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(54) IMITATION WOOD AND METHOD OF MAKING IT

(71) We, SEKISUI KASEIHIN KOGYO KABUSHIKI KAISHA, a Japanese body corporate, of 25, 1-chome, Minamikyobate-cho, Nara-shi, Japan, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a synthetic wood which is made from synthetic resin and has similar appearance and properties to natural wood, and also to a method for the preparation thereof.

The properties and appearance of timber from the same kind of wood vary according to the particular tree from which it has been obtained. Moreover, it is generally difficult to obtain a long and wide timber having no knot therein. Furthermore, recently wood has risen in price. Thus, there has been a demand for synthetic wood having similar appearance and properties to natural wood.

Expanded articles are known which are made from hard synthetic resins and have a great number of micropores of which the average diameter is less than 1 mm. For example, it is known to make a microporous polystyrene article expanded about 20—50 times in volume which is manufactured by extruding polystyrene containing hydrocarbons such as pentane, butane and propane as well as sodium bicarbonate and citric acid, through a die provided with a single aperture, at an elevated temperature. Such a microporous polystyrene article has physical properties more akin to those of natural wood than non-expanded polystyrene, but it does not have the properties equal to those of natural wood in cutting it with a saw, planing it, nail-holding strength and other mechanical strength properties.

The inventors of the present invention investigated the causes which make the properties of the microporous polystyrene article different from natural wood. They found that

one of the causes is due to the fact that the microporous polystyrene article does not possess the so-called annual ring structure of natural wood, i.e. the low density and high density portions coexisting alternately in natural wood. Thereupon, the inventors sought methods by which this defect could be remedied, and investigated the properties of the products resulting therefrom. The present invention is the successful outcome of this research.

According to the present invention there is provided a synthetic wood material of density 0.1 to 0.7 g./c.c. which comprises contiguous filaments of a foamed polymer of styrene or of methyl methacrylate containing at least 50 weight % of styrene or methyl methacrylate-derived units respectively, in which synthetic wood material:

- (1) each filament has a higher density at its periphery than at its interior;
- (2) each filament has a cross-sectional area of from 0.005 to 1 square centimetre;
- (3) some of the filaments individually have an average density which is greater than 110% or less than 90% of the average density of the whole synthetic wood material; and
- (4) there are substantially no gaps between individual filaments.

The present invention also provides a method of making a synthetic wood material which comprises extruding a composition comprising a molten styrene or methyl methacrylate polymer as defined above and a foaming agent through orifices into a bundle of filaments, and subsequently foaming the filaments in a foaming zone while they are still soft, the foaming being carried out so that the amount of expansion of each filament is limited to below the full extent by the presence of neighbouring filaments of the bundle and the confines of the foaming zone, and the proportion of polymer in the composition and extent of foaming being such that a material of density in the range 0.1 to 0.7 g./c.c. is produced, and

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the extrusion being so carried out that each of the expanded filaments has a cross-sectional area of from 0.005 to 1 square centimetre, and that some of the expanded filaments individually have an average density which is greater than 110% or less than 90% of the average density of the whole synthetic wood material.

As explained hereinafter it is possible to make many different kinds of synthetic wood, i.e. having different appearance and/or properties, within the above definition. In all the various kinds of synthetic wood the density of each individual filament is higher at the periphery than at the interior. The density of an individual filament sometimes increases substantially continuously from the centre to the periphery, in which case there is not necessarily a sharp boundary at which the periphery ends and the interior begins. On the other hand, in many kinds of synthetic wood material of the invention, it is possible to observe a boundary between periphery and interior. When a cross-cut is made through such a material i.e. a section transverse to the longitudinal axis of the filaments and the exposed cross-section is pigmented, the boundary can be observed. The filaments appear to have a high density "skin" and a much lower density interior. There are substantially no gaps between the filaments, so the appearance of this kind of material is of a bundle of filaments compressed together, having high density "skins" where they meet. The "skin" of one filament is contiguous with that of its neighbours and there is no boundary line visible to the naked eye from which one can determine where the "skin" of one filament ends and that of its neighbour begins. There is however the above-described sharp boundary between the "skin" and the interior of the filament. Another description of this kind of synthetic wood material is therefore that it consists, in cross section, of a reticulate (network) of higher density material with the holes in the network being completely filled with lower density material. The network of higher density material corresponds to the "skin" of the filaments in the alternative description.

In the above general definition of the synthetic wood material of the invention the filaments are said to be "contiguous". The precise point at which one filament ends and another begins is frequently not visible to the naked eye looking at a pigmented cross-sectional face of the synthetic wood material. It can of course be deduced, e.g. where a "skin" is visible by apportioning a part, usually half, the thickness of the skin to each of the contiguous filaments. As explained in more detail hereafter the synthetic wood material is conveniently made by extruding filaments under confined conditions so that each individual filament is not free to expand to the maximum extent, i.e. the extent to which it could have expanded in an unconfined environment. This

constraint on the expansion of individual filaments produces the higher density at the periphery than at the interior. During this process neighbouring filaments while still in a molten or soft condition "coalesce", in the sense that they are forced together so that there are substantially no gaps between filaments and they adhere to each other. The filaments could therefore be validly described as "coalesced" insofar as they are made by this process.

The filaments are contiguous in the sense that, considered in cross-section at any point along their length, most of the periphery is in contact with the periphery of a neighbouring filament. However, the possibility cannot be excluded that small gaps may exist between neighbouring filaments at certain points along their peripheries. In other words, while the aim is to create a synthetic wood material in which all the filaments are wholly contiguous (completely coalesced) without leaving any gaps, the occasional imperfection may result in a few small gaps occurring.

The term "filament" is used in the broad sense of meaning a distinct longitudinally extending element, without implying that its cross-section is necessarily circular. It may have any shape, e.g. circular, oval or polygonal, for instance rectangular, square or hexagonal. Normally the shape of most of the filaments except those at the edge of the synthetic wood material will be hexagonal: conveniently the filaments are extruded through circular orifices and since each filament is bounded by six neighbours, it is prevented from expanding by constraints in each of six directions, so producing a six-sided expanded filament.

In the synthetic wood material of the invention some of the filaments have an average density which differs from the average density of the whole synthetic wood material by more than 10%.

If the average density of the whole synthetic wood material is A and the average density of a single filament is B , B being a parameter which varies from one filament to another, B is preferably greater than $0.2 \times A$ for all filaments. The individual filaments may be classified into three groups each of which consists of filaments having a certain average density, namely lower density $0.2A < B < 0.95A$, intermediate density: $0.95A \leq B \leq 1.05A$, and higher density: $B < 1.05A$; it is preferable that the intermediate density filaments account for less than 30 volume % of the synthetic wood material and both said lower and higher density filaments account for more than 10 volume %. Further it is also preferable that the density difference is more than 0.1 g./c.c. between the average density of said lower density filaments and that of said higher density filaments.

The resins to be employed in the present invention are polymers (homopolymers and copolymers) of styrene and methyl methacryl-

ate. The reason is that the invention aims at obtaining synthetic wood which has similar properties to those of natural wood, and also that extruded filaments in a softened state should be able to coalesce with one another. The polymer of styrene referred to herein includes styrene homopolymer as well as the copolymers of styrene, for example, acrylonitrile-butadiene-styrene copolymer which is generally called as ABS resin. Likewise, the polymer of methyl methacrylate includes polymethyl methacrylate and the copolymers of methyl methacrylate.

The copolymers of styrene and methyl methacrylate contain at least 50 weight % of styrene and methyl methacrylate-derived units respectively.

The extrusion may be carried out so that the amount of polymer present in the filaments extruded from the peripheral orifices is less or greater than that present in filaments extruded from inner orifices, thereby producing respectively a synthetic wood material in which the average density of the filaments is lower or higher at the periphery of the material than at the interior.

In the process of this invention, a great number of micropores are formed in the resin. The micropores are preferably made as small as possible in size and as many as possible in number. For example, it is preferable to have 5—100 micropores exist in 1 mm². The foaming agent which forms above-mentioned micropores may be, for example, aliphatic hydrocarbons such as pentane, butane and propane; and gas-generating compounds such as azodicarboxylic acid amide (azodicarbonamide) and dinitrosopentamethylenetetramine. When sodium bicarbonate and citric acid or another expansion-assisting agent are added to said foaming agent, the micropores are made smaller and more numerous. The foaming agent is capable of increasing the apparent volume of the resin very greatly, e.g. the 20—50 times mentioned above in connection with a prior process, but we have found that for the purpose of this invention, i.e. to obtain a material similar to natural wood, the expansion ought normally to be limited to a maximum of about 10 times. Our experiments have shown that the average density A of whole desired article must be within the range from 0.1 to 0.7 g./c.c.

The foaming agent may be added to the thermoplastic resin before the resin is fed to the extruder or in the course of extrusion. That is, foaming agent is mixed with the resin beforehand, and then the mixture may be fed to the extruder, or the resin is fed to the extruder and foaming agent may be added to the molten resin in the extruder.

The synthetic wood material (S.W.M. for short) is usually more expensive the greater the width required. To obtain such a wide piece of S.W.M. it is generally necessary to

carry out the extrusion over a cross-sectional area having one long dimension. However, it is not easy to extrude the resin over such a long dimension because it is not easy to maintain the resin in a uniformly molten state over such a long dimension of cross-sectional area. In order to maintain the resin in a uniformly molten state, special means is required. One of such means is the provision of a temperature regulator between the extruder and the die, one example which is shown in Fig. 1 of the accompanying drawings.

Fig. 1 is a cross-sectional view of the temperature regulator taken along the direction of flow of the material.

In Fig. 1, numeral 51 denotes the side of the temperature regulator whereto the discharge end of extruder is attached, and numeral 52 denotes the other side of the temperature regulator whereto the die is attached. The temperature regulator houses a torpedo 53, and an annular passage 55 is defined between torpedo 53 and outer sheath 54. Torpedo 53 houses a cavity 50 whereto pipes 56 and 57 extend, and a heating or cooling medium is circulated through said pipes 56 and 57 to heat or cool torpedo 53. Outer sheath 54 is provided with a groove 58 along the outer surface of the outer sheath. The heating or cooling medium is also circulated through the groove 58 via pipes 59 and 59', whereby outer sheath 54 is heated or cooled. Thus, the resin passing through the passage 55 is heated or cooled through both outer sheath 54 and torpedo 53, and the resin temperature can be controlled within a narrow temperature range.

In the method of the invention it is necessary to extrude the resin containing the foaming agent through orifices. The orifices are conveniently apertures in a die which are distributed in said die over an area similar to the cross-sectional area required for the S.W.M. It is already well known to extrude the resin containing foaming agents through a die, but the die employed in the method of the invention is distinguished from the previously employed dies in several respects. Firstly, the ratio of the total cross-sectional area of the orifices against that of the die is bigger than the expanding ability of the resin containing expanding agents, thus letting the resin filaments extruded passing through the orifices have low density skins, secondly, all of said apertures are formed in specific shapes or some of said apertures are formed in the same shape, for example, orifices positioned at the inner part of the die differ in their shape, length, size, or distribution thus controlling the rate of flow of the resin through the apertures and producing filaments having different densities. The annual ring structure of the S.W.M. comparable to that seen in natural wood may be obtained by ensuring that the individual filaments extruded through the

apertures of the die have a high capacity for expansion and maintaining the volume available for the expansion of the filaments less than the volume which the filaments require to expand freely. In other words, each filament is constricted by adjacent filaments and accordingly, the space in which individual filaments are allowed to expand is restricted. Individual filaments therefore expand to have a low density in their centre portions and high density in their outer portions.

To make the S.W.M. of the present invention it is necessary to impart differences in density between individual filaments, i.e. inter-filament density differences. It will be recalled that some of the filaments have an average density greater than 110% or less than 90% of that of the average density of the whole S.W.M. One way of imparting such differences is to employ a die at least some of the apertures of which have different sizes, lengths or lands shapes, and distributions. Thus, density differences between the filaments are determined by the structure of the die. Structures of dies will be described hereinafter, referring to the accompanying drawings.

Fig. 2 is a schematic cross-sectional view of a die, together with the apparatus immediately upstream and downstream thereof.

In Fig. 2, character reference *a* denotes an extruder, character reference *b* denotes a die and character reference *a-1* denotes a breaker plate mounted at the discharge end of the extruder. The die shown in Fig. 2 is provided with two plates in the middle and rear, each having a number of apertures. In Fig. 2, numerals 1 and 2 denote the plates, each having apertures. These plates 1 and 2 are positioned at areas where the passage is enlarged, its diameter substantially corresponding to that desired for the S.W.M. The plate 1 has a number of apertures 11, 12, uniformly distributed and these apertures have the same size. The plate 2 also has a number of apertures 21, 22, uniformly distributed therein and these apertures have the same size. The diameters of the apertures in the plate 1 are greater at one end (the resin inlet side or resin outlet side of the plate) than the other. The land length of the enlarged portion is largest in the peripheral aperture 11 and decreases gradually in the inner apertures, accordingly being the smallest in the aperture 14. On the other hand, the apertures in the plate 2 have the same diameter throughout their lengths.

When die *b* having the structure as shown in Fig. 2 is employed in carrying out the invented method, the resin extruded from the extruder *a* advances into the die *b* and passes through plate 1. When the resin passes through aperture 11 of plate 1, since the land length of the enlarged portion is greater than that of aperture 14, the resin advances more easily through aperture 11 than through aperture 14.

Thus, after resin has passed through plate 1, the loss of pressure of the resin on passing through plate 1 is less in the vicinity of aperture 11 than in the vicinity of aperture 14. Whereas when the resin is extruded by the conventional extrusion process, the pressure on the resin is greater in the center portion than in the peripheral portion, by use of the plate 1, the pressure of the resin is substantially the same in the center and peripheral portions. As mentioned above, since plate 2 has apertures of the same size (diameter and length) uniformly distributed, the resin is extruded through apertures of plate 2 under substantially the same pressure, therefore, the resin filaments extruded through plate 2 are equalized. After being extruded through plate 2, the filaments are expanded in the confined space, thus forming high density portions on their outer surfaces.

Fig. 3 is a perspective view of S.W.M. obtained by using the die as shown in Fig. 2.

In Fig. 3, almost all filaments are equally expanded, however; each of the filaments has a higher density portion *y* and a lower density portion *x*. In addition, each filament is adhered to adjacent filaments to form a perfect unitary article. Thus, the S.W.M. article obtained, as shown in Fig. 3, has lower density portions and higher density portions therein, both extending through the length of article, and as seen in the cross-section the higher density portions *y* constitute a network which surrounds the lower density portions *x*. However, in such an article the individual filaments have expanded to substantially the same degree and each strand has a small cross-sectional area.

Fig. 4 is a schematic cross-sectional view of another embodiment of the invented method wherein a modified die is employed.

The die shown in Fig. 4 is similar to that of Fig. 2 in that the apertures are provided with two plates 1 and 2, and that plate 2 has apertures of the same size uniformly distributed. However, the die of Fig. 4 is different from that of Fig. 2 in that plate 1 of Fig. 4 has apertures of different diameters 11, 12,, each of the apertures 11, 12, respectively having the same diameter throughout its length without an enlarged portion, and also in that plate 1 of Fig. 4 has larger diameter apertures 14, 15, 16 in the interior portion and smaller diameter apertures 11, 19 in the peripheral portion.

When the invented method is carried out by using the die *b* of Fig. 4, a microporous elongate S.W.M. article is obtained which is constituted from a number of coalesced filaments, each filament having higher density at its periphery than at its interior and the filaments at the periphery of the S.W.M. article having a lower average density and than those at the interior. The latter result due to the fact that the apertures of the center portion have larger diameters than those of the peripheral portion

in plate 1, so the pressure on the resin of the center portion is greater than that of the peripheral portion in the passage, with the consequence that the amount of resin passing through the center portion is larger than that passing through the peripheral portion in the plate 2. Thus the less expanded filaments (higher density) are disposed in the central portion and the more highly expanded filaments (lower density) are disposed in the peripheral portion.

Fig. 5 is a perspective view of a synthetic wood obtained by using the die shown in Fig. 4. The higher density filaments are labelled Z and the lower density ones W.

Fig. 6 is a schematic cross-sectional view of a further different embodiment of the invented method wherein another kind of die is employed.

The die of Fig. 6 has only one plate 1 in the passage of the resin; therefore, the apertures 11, 12, are arranged in a single stage column. As shown in Fig. 6, plate 1 is thinner in the center portion; plate 1 is provided with apertures at uniformly spaced points, the length of each of apertures 11, 12, is shorter in the center portion and longer in the peripheral portion of the plate.

When the process is carried out by use of the die as shown in Fig. 6, since the lengths of the apertures 14, 15, in the center portion are shorter and those of apertures 11, 18, in the peripheral portion are longer, movement of the resin through the center portion is easier than that through the peripheral portion. Accordingly, when a number of resin filaments extruded through the die are coalesced together, a microporous elongate S.W.M. article can be obtained which includes less expanded (higher density) filaments disposed in the center portion and more highly expanded (lower density) filaments disposed in the peripheral portion.

The dies so far described have contained cylindrical apertures formed therein, but similar effects may be obtained by the use of dies having a number of small slits formed therein, the slits serving in the same way as the apertures.

The dies shown in Figs. 2, 4 and 6 are only examples of dies and the die to be employed in the present invention are not limited to those shown and described herein and accordingly, any combinations of the shown dies can be, of course, employed within the scope of the invention.

Another way to impart a quasi annual ring structure similar to an annual ring structure of natural wood to a microporous elongate article which has been formed by extruding resin into a number of filaments and coalescing the filaments together is that the cross-sectional area at the discharge end of individual apertures is made larger than that at the inlet end of said apertures

so that the resin is first formed into a number of filaments at the inlet end of individual apertures and then partially expanded at the inlet of the enlarged portion of the apertures and the filaments are passing through the enlarged portions of the apertures in keeping their expanded outer surfaces in contact with the walls of said enlarged portions.

Fig. 7 is a schematic view in cross section of the construction of another kind of die which may be employed in the invented method, together with an extruder.

In Fig. 7, *a* denotes an extruder and *b* denotes a die into which resin is fed through breaker plate *a-1* under pressure and the resin advances in the arrow direction. The resin passage within die *b* gradually increases in cross-sectional area towards the discharge end. At the discharge end of the passage is a mounted plate 2 having therein a number of apertures 21, 22, are distributed over the desired cross-sectional area. The inlet (upstream) of these apertures 21, 22, 23, have smaller cross-sectional area and remain non-enlarged 211, 221, 231, and the discharge (downstream) ends are enlarged and have larger cross-sectional area 212, 222, 232,

When the invented process is carried out by the use of the die as shown in Fig. 7, the resin is first formed into a number of filaments at the smaller diameter portions 211, 221, 231, and the filaments are caused to partially expand (by action of the foaming agent) upon reaching enlarged diameter portions 212, 222, 232. (It is assumed that the resin is caused to partially expand at enlarged portions 212, 222, 232, thereafter, the filaments advance with their outer surfaces in contact with the walls of enlarged portions 212, 222, 232, However, in fact, this phenomenon has not been visually observed). The filaments obtained have outer surfaces which are less expanded and have higher densities than the interior of the filament. Accordingly, when a microporous elongate article is formed by coalescing these filaments together, this kind of density distribution occurs in all the filaments.

As shown in Figures 8—12 below other kinds of aperture than those shown in Fig. 7 may be used to produce a similar effect.

Figs. 8 to 12 show schematic views in cross-section of plates which are to be mounted at the discharge end of die *b* in place of plate 2 of Fig. 7. Figure 12 also shows an end view (from the discharge end) of the plate.

In Fig. 8, there is shown a plate which includes peripheral apertures 21, 24 having no enlarged portions and center apertures 22, 23 having enlarged portions 222, 232. In Fig. 9 there is shown a plate which includes peripheral apertures 21, 24 being single-stage enlarged and having both non-enlarged portions 211, 241 and enlarged portions 212, 242, and

center apertures 22, 23 being two-stage enlarged and having non-enlarged portions 221, 231, enlarged portions 222, 232 and further enlarged portions 223, 233. In Fig. 10, there is shown a plate which has apertures 21, 22 the diameters of which increase gradually in the downstream (discharge) direction, wherein there is no apparent line dividing between non-enlarged and enlarged portions. In Fig. 11, there is shown a plate which has apertures wherein the land lengths of non-enlarged portions 211, 221, 231 are shorter than those of enlarged portions 212, 222, 232. Finally, in Fig. 12 there is shown a plate which is similar to that of Fig. 7, but provided with small slits of rectangular cross-section instead of the apertures circular cross-section shown in Fig. 7.

Fig. 13 is a front view from the discharge side of the die shown schematically in Fig. 7.

In order provide the confinement required to coalesce together the extruded filaments, it is preferable to provide a plurality of paired rolls which can rotate in the advancing direction of the filaments emerging from the extrusion orifices. The temperature of the outer portions of the filaments is preferably near the softening point of the resin, at the location of the rolls. The rolls are preferably so designed that when the filaments advance between the paired rolls the filaments are nipped and compressed by the rolls from above and below, also right and left, but the rolls themselves are not positively driven, but rotate by their frictional contact with the advancing filaments.

One kind of the above-mentioned rolls will be described in detail referring to Fig. 2 of the drawings. In Fig. 2, a plurality of paired rolls 4 are provided in a position where each of the resin filaments extruded through die 6 are allowed to expand while being restricted by adjacent filaments and the surface temperature of the resin has dropped below its softening point.

Fig. 14 is a perspective view of plurality of paired rolls. In Fig. 14, all these rolls 4 are arranged to be paired, rolls 41 and 42 providing a pair and rolls 43 and 44 providing another pair. The pair of rolls 41 and 42 have their axes disposed horizontally, but the other pair of rolls 43 and 44 have their axes disposed vertically. The resin filaments advance between the paired rolls in succession. The distance between the paired rolls can be adjusted so that they may apply a slight pressure against the outer filaments, and they are not positively driven, but rotate through their contact with the advancing filaments. When slightly compressed by the paired rolls, the resin filaments, being still maintained at an elevated temperature in the vicinity of the softening point of the resin are coalesced together to form a unitary article.

In the process mentioned above, since the

outer surfaces of the filaments present in the outer part of the finished article are cooled to have a temperature in the vicinity of the softening point of the resin at the position where the rolls 41, 42, 43 and 44 contact the said resin filaments there is less possibility that the pores formed in the filaments are destroyed or deformed by the pressure applied thereon by the contacting rolls. And moreover, since the inner portions of the filaments are at a temperature above the softening point of the resin, the filaments can be coalesced together in their surfaces while they are still in a softened state sufficient to adhere to one another. In addition, since the rolls are not positively driven but rotated through their contact with the advancing filaments, there is less the possibility that the pores formed in the filaments may be destroyed or deformed. Furthermore, since the resin filaments are coalesced between rolls rotating in the opposite directions, the surface of the filaments can be effectively smoothened and the article given clearly defined edges.

As seen in cross-section it is apparent that the outer portion of each filament of the S.W.M. of this invention has a higher density and contains relatively less number of micropores, and that the inner portion has a low density and contains relatively a larger number of micropores. In particular, when the filaments contain pigments or the other coloring agents, the lower expanded portions generally exhibit a darker color, while the higher expanded portions exhibit a lighter color. Thus the outer portion of each filament is darker while the inner portion is lighter in colour, enabling the density difference to be observed with the naked eye. Moreover, the individual filaments have different degrees of expansion, i.e. differences in average density.

In a synthetic wood to be used for manufacture of a furniture, it is desirable to have filaments expanded about 2 to 4 times in volume as higher density strands, filaments expanded about 6 to 15 times in volume as lower density filaments, and also that said higher density strands and lower density filaments account for 15 to 20% of the total volume.

Although some of the filaments have different densities, it is allowed that some of them have the same densities. However, it is desirable that strands of different density are interposed between those having the same density. Thus, there can be various embodiments in the arrangement of the filaments. One embodiment is that the higher density and lower density filaments are alternately arranged in a regular fashion; however such a regular arrangement is not mandate. In another embodiment some of the filaments of the same density are disposed adjacent to one another and the remainder of the filaments of the same density are separated by filaments of different density.

Various arrangements of the filaments in the S.W.M. will be described hereinbelow referring to Figs. 15 to 18 of the accompanying drawings.

Figs. 15 to 18 are perspective views of S.W.M. which show arrangements of filaments having different densities.

In Fig. 15, the higher density filaments Z, that is less expanded, are present in succession in a horizontal row to form a higher density layer, and the lower density strands W, that is more highly expanded, are also in present succession in a horizontal row to form a low density layer; said higher density layer and said lower density layers are alternately arranged in a regular fashion in the vertical direction.

In Fig. 16, the higher density filament Z and the lower density filaments W are randomly arranged.

In Fig. 17, the higher density filaments Z are present in succession to form two layers in the outer surface and the lower density filaments W are concentrated in the inner portion.

In Fig. 18, some of the higher density filaments Z forms outer layers, the rest of the higher density filaments form an inner block, and the lower density filaments W are disposed between said outer layers and said inner block.

The S.W.M. shown in these figures has satisfactory properties and can be produced by the methods mentioned hereinbefore.

In the present invention, the addition of coloring agents, flame retardants, fillers and other additives conventionally added to resins permissible. Fillers are useful for increasing the density of the S.W.M. In addition, to improve the strength of the S.W.M., synthetic fibres and/or glass fibres may be incorporated in the resin.

The S.W.M. has a great resistance against bending in the longitudinal direction, considering its light weight. Accordingly, it is characterised by a combination of rigidity and light weight. Moreover, since the S.W.M. is microporous, it is a good heat insulator. Since adjacent resin filaments in the S.W.M. are united together, the junctures between adjacent filaments provide an appearance similar to the annual ring of natural wood, and said junctures extend in the longitudinal direction of the synthetic wood similar to a straight grain structure without presence of knots as seen in natural wood thereby to give a fine appearance to the S.W.M.

As compared with a conventional synthetic wood which has been prepared by extruding the expandable resin through a die having single aperture as a whole, and has been provided with considerable difference in degree of expansion, the invented synthetic wood has relatively less difference in degree of expansion as a whole between outer and inner portions thereof. Thus, the properties of the in-

vented synthetic wood will not change even when subject to saw shearing and planing, and pieces of such synthetic wood can be secured together by nailing.

The fact that the S.W.M. can be very satisfactorily nailed will be manifested as follows. For natural wood, a nail pulling off test can be performed by the procedure of Japanese Industrial Standard Z-2121. According to the experimental procedure, when an iron nail having a length of 45 mm and diameter of 2.41 mm is driven into a piece of cryptomeria (Japanese cedar) wood by a depth of 15 mm in the direction perpendicular to the face of the piece, the force required to pull the nail off the wood piece is within the range 10 to 25 Kg. On the other hand, for the conventional synthetic wood, when the degree of expansion of the resin is not generally limited to 2 to 3 times, it is impossible to maintain the pulling force at 10 Kg. When the degree of expansion of the resin is more than 2 to 3 times, the pulling force is smaller than 10 Kg. However, in the invented synthetic wood, even when the average degree of expansion is increased to 4.2 to 4.7 times, the nail pulling-off force may be increased to 13 Kg. In this way, the nail pulling off force is comparatively large in spite of the large degree of expansion and accordingly, the invented synthetic wood can be secured by nailing.

The following Examples further illustrate the invention.

Example 1.

100 weight parts of granular polystyrene (diameter range of 2-3 mm.) containing about 4 weight % of butane was prepared. 0.5 weight part of sodium bicarbonate, 0.3 weight part of citric acid and 3 weight parts of fine powdery clay were added to said polystyrene. The resultant mixture was intimately mixed and charged into an extruder having the diameter of 50 mm. The thus obtained material was able to expand about 20 times in volume, when extruded through a die having a single aperture and expanded in a free space.

The apparatus used in this example was of the kind shown in Fig. 2. Die *b* mounted on the extruder *a* had the following dimensions. Plate 1 is a rectangular plate having the long side of 150 mm and the short side of 20 mm in the portion where it contacts with molten resin, and having the thickness of 30 mm. Over the whole surface of plate 1 are perforated 44 apertures extending through the direction of the thickness of the plate. Among the apertures, 30 apertures are distributed in a latticed form at the pitch of 10 mm in long and short side directions, and at the center of each area surrounded by 4 adjacent apertures is disposed one of the remaining 14 apertures. The apertures have the diameter of 4.4 mm. Among them, the apertures disposed in the

vicinity of short sides of plate 1 are provided with enlarged portions having the diameter of 6.0 mm at the resin inlet side. Depths of said enlarged portions are 20 mm with respect to three apertures disposed in the position nearest to said short sides, and 18 mm with respect to three apertures adjacent to said three apertures, and then 6 mm, 4 mm, 2 mm in order with respect to every three apertures, and the apertures at the center portion of plate 1 have no enlarged portion.

Plate 2 has the same dimensions as plate 1 in the long and short side, and the thickness of 20 mm. Over all the surface of plate 2 are perforated 329 apertures having the diameter of 1.6 mm in the direction of the thickness of plate 2. Among them, 185 apertures are distributed in a lattice form at the pitches of 4 mm in the direction of the short side and of 4 mm in the direction of the long side, and the remaining 155 apertures are distributed by one at every center of area surrounded by 4 adjacent apertures.

The temperature of the extruder was maintained at 150–200°C, solid mixture was extruded through said die. The resin filaments extruded through said die was compressed together between a die frame while they were

still in a softened state into a microporous board having the thickness of 25 mm and the width of 180 mm.

Said board had an average density of 0.103 g/cc as a whole. All individual filaments constituting said board had higher densities in the surface portions compared with the inner portions thereof.

The article was divided into individual filaments, and the weight and volume of each was measured. The average densities of individual filaments were within the range of 0.086 to 0.218 g/cc. Their cross-sectional areas were within the range of 0.21 cm² to 0.08 cm².

Basing upon these results, the filaments were classified into following three groups,

- (1) lower density 0.086 to 0.097 g/cc
- (2) intermediate density, 0.097 to 0.108 g/cc
- (3) higher density, 0.108 to 0.218 g/cc

Thus, deviations in density among all filaments were investigated. The results were as follows.

Classification of filaments	Numbers of filaments	Volume ratios (%)	Average densities (g/cc)
lower density	30	9.1	0.092
intermediate density	287	87.3	0.103
higher density	12	3.6	0.179

It was confirmed that the article had good properties, but not excellent, probably because of fewer deviations in density compared with those of the following Examples.

Incidentally, the above measured values were obtained as follows. A test specimen having 10 mm thick was prepared by cutting said board in the direction perpendicular to the longitudinal direction. The weight and volume of the specimen were measured and the density was calculated. Said density was assumed to be the average density of the board. Then, the specimen was cut into individual filaments, and the weight and volume of the individual filaments were measured. The densities of the individual filaments were calculated from above measured values. Basing upon the densities of the individual filaments, these filaments were classified into lower density, intermediate

density and higher density and then the numbers of filaments, volume ratios and average densities were calculated. This test was conducted by preparing three test specimens from arbitrary portions of the board and by taking the average value from measured values for every specimen. The same procedure is used in the following examples.

Said board has the surface hardness of 5–8 by means of Type-D Durometer according to ASTM D 2240-64T. A nail pulling-off test was conducted by driving an iron nail, 45 mm long and 2.41 mm in diameter, from the surface in a direction perpendicular to the longitudinal direction of the board to a depth of 15 mm and by measuring the maximum load required to pull out the nail. This load was 1.3 Kg. Incidentally, the average surface hardness was determined from tests at ten random

points on the board, and the average nail pulling-off load was determined from tests at five random points on the board. The same procedure is used in the following examples.

The microporous board obtained in this example had a fine appearance and good properties, similar to a straight-grained of natural wood, and could be employed as a construction material.

Example 2.

In this Example, the apparatus shown in Figs. 19 to 21 are employed.

Fig. 19 is a schematic cross-sectional view of the whole apparatus used for the method of Example 2.

Fig. 20 is a partial enlarged cross-sectional view taken along the line A—A of Fig. 19 seen in the arrowed direction.

Fig. 21 is a partial enlarged longitudinal sectional view taken along the line B—B of Fig. 20.

In Fig. 19, character *a* denotes an extruder, character *b* denotes a die, and numeral 5 denotes a temperature regulator as shown in Fig. 1.

In this example, 28 Kg of granular polystyrene containing 6.0 weight % of butane was mixed with 55 Kg of granular polystyrene containing no foaming agent, and to the mixture was added uniformly 160 g of polybutene having an average molecular weight of 470 and low viscosity, and to the thus obtained mixture were added 2.4 Kg of fine powdery talc 10—30 micron in diameter and 160 g of brown pigment. This mixture was employed as raw material after it had been intimately blended. The raw material was able to expand about 8 times in volume, when extruded through a die having a single aperture and expanded in a free space.

As for the extruder, two extruders having 50 mm and 65 mm diameters, respectively, are connected in series, and the former was rotated 60 r.p.m., the latter 42 r.p.m., whereby the resin was extruded at the rate of 32 Kg/hr.

In die *b* of Fig. 10 were mounted plates 1 and 2 as in Example 1. As for plate 1, it is a rectangular plate as shown in Figs. 20 and 21. Plate 1 has the long side *l* of 605 mm and the short side *m* of 22 mm in the position where it contacts with molten resin, and the thickness of 50 mm. Over the whole surface of plate 1 are perforated a total of 182 apertures 11, 12, ..., 12', 11' extending through the direction of the thickness. The total of 182 apertures is made up of (a) 122 apertures 11, 115, 13, 135, 14, 145, 16, 165 ... distributed in a latticed form wherein the pitch *n'* in the direction of long side *l* and the pitch *n* in the direction of short side *m* are all 10 mm, and (b) a further 60 apertures, 12, 15, 18 ... distributed centrally so that (leaving aside the two end apertures 11', 115') each of the said 60 apertures is surrounded by 4 adjacent aper-

tures of the set of 122, for example, 11, 115, 135, 13; 14, 145, 165, 16; ... Of course on average each of the 60 apertures is surrounded by 2 only of the 122 apertures, and Nos. 11' and 115' are the left over ones. Hereinafter this distribution of apertures is referred to a "double zigzag distribution of pitch $n \times n'$ ". The diameters of these apertures 11, 115, 12 ... are as follows. Plate 1 is divided into five parts along the long side *l*, and the divided parts are referred to *A*, *B*, *C* in order of position from both sides. Part *A* has the length of 105.5 mm along long side *l*, *B* the length of 100 mm, *C* the length of 195 mm. Part *A* has 64 apertures, 11, 115, 12, ... and 11', 12' ... diameters of which are all 5 mm. Part *B* has 60 apertures, 15, 16, ..., and 15', 16' ... diameters of which are all 4.8 mm. Part *C* has 58 apertures, 18, 19, 195, 18', 19' ... diameters of which are all 4.6 mm.

Among the apertures perforated in part *A*, apertures 11, 115, 12 ... and 11', 115', 12', disposed in the vicinity of short sides *m* are provided with enlarged portions having the diameter of 6 mm at the resin inlet side. Depths *p* of said enlarged portions are 20 mm with respect to three apertures 11, 111, 12; 11', 111', 12', disposed in the position nearest to short sides *n*, and 15 mm with respect to three apertures adjacent to said three apertures, and then 10 mm, 8 mm, 6 mm in order with respect to every three apertures, at last the apertures 14, 14' positioned close to the center have no enlarged portion *p*.

Referring to the perforated plate 2 shown in Fig. 19, it is a rectangular plate having the same dimensions as plate 1 in the long and short side in the portion where it contacts with molten resin, and having the thickness of 20 mm. Over the whole surface of plate 2 are perforated 1085 apertures having the diameter of 1.6 mm extending through the direction of the thickness. The distribution of said apertures is a double zigzag distribution of pitch 5×5 according to the definition mentioned above.

The apparatus used in this Example had the temperature regulator 5 as shown in Fig. 1 between extruder *a* and die *b*. By means of said temperature regulator 5 wherein heated oil was circulated, the resin was maintain within a certain temperature range and was extruded through die *b* into a number of filaments.

Extruded resin filaments were passed through frame 3 while they were still in a softened state; they were compressed to be coalesced by said frame 3, and coalescence was completed by means of a plurality of paired rolls 4.

The plurality of paired rolls comprised eight rolls on each side of the extrudate one set being shown at 43, said rolls having a diameter of 10 mm and their axes being in the vertical

direction, and nine rolls 42 and 44 disposed above and below the extrudate, said rolls being 25 mm in diameter and their axes being in the horizontal direction. The cross-sectional area surrounded by said paired rolls was 20 × 600 mm.

Expanded resin filaments passing through said paired rolls 4 were cooled by water, then pulled off by being nipped through a pair of rubber rolls and thus formed into an elongate article.

The article thus obtained was a board having 20 mm in thickness and 600 mm in width. Individual filaments had their inner portions highly expanded (lower densities) and their outer portions less expanded (higher densities). Their higher density outer portions were coalesced firmly with adjacent filaments. Moreover, since said coalesced outer surfaces extended through the longitudinal direction,

the article had a fine appearance and properties similar to a straight grain structure of natural wood.

Various measurements were conducted on the board thus obtained, and the results were as follows.

Average density of the board as a whole was 0.238 g/cc (expanding ratio about 4.2). Then, the board was divided into individual filaments, and the weight and volume of each filament were measured. The cross-sectional areas of individual filaments were in the range of 0.056 to 0.860 cm². Their densities were in the range of 0.181 to 0.295 g/cc. All filaments were classified into three groups according to their densities, i.e. lower density, 0.181 to 0.225 g/cc, intermediate density, 0.226 to 0.250 g/cc and higher density, 0.251 to 0.295 g/cc. The results were as follows.

Classification of filaments	Number of filaments	Volume ratios (%)	Average densities (g/cc)
lower density	99	9.1	0.208
intermediate density	841	77.5	0.236
higher density	145	13.4	0.270

It was confirmed that the article had excellent properties as mentioned below, probably because of rather broad deviations in density.

The board had a fine appearance and good properties similar to straight grain structure of natural wood, and could be employed in the same way as natural wood, since it could be planed or cut by a saw. The board had the surface hardness of 14—20 when measured by the testing method described in Example 1. The board had a nail pulling-off strength of 8.0 Kg when measured by the method described in Example 1. This nail pulling-off strength was superior to that of conventional microporous synthetic resin woods having the same density.

Example 3.

In this Example, the raw materials and apparatus was the same as in Example 2. However, the die used in this Example was different from that of Example 2 both in the numbers of apertures perforated in plate 1 of die *b* and in the distribution of said apertures.

The plate had the same dimensions, and thickness and the diameter of the apertures was the same as that of Example 2. These were 1577 apertures, the distribution of which was that 984 apertures were arranged in

double lines in the peripheral portion at the pitch of 2.5 mm along both short and long sides, and the remaining 593 apertures arranged in the center portion in a double zigzag distribution of 5 × 5.

Using the die having said plate 1, a microporous board 600 mm in width and 20 mm in thickness was obtained in the same way as in Example 2.

The board thus obtained was tested in the same way as in Example 1, and the results obtained were as follows.

The whole board had an average density of 0.244 g/cc. The individual filaments had higher densities in their outer portions and lower densities in their inner portions, and the cross-sectional areas of the filaments were within the range of 0.006 to 0.518 cm². Said filaments had average densities within the range of 0.151 to 0.330 g/cc. The filaments were classified into following three groups in the same way as in the preceding Examples.

- (1) lower density, 0.151 to 0.231 g/cc
- (2) intermediate density, 0.232 to 0.256 g/cc
- (3) higher density, 0.257 to 0.330 g/cc.

The results were as follows.

Classification of filaments	Number of filaments	Volume ratio (%)	Average density (g/cc)
lower density	593	40.4	0.189
intermediate density	375	18.2	0.238
higher density	609	41.4	0.299

It was confirmed that the article had quite excellent properties as mentioned below, probably because of further broad deviations in density.

The board had the structure as shown in Fig. 17, in which the higher density filaments were concentrated in the outer portion of the board. The board had the surface hardness of 24-35 and the nail pulling-off strength of 10.2 Kg when tested in the same way as in Example 1. The other properties measured by the conventional methods were as follows.

- compressive strength (direction of thickness) 20 Kg/cm²
- compressive strength (longitudinal direction) 93 Kg/cm²
- tensile strength (longitudinal direction) 55 Kg/cm²
- Bending strength (longitudinal direction) 120 Kg/cm²

These properties made the S.W.M. board suitable for use as structural material.

Example 4.

In this Example, the apparatus was the same as in Example 2, except for die *b*. The die *b* used in this example was the same as in Example 1, except plate 2.

Plate 2 used in this Example is shown in Fig. 22.

Fig. 22 (a) is a partial front view of plate 2 used in this Example, as seen from the upstream (resin inlet) side.

Fig. 22 (b) is a partial cross-sectional view taken along the line c-c of Fig. 22 (a).

Plate 2 shown in Fig. 22 is a rectangular plate having 150 mm in long side *l*, 20 mm in short side *m* and 20 mm in thickness. Over the whole surface of plate 2 were perforated 219 apertures, 21, 22, . . . extending in the direction of the thickness. Said apertures were arranged in a double zigzag distribution of 6 (short side direction) × 4 (long side direction).

The apertures which were disposed in the peripheral portion had enlarged diameters at the resin inlet side, a fact which distinguishes die *b* used in this example was different from that of Example 3. 150 apertures indicated by numeral 21, which were arranged in double lines in the peripheral portion had a diameter of 1.4 mm at the resin discharge side and enlarged diameter of 2.0 mm at the resin inlet side, length of the enlarged diameter portion being 10 mm. The remaining 69 apertures 22 were arranged in the center portion and had a diameter of 1.6 mm.

As for the raw material, 25 Kg of polystyrene particles containing 7.9 weight % of butane were added to 65 Kg of polystyrene particles containing no foaming agent; to the mixture thus obtained were added 180 g of polybutene then mixed well; further to the above mixture were added 2.7 Kg of fine powdery talc, and the mixture obtained was employed as the raw material. The raw material was able to expand about 9 times in volume, when extruded through a die having a single aperture and expanded in a free space.

Said raw material was fed into an extruder and the process was carried out in the same way as in Example 2. A microporous article having 20 mm in thickness and 150 mm in width was thus obtained.

Measurements were conducted on the article according to the same methods as in Example 1.

Said article had the average density of 0.25 g/cc as a whole.

Said article was divided into individual filaments, and the weight and volume of each filament were measured.

Individual resin filaments had their cross-sectional areas within the range of 0.023 cm² to 0.25 cm², and had higher density in the outer portions and lower density in the center portions. The densities of the individual fila-

ments were within the range of 0.081 g/cc to 0.54 g/cc. Based upon these results, all filaments were classified into the following three groups:

- 5 (1) lower density, 0.081 g/cc to 0.240 g/cc

- (2) intermediate density, 0.241 to 0.260 g/cc

- (3) higher density, 0.261 to 0.356 g/cc.

Thus, the deviations in density among all filaments were investigated. The results were as follows.

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Classification of filaments	Number of filaments	Volume ratio (%)	Average density (g/cc)
lower density	73	34.2	0.191
intermediate density	42	19.3	0.255
higher density	104	46.5	0.291

15 It was confirmed that the article had quite excellent properties as mentioned below, probably because of further broad deviations in density.

20 The microporous article had the structure as shown in Fig. 17, in which the higher density filaments were concentrated in the outer portion of the article. The structure of the article is thus the same as in Example 3.

25 The surface hardness and nail pulling-off strength of the article were measured in the same way as in Example 1, and the results were as follows:

Surface hardness: 22—30

Nail pulling-off strength: 11.2 Kg.

Example 5.

30 In this Example, the raw material was identical with that employed in Example 4, and the procedure was identical with that of Example 3. However, plate 2 of die *b* employed in this Example had different dimensions, distribution and shape of apertures from those of Example 3. Said plate 2 is shown in Fig. 23.

35 Fig. 23 (a) is a partial front view of plate 2 employed in this Example 5, as seen from resin inlet side.

40 Fig. 23 (b) is a partial cross-sectional view of plate 2 taken along the line D—D of Fig. 23 (a).

45 Plate 2 is identical with that employed in Example 4 in distribution and dimensions of apertures, as easily seen from comparison of Fig. 23 with Fig. 22. However, plate 2 employed in this Example is different from Ex-

ample 4 in that the portions of enlarged diameter are provided in the resin discharge side. In particular, 150 apertures indicated by numeral 21, which were arranged in double lines in the peripheral portion had the diameter of 1.4 mm at the resin inlet side and the enlarged diameter of 2.0 mm at the resin discharge side, depth of the enlarged diameter being 10 mm. The remaining 69 apertures indicated by numeral 22 were arranged in the center portion and had the diameter of 1.6 mm.

Thus, a microporous article was obtained. Measurements were conducted on the article in the same way as in Example 1, and the results were as follows.

Said article had the average density of 0.24 g/cc as a whole.

Said article was divided into individual filaments, and the weight and volume of each filament were measured.

Individual filaments had cross-sectional areas within the range of 0.032 to 0.200 cm², and higher density in the outer portions and lower density in the inner portions. The densities of the individual filaments were within the range of 0.071 to 0.420 g/cc. Based upon these results, all the filaments were classified into the following three groups:

- (1) lower density, 0.071 to 0.228 g/cc

- (2) intermediate density, 0.228 to 0.252 g/cc

- (3) higher density, 0.252 to 0.420 g/cc.

Thus, the deviations in density among all filaments were investigated. The results were as follows.

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Classification of filaments	Number of filaments	Volume ratio (%)	Average density (g/cc)
lower density	101	47.1	0.140
intermediate density	12	5.5	0.248
higher density	107	47.4	0.345

It was confirmed that the article had quite excellent properties as mentioned below, probably because of above deviations in density.

The surface hardness and nail pulling-off strength of the article were measured in the same way as in Example 1, and the results were as follows:

Surface hardness: 35—45

Nail pulling-off strength: 12.5 Kg.

Comparing the above results with those of Example 3, it is clear that the article obtained in this Example has a little higher nail pulling-off strength, and much greater surface hardness than that of Example 3.

Example 6.

In this Example, the raw material was identical with that employed in Example 4 and 5, and the procedure was identical with that of Example 4. However, die *b* employed in this Example was different from that of Example 4 in that the die *b* had a single plate 1, as shown in Fig. 24, instead of plate 1 and 2. Incidentally, in this Example, the procedure was carried out without circulating the medium in the temperature regulator.

Fig. 24 (a) is a partial front view of plate 1 employed in this Example 6, as seen from the resin inlet side.

Fig. 24 (b) is a partial cross-sectional view of plate 1 taken along the line E—E of Fig. 24 (a).

Plate 1 is a rectangular plate having the long side 36 mm, the short side 20 mm and thickness 30 mm, and has 23 apertures perforated in a double zigzag distribution of 7 × 7. Said apertures are classified into three groups according to the shape thereof. The first group includes four apertures which are located at the corner and are denoted by numeral 11 in Fig. 24. Said apertures have the identical diameter of 2.5 mm throughout the whole length. The second group includes the

8 apertures which are located in the peripheral portion and denoted by numeral 12 in Fig. 24. Said apertures 12 have the diameter of 1.6 mm at the resin inlet side and the enlarged diameter of 2.2 mm at the resin discharge side. Said enlarged diameter begins at the depth of 1.6 mm from the resin inlet side. The third group includes 11 apertures which are located in the center portion and denoted by numeral 13 in Fig. 24. Said apertures 13 have the diameter of 1.6 mm at the resin inlet side, the first enlarged diameter of 2.2 mm in the middle portion, and the second enlarged diameter of 2.4 mm at the resin discharge side. Said first enlarged diameter begins at the depth of 15 mm from the resin inlet side, and said second enlarged diameter at the depth of 22.5 mm.

Employing above-mentioned apparatus, a microporous article having a rectangular cross-section of 20 × 36 mm was obtained. Measurements were conducted on this article in the same way as in Example 1. The results were as follows.

The whole article had an average density of 0.213 g/cc. Individual filaments had cross-sectional areas within the range of 0.031 to 0.483 cm², and higher density in the outer portions and lower density in the inner portions.

The article was divided into individual filaments and their weight and volume were measured. The densities of the individual filaments were within the range of 0.075 to 0.341 g/cc. Based upon these results, the filaments were classified into the following three groups in the same way as in the preceding Examples:

- (1) lower density, 0.075 to 0.202 g/cc
- (2) intermediate density, 0.202 to 0.224 g/cc
- (3) higher density, 0.224 to 0.341 g/cc.

The number of filaments in each group and their volume and average density were investigated. The results were as follows.

Classification of filaments	Number of filaments	Volume ratio (%)	Average density (g/cc)
lower density	8	45.5	0.146
intermediate density	3	7.0	0.203
higher density	12	48.5	0.278

Said article had the higher density filaments concentrated in the center portion of the article, and had a structure similar to that shown in Fig. 5.

It was confirmed that the article had good properties as mentioned below, probably because of this structure.

The surface hardness and nail pulling-off strength of the article measured in the same way as in Example 1, and the results were as follows.

Surface hardness: 15—20

Nail pulling-off strength: 13.8 Kg.

The article was suitable for use as a structural material, because it had a high nail pulling-off strength and a fine appearance as well as properties similar to natural wood having a straight grain structure.

Example 7.

In this Example, the raw material, apparatus and procedure were identical with those in Example 3, except that blower denoted by numeral 6 in Fig. 25 was established at the resin discharge end of die *b*, wherein the extruded resin filaments disposed in the outer portion were cooled by blowing air at room temperature. Fig. 25 is a schematic cross-sectional view of the apparatus employed in this Example. The reference numerals, apart from 6 indicating the blower, have the same significance as in Fig. 19.

Thus, a microporous board which was similar to that of Example 3 and had the density of 0.26 g/cc was obtained.

The surface hardness of the article was measured in the same way as in Example 1, and was found to have a large value 50—60. However, said article had a rough surface.

Example 8.

In this Example, the raw material, apparatus and procedure were identical with those of Example 7, except that air at 20°C is circulated through a pipe denoted by numeral 7 in Fig. 26 was established instead of blower

6. By use of air as a circulating cooling medium, the extruded filaments disposed in the outer portion were cooled. Fig. 26 is a schematic cross-sectional view of the apparatus employed. The reference numerals, apart from the pipe 7 have the same significance as in Fig. 19 in this Example. A microporous article having high surface hardness (55—65) and a smooth surface, which is quite different from that of Example 7, was obtained.

WHAT WE CLAIM IS:—

1. A synthetic wood material of density 0.1 to 0.7 g./c.c. which comprises contiguous filaments of a foamed polymer of styrene or of methyl methacrylate containing at least 50 weight % of styrene- or methyl methacrylate-derived units respectively, in which synthetic wood material:

(1) each filament has a higher density at its periphery than at its interior;

(2) each filament has a cross-sectional area of from 0.005 to 1 square centimetre;

(3) some of the filaments individually have an average density which is greater than 110% or less than 90% of the average density of the whole synthetic wood material; and

(4) there are substantially no gaps between individual filaments.

2. A material according to Claim 1 wherein the density of each filament increases continuously from the centre radially outwards to the periphery.

3. A material according to Claim 1 or 2 containing from 5 to 25 filaments per square centimetre of cross-section.

4. A material according to any preceding Claim, wherein all the filaments individually have an average density which is greater than 20% of the average density of the material and comprise:

(1) low density filaments having individually an average density less than 95% of the average density of the material, these filaments constituting more than 10% by volume of the material,

Classification of filaments	Number of filaments	Volume ratio (%)	Average density (g/cc)
lower density	8	45.5	0.146
intermediate density	3	7.0	0.203
higher density	12	48.5	0.278

Said article had the higher density filaments concentrated in the center portion of the article, and had a structure similar to that shown in Fig. 5.

It was confirmed that the article had good properties as mentioned below, probably because of this structure.

The surface hardness and nail pulling-off strength of the article measured in the same way as in Example 1, and the results were as follows.

Surface hardness: 15—20

Nail pulling-off strength: 13.8 Kg.

The article was suitable for use as a structural material, because it had a high nail pulling-off strength and a fine appearance as well as properties similar to natural wood having a straight grain structure.

Example 7.

In this Example, the raw material, apparatus and procedure were identical with those in Example 3, except that blower denoted by numeral 6 in Fig. 25 was established at the resin discharge end of die *b*, wherein the extruded resin filaments disposed in the outer portion were cooled by blowing air at room temperature. Fig. 25 is a schematic cross-sectional view of the apparatus employed in this Example. The reference numerals, apart from 6 indicating the blower, have the same significance as in Fig. 19.

Thus, a microporous board which was similar to that of Example 3 and had the density of 0.26 g/cc was obtained.

The surface hardness of the article was measured in the same way as in Example 1, and was found to have a large value 50—60. However, said article had a rough surface.

Example 8.

In this Example, the raw material, apparatus and procedure were identical with those of Example 7, except that air at 20°C is circulated through a pipe denoted by numeral 7 in Fig. 26 was established instead of blower

6. By use of air as a circulating cooling medium, the extruded filaments disposed in the outer portion were cooled. Fig. 26 is a schematic cross-sectional view of the apparatus employed. The reference numerals, apart from the pipe 7 have the same significance as in Fig. 19 in this Example. A microporous article having high surface hardness (55—65) and a smooth surface, which is quite different from that of Example 7, was obtained.

WHAT WE CLAIM IS:—

1. A synthetic wood material of density 0.1 to 0.7 g./c.c. which comprises contiguous filaments of a foamed polymer of styrene or of methyl methacrylate containing at least 50 weight % of styrene- or methyl methacrylate-derived units respectively, in which synthetic wood material:

(1) each filament has a higher density at its periphery than at its interior;

(2) each filament has a cross-sectional area of from 0.005 to 1 square centimetre;

(3) some of the filaments individually have an average density which is greater than 110% or less than 90% of the average density of the whole synthetic wood material; and

(4) there are substantially no gaps between individual filaments.

2. A material according to Claim 1 wherein the density of each filament increases continuously from the centre radially outwards to the periphery.

3. A material according to Claim 1 or 2 containing from 5 to 25 filaments per square centimetre of cross-section.

4. A material according to any preceding Claim, wherein all the filaments individually have an average density which is greater than 20% of the average density of the material and comprise:

(1) low density filaments having individually an average density less than 95% of the average density of the material, these filaments constituting more than 10% by volume of the material,



(2) intermediate filaments having individually an average density of from 95 to 105% of the average density of the material, these filaments constituting less than 30% by volume of the material, and

(3) high density filaments having individually an average density of from more than 105% of the average density of the material, these filaments constituting more than 10% by volume of the material, the difference between the densities of filaments (1) and (3) being greater than 0.1 g./c.c.

5. A material according to any preceding claim wherein the filaments at the periphery of the material, are of higher average density than those at the centre.

6. A material according to any one of claims 1—4 wherein the filaments at the periphery of the material are of lower average density than those at the centre.

7. A material according to any preceding claim wherein the filaments are of polystyrene or poly(methyl methacrylate).

8. A synthetic wood material substantially as herein described with reference to Fig. 3, 5, 15, 16, 17 or 18 of the accompanying drawings.

9. A synthetic wood material according to claim 1 substantially as described in any one of the Examples.

10. A method of making a synthetic wood material which comprises extruding a composition comprising a molten styrene or methyl methacrylate polymer, containing at least 50 weight % of styrene- or methyl methacrylate-derived units respectively and a foaming agent through orifices into a bundle of filaments, and subsequently foaming the filaments in a foaming zone while they are still soft, the foaming being carried out so that the amount of expansion of each filament is limited to below the full extent by the presence of neighbouring filaments of the bundle and the confines of the foaming zone, and the proportion of polymer in the composition and extent of foaming being such that a material of density in the range 0.1 to 0.7 g./c.c. is produced, and the extrusion being so carried out that each of the expanded filaments has a cross-sectional area of from 0.005 to 1 square centimetre, and that some of the expanded filaments individually have an average density which is greater than 110% or less than 90% of the average density of the whole synthetic wood material.

11. A method according to Claim 10 wherein the extrusion is carried out so that the amount of polymer present in the filaments extruded from the peripheral orifices is less than that present in the filaments extruded from inner orifices.

12. A method according to Claim 11 where-

in the shapes, lengths, sizes or distribution of the orifices are such that the amount of polymer extruded through each of the peripheral orifices is greater than that extruded through each of the inner ones.

13. A method according to Claim 10 wherein the extrusion is carried out so that the amount of polymer present in the filaments extruded from the peripheral orifices is greater than that present in the filaments extruded from the inner orifices.

14. A method according to Claim 13 wherein the shapes, lengths, sizes or distribution of the orifices is such that the amount of polymer extruded through the peripheral orifices is less than is extruded through each of the inner ones.

15. A method according to Claim 14 wherein the polymer is extruded through a first plate having apertures extending therethrough, each of which has a constant diameter through the thickness of the plate, the peripheral apertures having a smaller diameter than the interior ones and a second plate having apertures extending therethrough, each of which has the same average diameter.

16. A method according to Claim 14 wherein the polymer is extruded through a single plate which is thicker at the periphery than at the interior and has apertures extending therethrough, each of which has the same average diameter.

17. A method according to any one of Claims 10—16 wherein the differences in densities of the several filaments are produced by foaming the filaments by different extents.

18. A method according to claim 10 of making synthetic wood material by extruding a polymer into filaments and subsequently foaming the filaments, while restricting the amount of expansion of each filament, substantially as hereindescribed.

19. A method according to Claim 10 carried out in apparatus constructed and arranged substantially as herein described with reference to and as illustrated in any one of Figures 1, 7—14, and 19—26 of the accompanying drawings.

20. A method according to Claim 10 carried out in apparatus constructed and arranged substantially as herein described with reference to and as illustrated in Figures 2, 4 or 6.

21. A method according to Claim 10 substantially as described in Example 1.

22. A method according to Claim 10 substantially as described in any one of Examples 2—8.

23. A synthetic wood material made by a method claimed in any one of Claims 10—19 and 22.

24. A synthetic wood material made by a method claimed in Claim 20 or 21.



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