-filament thread of specular appearance comprising a first narrow ribbon of cellulose acetate butyrate, a deposit of metal coating one surface of said ribbon, a second ribbon of cellulose acetate butyrate in contiguous relation with said deposit of metal, a flexible and transparent adhesive binding said second ribbon to said deposit of metal and said first ribbon, the thickness of said deposit of metal being less than .001 millimeter.

2. A subjectively bright continuous-filament thread comprising a first narrow ribbon of cellulose acetate butyrate, a deposit of aluminum coating one surface of said ribbon, a second ribbon of cellulose acetate butyrate in contiguous relation with said deposit of aluminum,

a flexible and transparent adhesive binding said second ribbon to said deposit of aluminum and said first ribbon, the thickness of said deposit of aluminum being less than .001 millimeter.

3. A continuous-filament thread of specular appearance comprising a first narrow ribbon of cellulose acetate butyrate, a deposit of metal coating one surface of said ribbon, a second ribbon of cellulose acetate butyrate in contiguous relation with said deposit of metal on said one surface of said first ribbon, a third ribbon of cellulose acetate butyrate in contiguous relation with the surface of said first ribbon opposite to said one surface, flexible and transparent adhesive laminae binding said second ribbon to said deposit of metal and said first ribbon and binding said third ribbon to said first ribbon, the thickness of said deposit of metal being less than .001 millimeter.

4. A continuous-filament thread of specular appearance comprising a first narrow ribbon of cellulose acetate butyrate, a deposit of aluminum coating one surface of said ribbon, a second ribbon of cellulose acetate butyrate in contiguous relation with said deposit of aluminum on said one surface of said first ribbon, a third ribbon of cellulose acetate butyrate in contiguous relation with the surface of said first ribbon opposite to said one surface, flexible and transparent adhesive laminae binding said second ribbon to said deposit of aluminum and said first ribbon and binding said third ribbon to said first ribbon, the thickness of said deposit of aluminum being less than .001 millimeter.

5. A continuous-filament thread of specular appearance comprising a first narrow ribbon of polymerized ethylene glycol terephthalate, a deposit of metal coating one surface of said ribbon, a second ribbon of polymerized ethylene glycol terephthalate in contiguous relation with said deposit of metal, a flexible and transparent adhesive binding said second ribbon to said deposit of metal and said first ribbon, the thickness of said deposit of metal being less than .001 millimeter.

6. A continuous-filament thread comprising a first narrow ribbon of polymerized ethylene glycol terephthalate, a deposit of aluminum coating one surface of said ribbon, a second ribbon of polymerized ethylene glycol terephthalate in contiguous relation with said deposit of aluminum, a flexible and transparent adhesive binding said second ribbon to said deposit of aluminum and said first ribbon, the thickness of said deposit of aluminum being less than .001 millimeter.

7. A continuous-filament thread of specular appearance comprising a first narrow ribbon of polymerized ethylene glycol terephthalate, a deposit of metal coating one surface of said ribbon, a second ribbon of polymerized ethylene glycol terephthalate in contiguous relation with said deposit of metal on said one surface of said first ribbon, a third ribbon of polymerized ethylene glycol terephthalate in contiguous relation with the surface of said first ribbon opposite to said one surface, flexible and transparent adhesive laminae binding said second ribbon to said deposit of metal and said first ribbon and binding said third ribbon to said first ribbon, the thickness of said deposit of metal being less than .001 millimeter.

8. A continuous-filament thread of specular appearance comprising a first narrow ribbon of polymerized ethylene glycol terephthalate, a deposit of aluminum coating one surface of said ribbon, a second ribbon of polymerized ethylene glycol terephthalate in contiguous relation with said deposit of aluminum on said one surface of said first ribbon, a third ribbon of polymerized ethylene glycol terephthalate in contiguous relation with the surface of said first ribbon opposite to said one surface, flexible and transparent adhesive laminae binding said second ribbon to said deposit of aluminum and said first ribbon and binding said third ribbon to said first ribbon,

the thickness of said deposit of aluminum being less than .001 millimeter.

9. A continuous-filament thread of specular appearance comprising a first narrow ribbon of cellulose acetate, a deposit of metal coating one surface of said ribbon, a second ribbon of cellulose acetate in contiguous relation with said deposit of metal, a flexible and transparent adhesive binding said second ribbon to said deposit of metal and said first ribbon, the thickness of said deposit of metal being less than .001 millimeter.

10. A continuous-filament thread of specular appearance comprising a first narrow ribbon of cellulose acetate, a deposit of aluminum coating one surface of said ribbon, a second ribbon of cellulose acetate in contiguous relation with said deposit of aluminum, a flexible and transparent adhesive binding said second ribbon to said deposit of aluminum and said first ribbon, the thickness of said deposit of aluminum being less than .001 millimeter.

11. A continuous-filament thread of specular appearance comprising a first narrow ribbon of cellulose acetate, a deposit of metal coating one surface of said ribbon, a second ribbon of cellulose acetate in contiguous relation with said deposit of metal on said one surface of said first ribbon, a third ribbon of cellulose acetate in contiguous relation with the surface of said first ribbon opposite to said one surface, flexible and transparent adhesive laminae binding said second ribbon to said deposit of metal and said first ribbon and binding said third ribbon to said first ribbon, the thickness of said deposit of metal being less than .001 millimeter.

12. A continuous-filament thread of specular appearance comprising a first narrow ribbon of cellulose acetate, a deposit of aluminum coating one surface of said ribbon, a second ribbon of cellulose acetate in contiguous relation with said deposit of aluminum on said one surface of said first ribbon, a third ribbon of cellulose acetate in contiguous relation with the surface of said first ribbon opposite to said one surface, flexible and transparent adhesive laminae binding said second ribbon to said deposit of aluminum and said first ribbon and binding said third ribbon to said first ribbon, the thickness of said deposit of aluminum being less than .001 millimeter.

13. A continuous-filament thread of specular appearance comprising a first narrow ribbon of film selected from the group consisting of cellulose acetate, cellulose acetate butyrate and polymerized ethylene glycol terephthalate, a deposit of metal coating one surface of said ribbon, a second ribbon of said film in contiguous relation with said deposit of metal, a flexible and transparent adhesive binding said second ribbon to said deposit of metal and said first ribbon, the thickness of said deposit of metal being less than .001 millimeter.

14. A method of fabricating a thread comprising passing a first sheet of normally transparent thermoplastic material through an evacuated atmosphere, heating a metal within said evacuated atmosphere whereby said metal volatilizes and depositing said metal on said first sheet in said evacuated atmosphere to a thickness less than .001 millimeter, laminating a second sheet of said material on said first sheet in contiguous relation with said deposited metal to form a lamination, severing said lamination along narrowly spaced parallel lines to form a plurality of thread strips, and elongating each longitudinal increment of said strips by a percentage of the initial increment length which is less than the elongation limit of said thread.

15. A method of fabricating a thread comprising depositing a thin film of metal on a first sheet of normally transparent thermoplastic material to a thickness of less than .001 millimeter, laminating a second sheet of said material on said first sheet in contiguous relation with said deposited metal to form a lamination, severing said lamination along narrowly spaced parallel lines to form a plurality of thread strips, and elongating each longitudinal increment of said strips by a percentage of the initial

increment length which is less than the elongation limit of said thread.

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