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PROCESS FOR PRODUCING FOAM FABRICS

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FIG. 1

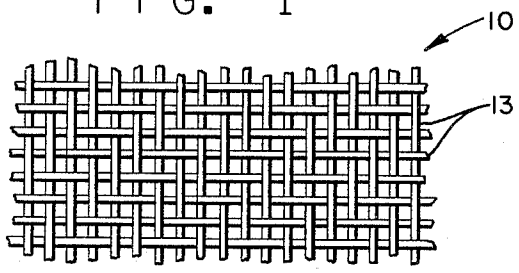
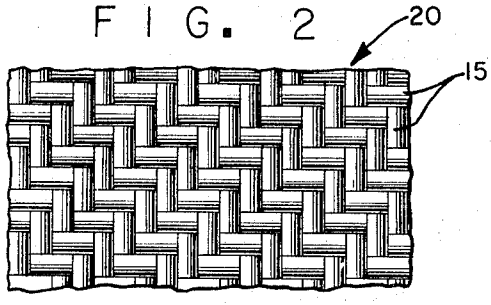


FIG. 2



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PROCESS FOR PRODUCING FOAM FABRICS

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ABSTRACT OF THE DISCLOSURE

Foam fabrics are produced by a process which includes the steps of flash-extruding a solution of an organic polymer to form closed-cell, gas-inflated foam filaments, collapsing the filaments by reducing the quantity of gas within the cells, forming the filaments while collapsed into a fabric, then re-inflating the filaments by introducing gas into the cells.

This invention relates to fabrics comprised of foamed polymeric filaments. More particularly, it relates to an improved method for forming these fabrics, by weaving, knitting, or needling, using closed-cell foam-filaments with collapsed cells.

Foamed materials, especially foils or sheets of resilient polyurethane foam, have become very popular in fabric applications. They provide bulk without extra weight, and their thermal insulation properties are excellent for cold weather apparel. In some applications, such as carpet backing, foams also provide outstanding cushioning properties. These polyurethane foam foils have, however, severe disadvantages. They are weak and easily torn, and they are visually unattractive especially because they tend to yellow severely on exposure to the atmosphere. Consequently, it has been necessary to laminate them on one or both faces to customary fabrics. Besides being expensive, lamination leads to problems from delamination, as is well understood.

An obvious means for imparting the advantages of foam to fabrics while avoiding lamination/delamination problems is to manufacture the fabric from foam-filaments. Many known resilient foams in filament form are, however, too weak to withstand the stresses of weaving, knitting, or needling. Moreover, at the desirably low foam densities of about 0.05 gm./cc. or less, the length of filament that can be wrapped on a yarn package is so limited that fabric formation can proceed only for a very short interval before filament ends are encountered.

In U.S. Patent No. 3,100,926 is described a method for providing fabrics of foamed filaments whereby weaving is done with solid thermoplastic filaments containing a thermally decomposable blowing agent. Heating of the woven fabric to a sufficiently high temperature causes the filaments to foam and also to fuse at all the filament cross-over points. While this method avoids some of the above problems, it cannot provide fabrics with customary fabric drape because of the unavoidable fusion at cross-over points.

The disadvantages of heretofore known processes for constructing fabrics comprising foams are overcome by the process of this invention which comprises the steps of (1) forming a fabric using collapsed microcellular filaments and (2) post-inflating the fabric to provide tightness-of-weave, cover, drape, bulk, and resilience.

A microcellular filament is generally composed of polyhedral-shaped, closed, uniform-sized foam cells of which the maximum transverse cell dimensions should be less than about 1000 microns. Each cell is a void or gas-filled space completely enclosed by cell walls which are film-like elements of thermoplastic synthetic-organic polymer less than about 2 microns thick and substantially uniform in thickness over the whole area of each cell wall. Substantially all of the polymer is in these cell walls rather than being concentrated at the cell wall intersections. A minor proportion of cell walls may be ruptured to produce tunnel-like cells generally oriented parallel to the filament axis, but extrusion conditions are preferably chosen to minimize the formation of tunnel-like cells.

Microcellular filaments can be formed directly by extrusion of foamable solutions through extrusion orifices. A point of maximum cell expansion is reached shortly after exit from the orifice, at which point each cell wall solidifies so that its area is fixed. Methods are known by which gases can be introduced to or withdrawn from the foam cells without harming their integrity or low gas permeability. Introduction of gases expands the cells, but only to the maximum sizes reached immediately following extrusion, after which more gas introduction increases pressure within the cells to superatmospheric values with substantially no increase in cell volume. On continuous withdrawal of gases, however, a pressure less than atmospheric is created within the cells; and then ambient external gas pressure causes each cell to decrease in volume by wrinkling and folding of its cell walls, which remain constant in area. A microcellular filament is said to be collaped if its cross-sectional area (i.e., its volume) is less than 50%, and preferably less than 25%, of that characteristic of the fully inflated state.

Microcellular filaments in the fully inflated state have densities in the range from about 0.005 gm./cc. up to about 0.05 gm./cc. On collapse of these microcellular filaments, density naturally increases; and fully collapsed filaments can have densities which are as high as 75% of the density of the unfoamed solid polymer of which they are comprised. Typical densities for collapsed microcellular filaments are in the range from 0.1 to 0.3 gm./cc. This high degree of collapsibility results not only from the flexibility of the ultrathin cell walls but also from the high ratio of maximum transverse dimension to wall thickness for each cell. This ratio for microcellular foams is ordinarily in the range from about 30 to 3,000.

FIGURE 1 is a perspective view of a portion of a woven fabric comprised of collapsed microcellular filaments.

FIGURE 2 represents the fabric of FIGURE 1 after its microcellular filaments have been post-inflated.

Weaving, knitting, or needling with collapsed microcellular filaments is accomplished with the same equipment and techniques well-known for customary dense, non-foamed filaments or yarns whether they be of synthetic or natural origin. A loosely woven fabric **10** as in FIGURE 1 is formed to have both warp and weft of collapsed microcellular filaments **13**. On introduction of gases by a post-inflation technique, described hereinafter, the collapsed microcellular filaments **13** are converted to the fully inflated filaments **15** of FIGURE 2.

Fabric construction is in no way limited to that illustrated by FIGURES 1 and 2. Thus, both warp and weft can be only of microcellular filaments, or either can be comprised of both microcellular filaments **13** and dense unfoamed filaments or yarns in any proportion. Likewise, knitting or needling techniques can be used to form fabrics comprising collapsed microcellular filaments. Fabric formation is followed by post-inflation of the collapsed filaments. A loosely woven scrim **10**, for example, is thereby converted to a tight, resilient and opaque fabric **20** which can become much more tightly woven than if fully inflated filaments were employed during weaving.

Loosely woven scrims containing collapsed microcellular filaments **13** are particularly useful in another aspect

of this invention which is the manufacture of a novel tufted structure. Tufts are easily inserted into the large openings of scrim **10** which is then post-inflated to firmly lock the tufts into the fabric. The structure then serves as a tufted carpet with both bulk and resilient cushioning provided by the inflated microcellular filaments. The carpeting so obtained is an integral structure devoid of adhesive bonding, stitching, or lamination; and the foam in the structure has high frictional properties which provide anti-skid performance.

When dense yarns and microcellular filaments are to be combined in a fabric construction, it is occasionally preferred to use sheath-core filaments in which the core is a dense yarn and the sheath is collapsed microcellular foam. Such sheath-core yarns are particularly advantageous either when the microcellular filament without a core is too weak to withstand the stresses of fabric formation, or when it is aesthetically or chemically desirable to completely cover the dense yarn.

For some fabrics, the need for tightness-of-weave, cover, and opacity requires the use of so much customary dense yarns that the tensile and tear properties of the fabrics far exceed those required for the fabric end-use. Certain synthetic textile yarns with otherwise superior properties are frequently excluded from such end-use applications because of their cost. When such fabrics are woven from both collapsed microcellular filaments **13** and dense unfoamed yarns, only enough dense yarn is used to provide the desired fabric strength properties. Post-inflation of the microcellular filaments **13** separately provides the required cover and tightness of weave while at the same time accomplishing a reduction in both area weight and cost of the finished fabric. Not only can the use of microcellular filaments result in more tightly woven fabrics than can otherwise be obtained, but also it eliminates the added expense of weaving tightly and decreases the number of ends and picks required. As is obvious to one skilled in the art, separate provision of strength and cover is extremely valuable to fabric designers.

A characteristic of collapsed microcellular filaments which renders them superior to inflated filaments for weaving or knitting is their significantly higher tensile strength. Thus they are better able to withstand weaving stresses. Their higher strength presumably results from the lack of pre-stress present in inflated foam cells and also from the fact that cell collapse brings more cell walls into parallelism with the filament axis.

The surfaces of callpsed microcellular filaments have much less frictional resistance to sliding than do the surfaces of inflated foam filaments, which greatly facilitates weaving and knitting. When fully inflated, a foam filament presents a large surface which, since it is drawn taut, is completely exposed for frictional contact. Although usually detrimental to weaving or knitting, these frictional forces are frequently desirable in finished fabrics. The collapsed microcellular filament, by virtue of its decreased diameter, has less surface; the surface is denser and smoother; and less of the surface is contactable because of the wrinkled cross-sectional margin formed during collapse.

Finally, filament length remains substantially constant during collapse and inflation. This is in direct contrast to dense filaments containing solid blowing agents. When the latter are foamed by thermal treatment after fabric formation, they enlarge in all dimensions so that foaming cannot produce as tight a fabric. Collapsed microcellular filaments have already been inflated and have collapsed under external atmospheric forces directed normal to the filament surface. Thus, the cell walls wrinkle and fold only to form a smaller diameter with substantially no change in length. On post-inflation, the cell walls unfold to provide a larger diameter, again with substantially no change in filament length.

Microcellular filaments useful in this invention have fully inflated diameters generally in the range from about 0.01 inch (0.025 cm.) up to about 0.25 inch (0.64 cm.), but inflated filaments up to 1.0 inch (2.5 cm.) or more can readily be provided. Collapsed microcellular filaments normally have effective diameters of from about 0.1 to 0.5 times the corresponding fully inflated diameter. Since they frequently flatten to a ribbon-like shape during collapse, effective diameter becomes maximum filament width.

The preferred microcellular filaments for use according to this invention are "ultramicrocellular" as disclosed in Blades et al. U.S. Patent 3,227,664, filed Jan. 31, 1962. By virtue of their crystallinity and of their high level of unique uniplanar crystallite orientation, ultramicrocellular filaments are very strong. In addition, both uniplanar orientation and uniform texture (as defined therein) render their cell walls particularly resistant to gas permeation.

Foamed filaments useful in the process of this invention are comprised of thermoplastic polymers, e.g., polyhydrocarbons such as polyethylene, polypropylene, or polystyrene; polyethers such as polyformaldehyde; vinyl polymers such as polyvinylidene fluoride or polyvinyl chloride; polyamides both aliphatic and aromatic, such as polyhexamethylene adipamide and polymetaphenylene isophthalamide; polyurethanes, both aliphatic and aromatic, such as the polymer from ethylene bischloroformate and ethylene diamine; polyesters such as polyhydroxypivalic acid and polyethylene terephthalate; copolymers such as polyethylene terephthalate-isophthalate; polynitriles such as polyacrylonitrile and polyvinylidene cyanide; polyacrylates such as polymethyl methacrylate; and equivalents. The polymers must be of at least film-forming molecular weight.

One of the features of the preferred ultramicrocellular material is its high degree of molecular orientation in the cell walls, which contributes to its unique strength. Therefore, a preferred class of polymers from which to make foam-filaments for use in this process is one including polymers which respond to orienting operations by becoming substantially tougher and stronger. This class is well-known to one skilled in the art and includes, for example, linear polyethylene, stereo-regular polypropylene, 6-nylon, and polyethylene terephthalate. A feature of any inflated microcellular material is its pneumaticity resulting directly from its unique structure, which may be regarded as multitudinous tiny bubbles of gas enclosed in thin polymer skins. Retention of this gas, and hence of the pneumaticity of the structure, depends on a low rate of gas permeation through the cell walls. A further preferred class of polymers for preparing microcellular material contains those polymers for which permeability coefficients for most gases are low, such as polyethylene terephthalate and polyvinyl chloride.

In the preparation of microcellular materials, various polymer additives such as dyes, pigments, antioxidants, delusterants, antistatic agents, reinforcing particles, adhesion promoters, ion exchange materials, ultraviolet stabilizers and the like may be incorporated provided the particle sizes are not so large as to interfere with the extrusion operation.

If, in the extrusion of microcellular filaments, the volatile blowing agent employed is one which permeates the polymeric cell walls much faster than air, the blowing agent will diffuse out from the foam before it can be replaced with air, and the filament will collapse. This is the preferred means for providing collapsed filaments according to this invention. Further preferred are those blowing agents which, cooled by their own expansion after extrusion, liquefy to cause very rapid filament collapse. Methylene chloride, for example, is very volatile, permeates cell walls faster than air, and liquefies at room temperature so that its use as a blowing agent results in suitable collapsed but reinflatable filaments without further treatment.

Fully or partially inflated microcellular filaments can

be collapsed by immersion in a bath containing a readily volatilized liquid which weakly plasticizes the cell walls and temporarily increases the rate of permeation without permanently affecting crystallinity or molecular orientation of polymer in the cell walls. In the bath, the inflating gas escapes by rapid permeation; and the filament collapses in diameter. The weakly plasticizing liquid is then removed by vaporization to form a strong, collapsed but reinflatable microcellular filament. Methylene chloride and fluorotrichloromethane are examples of frequently effective weak plasticizers for this use.

Post-inflation of microcellular filaments is readily accomplished by immersing them in a bath containing both a volatile weakly plasticizing component and a component which is normally gaseous at ambient temperature and which permeates the cell walls more slowly than air. On removal from the bath and on rapid vaporization of the weakly plasticizing component, the slowly permeating component is trapped within the cells providing an osmotic gradient for the inward permeation of air and reliable post-inflation. Equilibration with air is frequently speeded by brief warming of the filaments to temperatures usually less than or about 125° C. When the slower permeating component has essentially a zero permeation coefficient as compared to that for air, it is termed an impermeant inflatant. Presence of an impermeant inflatant within the foam cells results not only in full inflation of the filament but also in spontaneous osmotic reinflation if compressive loading has caused the outward permeation of some of the contained air.

The rate of permeation for an inflatant through a given polymer increases as its diffusivity and solubility increase. Accordingly, candidates for impermeant inflatants should have as large a molecular size as is consistent with a sufficiently great vapor pressure at ambient temperatures, which is preferably 50 mm. of mercury or greater, and they should have substantially no solvent power for the polymer. A preferred class of impermeant inflatants is exemplified by compounds whose molecules have chemical bonds different from those in the confining polymer, a low dipole moment, and a very small atomic polarizability.

Suitable impermeant inflatants are selected from the group consisting of sulfur hexafluoride and saturated aliphatic and cycloaliphatic compounds having at least one fluorine-to-carbon covalent bond and wherein the number of fluorine atoms exceeds the number of carbon atoms. Preferably the saturated aliphatic and cycloaliphatic inflatants are, respectively, perhaloalkanes and perhalocycloalkanes in which at least 50% of the halogen atoms are fluorine. Although these inflatants may contain ether-oxygen linkages, they are preferably free from nitrogen atoms, carbon-to-carbon double bonds, and reactive functional groups. Specific examples of impermeant inflatants include sulfur hexafluoride, perfluorocyclobutane. symdichlorotetrafluoroethane, perfluoro-1,3 - dimethylcyclobutane, perfluorodimethylcyclobutane mixtures, 1,1,2-trichloro-1,2,2-trifluoroethane, $CF_3CF_2CF_2OCFHCF_3$, chlorotrifluoromethane, and dichlorodifluoromethane. Mixtures of two or more impermeant inflatants can often be used to advantage.

It will be understood that impermeant inflatants must be inert; i.e., they must be chemically stable under conditions of use for fabrics containing inflated microcellular filaments.

A broad range of fabric types can be obtained according to this invention. In addition to the relatively simple net-like fabrics described, much more complex fabrics are readily woven. By proper programming of the weaving operation and/or by employing two or more warps simultaneously, it is possible to produce layered wovens in which decorative customary fabrics are formed on either or both faces of a layer of microcellular filaments. Or collapsed microcellular filaments can be used in multiple layers which, after post inflation, result in a thick, bulky, tightly woven fabric. Customary knitting machines can create a variety of knit goods containing microcellular filaments. Loops of microcellular filaments extending out from a face of a net-like fabric can be formed by needling, or net-like fabrics of microcellular filaments can be needled or tufted with other yarns. In every case, the collapsed microcellular filaments incorporated in the fabric during formation are subsequently post-inflated to yield the desired final product.

Fabrics produced in accordance with this invention are useful, for example, as upholstery materials, as substrates for vinyl-calendered upholstery materials, as cushioning and insulating clothing fabrics, as cushioning mats or carpets and for decorative wall hangings.

Because many variations of the process of this invention are obvious to one skilled in the art, the following examples are intended to illustrate but not to limit the invention, except as provided in the appended claims.

Example I

This example is a plain-weave fabric comprising only microcellular filaments. The filaments were obtained by extruding a polymer solution through a circular orifice of 0.020 inch (0.51 mm.) diameter into the ambient atmosphere. The homogeneous polymer solution was formed in a three-liter cylindrical pressure vessel containing 1,000 gms. of "Profax" stereo-regular polypropylene (Hercules Powder Co.), 750 cc. of methylene chloride, and 250 gms. of trichlorofluoromethane. Dispersed throughout these components was 5 gms. of finely divided "Santocel"–54 silica aerogel (Godfrey L. Cabot, Inc.). While the pressure vessel was rotated end over end, it was heated to 150° C. and kept at that temperature for 16 hours under autogenous pressure. At the end of that time, 320 p.s.i.g. (22.5 kg./cm.^{2} gauge) of nitrogen pressure was applied. The extruded filament collapsed within seconds after extrusion to about 0.060 in. (1.5 mm.) in diameter at 535 denier.

The plain-weave fabric construction used 14 ends and 8 picks per inch (about 5.5 ends and 3.15 picks per cm.) of these collapsed ultramicrocellular filaments. After immersing the fabric in a roughly 50:50 (vol./vol.) mixture of methylene chloride and 1,1,2-trichloro-1,2,2-trifluoroethane, it was removed and dried in warm air. While drying, the filaments post-inflated to create a fabric so tight in weave as to have been impossible to obtain by weaving a fully inflated microcellular filament.

Example II

This example illustrates the use of a filament with a dense fiber core and a collapsed microcellular sheath to form a Bedford cord type of fabric. The core was approximately 260 denier 66-nylon yarn sheathed in approximately 400 denier ultramicrocellular polypropylene. This sheath-core filament replaced the heavy cotton-warp cords in an otherwise typical Bedford cord weave. The woven fabric exhibited only a slight cording effect in the warp direction; but after post-inflation as in Example I, fabric thickness increased from about 0.030 in. (0.76 mm.) to about 0.055 in. (1.40 mm.) and the cording effect became pronounced. At the same time, a considerably lighter fabric was obtained by replacing the customarily heavy cotton cords with this light sheath-core filament.

Even lighter, but otherwise substantially identical, Bedford cords resulted when unsupported, collapsed, ultramicrocellular, polyethylene terephthalate filaments were used in place of the above sheath-core filaments.

Example III

This example illustrates the use of this invention to provide a cushioning bulky automotive upholstery fabric. Two separate batches of microcellular filament were used. Both were prepared by charging a 1-liter cylindrical pressure vessel with 440 gms. of high-molecular-weight polyethylene terephthalate, previously dried at 206° C., and 300 ml. of dry methylene chloride, pressurizing the vessel with nitrogen gas, heating the contents to 220° C., hold-

ing them at that temperature for 30 minutes, and then extruding through a circular spinneret. In one case the nitrogen pressure was 850 p.s.i.g. (59.8 kg./cm.^{2} gauge), the spinneret was 0.020 in. (0.508 mm.) in diameter and 0.040 in. (1.16 mm.) in length, and the ultramicrocellular filament formed was of 760 denier with a fully inflated diameter of 0.104 in. (2.6 mm.). In the other case the extrusion pressure was 950 p.s.i.g. (66.9 kg./cm.^{2} gauge) and the spinneret was 0.030 in. (0.76 mm.) in diameter and 0.060 in. (1.52 mm.) in length. This fully inflated filament had a diameter of 0.149 in. (3.8 mm.). Within seconds after extrusion, however, both of these products collapsed into narrow ribbon-like filaments with widths of about half the diameters specified above.

Fabric construction used a double warp, the first of which employed 3 types of yarns: 140/68/.5 Z type 180 nylon, 200/20/.75 Z nylon and 70/—/.5 Z black nylon. The second warp was completely of the above collapsed ultramicrocellular filaments. The ratio of warp ends for these four types of filaments, in the order given, was 104:32:24:8. The fill was 12/2 spun rayon yarn plus various decorative yarns including metallic luster yarns. Programming of the filling picks was such that the first warp was converted to a decorative cover fabric while simultaneously the warp of collapsed filaments was lightly "stitched" to its lower surface. The woven fabric was then dyed to a medium blue shade by a process appropriate to the dense conventional fibers used, which process had no effect on the collapsed ultramicrocellular filaments. Then the fabric was immersed in a boiling 50:50 by volume mixture of methylene chloride and 1,1,2-trichloro-1,2,2-trifluoroethane. Removed from this bath, the fabric was put through a pin tenter at approximately 200° F. (93° C.) which treatment resulted in a greater than 2× increase in diameter of the ultramicrocellular filaments. The inflated filaments provided a substantially continuous, close-packed, backing layer. Fabric thickness before inflation was about 0.065 in. (1.65 mm.) increasing to about 0.120 in. (3.05 mm.) thereafter. The foam-layer contributed body, fullness, and excellent cushioning to the fabric. The weave design created a warp-wise wide rib effect which, without the cushioning foam backing, would have readily crushed in use.

Example IV

A novel, thick, woven, cushioning pad, obtainable only by the practice of this invention, is illustrated by this example. The products of four separate extrusions were used in constructing this fabric, but all four were as nearly identical as possible. As in Example III, 440 gms. high-molecular-weight polyethylene terephthalate and 300 ml. of methylene chloride were charged to the pressure vessel. The contents were heated to 220° C., held there for 15 minutes, and extruded under approximately 900 p.s.i.g. (63.3 kg./cm.^{2} gauge) of nitrogen pressure through a spinneret of 0.03 in. (0.76 mm.) diameter and 0.060 in. (1.52 mm.) length. These four products had deniers in the range from 2,000 to 2,200, and inflated diameters in the range from 0.165 to 0.172 in. (4.2 to 4.4 mm.). All these filaments collapsed subsequent to extrusion into flattened filaments as described in Example III.

Only these collapsed ultramicrocellular filaments were woven into a fabric which was a five-layer Dobby-weave interwoven construction employing straight draw on twelve hardnesses. The weave diagram is not susceptible to ready verbal description but is obvious to one skilled in the weaving art. The off-loom, woven structure was about 0.20 in. (5.1 mm.) thick. After post-inflation substantially as described in Example III, thickness increased to about 0.625 in. (15.9 mm.). The inflated filaments in this thick mat were so tightly interlocked that an approximately 3 x 3 in. (7.6 x 7.6 cm.) piece could be cut from its center with no disturbance of the weave. A skilled weaver on seeing this inflated fabric would not hesitate to state that such a structure could not possibly have been woven.

Example V

In this example a woven structure is described in which two customary fabric facing layers are held apart by inflated ultramicrocellular trusses to create an insulating air space. The ultramicrocellular filaments were prepared substantially as described in Example III except that the solution was held only 20 minutes at 210° C., the extrusion orifice was .025 x .025 in. (0.63 x 0.63 mm.), and the extrusion pressure was 675 p.s.i.g. (47.5 kg./cm.^{2} gauge). The collapsed filaments obtained were of about 1060 denier at a density of approximately 0.1 gm./cc. The post-inflated diameter of these filaments was 0.115 in. (2.9 mm.).

Two warp beams were employed. The first warp was composed of Orlon® acrylic fiber yarns (E. I. du Pont de Nemours & Co., Inc.). The second warp was of the loosely spaced collapsed ultramicrocellular filaments described. The first warp was split by the loom so as to effectively provide two warps simultaneously woven into an upper decorative fabric and a lower, more open, net-like fabric. The upper fabric could, if desired, be napped to produce a soft fluffy surface characteristic of blankets. The second microcellular warp was arranged to move incrementally at an overall greater rate than the first warp with the foam-filaments between the forming upper and lower fabric layers. Programming of the filling yarns was such that each collapsed ultramicrocellular filament was alternately "stitched" first to one and then to the other of the inner fabric faces, thus forming U-shaped trusses of the ultramicrocellular filaments. The fabric as woven was about 0.24 in. (6.1 mm.) thick, but the collapsed filaments were of insufficient rigidity to resist extensive compressive distortion. After post-inflation as described in Example III, however, thickness increased to about 0.68 in. (17.3 mm.) with the air space stabilized so that the cushioning inflated filaments recovered the initial separation after compression. Again, practice of this invention is the only conceivable way to obtain this blanket fabric.

Example VI

The open, woven, net-like fabric of this example served as a tufting substrate for a carpet. The collapsed, ultramicrocellular, polyethylene terephthalate filaments used were substantially as described in Example V having a diameter in the fully inflated state of 0.14 in. (3.6 mm.) and a denier of from 1200 to 1500. Weaving was carried out on a warp having 4 ends per inch (about 1.58 ends per cm.) of the collapsed ultramicrocellular filaments, each end plied with a 200 denier, 20/3/4 Z, type 860 (Du Pont) nylon yarn. The fill yarns were inserted at 3.2 picks per inch (about 1.26 picks per cm.), each being a 12/2 cc. 7/30 rayon/nylon blended yarn plied in alternate picks with an ultramicrocellular filament. Because this woven fabric was so loosely woven, it was necessary to apply a sizing solution to it during weaving to prevent its disintegration on later handling. The fabric was then supported in such a way that it was spaced above a fine screen so that, when sprayed by a water jet carrying type 501 nylon continuous filament (E. I. du Pont de Nemours & Co., Inc.), the continuous nylon filament passed through the openings in the fabric and onto the screen; and since the water jet traversed the fabric, the continuous filament looped over the yarn elements of the fabric to create tufts. As tufted, this fabric was not durably stable but was handleable without disintegration. It was post-inflated substantially as described in Example III causing the ultramicrocellular filaments to expand greatly in size and to lock the tufts into place. The tufts were uniformly distributed over the fabric at an area weight of about 10 oz./yd.^{2} (340 gm./m.^{2}). The post-inflated structure was about 0.5 in. (about 1.27 cm.) thick, and the tufts extended about 0.375 in. (about 0.95 cm.) above

the fabric backing. Not only did the post-inflation lock the tufts into place but at the same time it transformed the ultramicrocellular filaments into a cushioning base structure for the tufted carpet.

Example VII

This example is a variation of the invention involving conventional needling of collapsed microcellular filaments to a conventional burlap carpet backing to form a loop-pile cushioning carpet. The microcellular filaments in this example were substantially the same as those described in Example V. The collapsed filaments were ribbon-like at a width of about 0.040 in. (1.02 mm.). A conventional needle-tufting apparatus was used; and, to prevent breakage of the filaments in the eyes of the tufting needles, the filaments were prelubricated with Clearco Knitting Oil (Clearco Products Co.).

Before post-inflation, the filaments were shaggy looking and so open that the burlap backing was clearly visible over the whole face of the fabric. After post-inflation substantially as described in Example III, the filaments were so expanded as to make their loops close-packed, completely obscuring the burlap backing from view. The inflated filaments were about 0.110 inch (2.8 mm.) in diameter and protruded about 0.325 inch (8.25 mm.) above the burlap backing which, itself, contributed about 0.045 inch (1.14 mm.) to the total thickness.

Example VIII

A woven vinyl-substrate fabric for cushioning, bulky, furniture upholstery was prepared. The collapsed ultramicrocellular polyethylene terephthalate filaments, prepared substantially as described in Examples III–VI, were of about 100 denier at a density of about 0.30 gm./cc. The loom was set up with two warp beams, one of the above ultramicrocellular filaments and the other of 220/50 type 51 Dacron® polyester yarn (E. I. du Pont de Nemours & Co., Inc.). The loom was a conventional power pick-and-pick loom, alternating the ultramicrocellular filaments and the dense yarns in an end-and-end, pick-and-pick, 2 x 2 basket weave with 40 ends and picks per inch (about 15.7 ends and picks per cm.). "Ruxite" RK–2 finish (Laurel Soap Mfg. Co.) was sprayed onto the warp during weaving and brushed onto the quills prior to weaving. The fabric formed was scoured on a jig for one hour at 110° F. (43.3° C.) and then dried to the wet width in air at 200° C.

After immersion for 50 minutes in a refluxing 50:50 by volume mixture of methylene chloride and 1,1,2-trichloro-1,2,2-trifluoroethane, the fabric was dried on a pin tenter for 5 minutes at 100° C. The microcellular filaments more than doubled in diameter to yield an expanded, tight fabric 0.033 inch (0.84 mm.) thick with about 44 x 48 ends and picks per inch (about 17.3 x 18.9 ends and picks per cm.). Table I compares pertinent properties of this fabric with commercial vinyl substrate fabrics. Grab tensile, elongation, and ravelled strip tests are according to A.S.T.M. Test Method D 1682–64, and tongue tear according to A.S.T.M. D 2262–64T. Where results are given in the A/B form, A is for the warp direction and B for the fill direction.

From Table I it is seen that the fabric of this invention is equivalent to standard vinyl substrates at considerably reduced fabric weight.

This, and other similar substrates, were readily vinyl-calender-coated on commercial equipment to provide attractive, high-bulk, cushioning, upholstery fabrics.

Example IX

Collapsed, ultramicrocellular, polyethylene terephthalate filaments as described in Example VIII were knitted coaxially with a 260 denier nylon yarn into a plain jersey tricot knit. A flat-bed Duby knitting machine was used. The ultramicrocellular filament was wet down with "Clearco" knitting oil (Clearco Products Co.), pulled from its cone under light tension, and combined with the nylon yarn just prior to knitting. Knitting proceeded smoothly, and knits of 10–15 courses per inch (3.9 to 5.9 courses per cm.) were prepared.

These knits were scoured for 30 minutes in a home washing machine containing a solution of "Tide" detergent (Procter and Gamble) in water at 180–200° F. (82.2 to 93.3° C.). They were tumble-dried in a home laundry drier. Post-inflation was by immersion in the bath of Example VIII for 10 minutes followed by drying for 15 minutes on a tenter at 100 °C. The foam-filaments more than doubled in diameter to provide an attractive, bulky, pneumatic, knit fabric.

Example X

The collapsed ultramicrocellular polyethylene terephthalate filament of Example VIII as plied with one end of 100–34–0–56 Dacron® polyester yarn (E. I. du Pont de Nemours & Co., Inc.) using Dow-Corning Emulsion #36. Knitting was done on a 7-cut Duby flat-bed knitting machine without further lubricant and with only normal tensioning devices. Scouring, drying, and post-inflation were as described in Example IX except that Procter and Gamble's "Dash" detergent was substituted for "Tide." A full-cardigan knit with 12 courses and 7 wales per inch (about 4.7 courses and 2.8 wales per cm.) was prepared.

TABLE II.—PROPERTIES OF THE FULL CARDIGAN KNIT

Thickness	0.038 inch (0.97 mm.).
Area weight	1.5 oz./yd.² (51 gm./m.²).
Grab tensile	25.5/22.2 lbs. (11.6/10.1 kg.).
Elongation	133/124 percent.
Tongue tear	4.0/5.2 lbs. (1.8/2.4 kg.).

Where values above are given in the A/B form, A is machine direction and B the cross direction. The post-inflated knit was attractive, bulky, and tight while being very light.

In the same fashion and with the same materials a plain jersey knit was formed having 14 courses and 10 wales per inch (about 5.5 courses and 3.9 wales per cm.).

Both of these fabrics were vinyl-calender-coated on commercial equipment to form bulky, conformable upholstery fabrics.

TABLE I.—COMPARISON OF VINYL SUBSTRATE FABRICS

	This example	Cotton Knit	Cotton Osnaburgh	Cotton Broken Twill
Area Weight:				
Oz./yd.²	2.1	3.8	4.7	8.6
Gm./m.²	(71)	(129)	(159)	(292)
Grab Tensile:				
Lb	92.9/84.6	41.0/35.0	57.5/63.0	122.7/143.6
Kg	(42.1/38.4)	(18.6/15.9)	(26.1/28.6)	(55.7/65.1)
Elongation (percent)	23.3/22.3	50.7/134.0	9.7/13.7	14.0/16.7
Ravelled Strip:				
Lb	63.4/66.6	22.2/16.4	52.1/55.6	109/108
Kg	(28.8/30.2)	(10.1/7.4)	(23.6/25.2)	(49.4/49.0)
Tongue Tear:				
Lb	15.0/17.4	4.4/4.4	13.4/16.0	17.5/30.7
Kg	(6.8/7.9)	(2.0/2.0)	(6.7/7.3)	(7.9/13.9)

Example XI

A moldable fabric backed with a layer of inflated ultramicrocellular filaments is illustrated by this example. Collapsed ultramicrocellular filaments were prepared by extrusion of a foamable composition into the ambient atmosphere through a cylindrical orifice 0.030 inch (0.76 mm.) in diameter and length. A 1-liter cylindrical pressure vessel was charged with 400 gm. of high-molecular-weight polyethylene terephthalate pellets and 250 cc. (at @ 25° C.) of methylene chloride. The sealed pressure vessel was rotated end-over-end in a hot air oven until temperature of the contents reached 225° C. The vessel was then stopped with its spinning-orifice end directed downward, and 850 p.s.i.g. (59.8 kg./cm.^{2} gage) of pressure from a nitrogen ballast tank was applied through a valve near the top of the vessel. The extruded filament was collected as a fine, collapsed, and flattened ribbon which, after post-inflation as previously described, returned to a round cross-section with a diameter of about 0.125 inch (0.318 cm.). Average transverse dimension for the fully inflated foam cells was about 20 microns. Density of the inflated filament was about 1.0 lb./ft.^{3} (0.016 gm./cc.).

A fabric was woven using two warps, one of which was composed of the above collapsed, approximately 0.0625 inch (0.159 cm.) wide, ultramicrocellular filaments at two ends per inch (about 0.79 end per cm.). The other warp and all of the fill yarns were of 2-ply, 3 S-twisted, 180 denier, Dacron® polyester yarn. Weaving was programmed to provide a tightly woven Dacron® fabric with 60 ends and 44 picks per inch (about 23.6 ends and 17.3 picks per cm.). Picks were inserted in such a way that about every 0.125 inch (0.318 cm.) along each foam-filament of the first warp a pick went around the foam-filament to stitch it to the back face of the forming Dacron® fabric. Area weight of the finished fabric was 9.33 oz./yd.^{2} (0.317 kg./m.^{2}).

The Dacron® polyester yarn employed was a continuous-filament yarn prepared from polyethylene terephthalate homopolymer with a relative viscosity of 30 (measured in a solvent composed of phenol and 2,4,6-trichlorophenol mixed 100/70 by weight). Drawn in a draw-bath about 6° C. hotter than usual and at a very low draw-ratio, the yarn produced had a very high elongation at break of 71% and a low shrinkage in boiling water of 6.7%.

Three specimens about 1 foot square (about 0.3 meter square) were cut from the woven, two-layer fabric, and each was molded into a medium brassiere cup in a typical ring and plug mold. The fabric specimen was clamped to the ring, and then the brassiere-cup-shaped, heated, male plug was pushed down through the ring to mold a cup. Just before each sample was clamped to the ring, it was immersed for several minutes in a bath of methylene chloride and 1,1,2-trichloro-1,2,2-trifluoroethane (50:50 by volume at room temperature), thus causing the chlorofluorocarbon to permeate into the foam-cells. The heated male plug was inserted for about 30 sec. in each case. At 150° C., the fabric was badly degraded. At 130° C., a good brassiere-cup formed with only a tiny area of fabric degradation, but the foam-filaments did not fully inflate. At 110° C., an excellent cup was formed with no separation of picks in the fabric. Not only did the heated mold heat-set the molded fabric to a stable shape, but it also caused the foam-filaments to fully inflate. In each case the foam-filament layer was against the heated plug.

These results show that, by proper selection of molding conditions, deep-drawn molded objects are readily obtained using fabrics comprising both elongatable dense yarns and collapsed microcellular filaments. Post-inflation of the microcellular filaments in the fabric creates bulk and excellent pneumatic cushioning. This technique is particularly useful for forming molded, conformable, cushioning, and decorative upholstery coverings.

What is claimed is:

1. A process for producing an inflated foam fabric which comprises:
   - providing gas-inflated microcellular foam filaments of a thermoplastic synthetic organic polymer, substantially all of the polymer being present as film-like walls of less than about 2 microns thickness, the walls defining polyhedral shaped, closed, uniform-sized cells having a maximum transverse dimension less than about 1000 microns;
   - collapsing the filaments by reducing the quantity of gas within the cells;
   - forming the collapsed filaments into a fabric; and
   - reinflating the filaments by introducing a gas into the cells.

2. The process of claim 1 wherein said microcellular filaments are ultramicrocellular filaments, said polymer being a crystalline polymer and exhibiting in the cell walls uniplanar orientation and uniform texture.

3. The process of claim 2 wherein said polymer is selected from the group consisting of stereo-regular polypropylene and polyethylene terephthalate.

4. The process of claim 1 wherein the fabric is a woven fabric containing said microcellular filaments in both warp and weft.

5. The process of claim 1 wherein said microcellular filaments have a fully inflated diameter of from about 0.01 inch to about 0.25 inch.

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