LOW THICKNESS SOUND ABSORPTIVE MULTILAYER COMPOSITE

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ABSTRACT
A sound absorptive multilayer composite having an air-impermeable barrier, an air-permeable reinforcing core having an airflow resistance of at least about 100 mks Rayls and a thickness at least about ½ the final composite thickness, and a semipermeable airflow-resistive decorative membrane having an airflow resistance of about 500 to about 4000 mks Rayls can provide improved acoustic performance while maintaining a low thickness.
LOW THICKNESS SOUND ABSORPTIVE MULTILAYER COMPOSITE

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of copending U.S. patent application Ser. No. 10/335,752 filed Jan. 2, 2003, entitled ACOUSTIC WEB, the entire disclosure of which is incorporated by reference herein.

FIELD OF THE INVENTION

This invention relates to sound absorbing multilayer composites, and to precursor components and methods for the preparation or such composites.

BACKGROUND

Multilayer composite articles are sometimes used to absorb sound and thereby reduce noise levels in nearby spaces. For example, sound absorbent multilayer composites may be employed in headliners, trunk linings, hood linings, dash mats, interior panels, carpeting and other porous decorative or functional vehicular facing materials to provide enhanced noise reduction in a vehicle interior.

References relating to acoustic insu...
absorptive composite, the phrase “air-permeable” refers to a layer that can permit the passage of sufficient air through the layer so that the composite can absorb sound in a frequency band of interest in a vehicle interior.

When air permeability values for a component (e.g., a membrane, reinforcing core or barrier) of a multilayer sound absorptive composite are expressed using values in mks Rayls, the recited values may be determined according to ASTM C522 and by measuring the component in place, or carefully removed from, the finished composite. In some instances such values may be deduced or otherwise determined based on the measured airflow resistance of the finished composite or one or more individual or aggregate components.

When used with respect to a barrier, the word “impermeable” refers to an air-permeable film, foil or other substantially non-porous article whose airflow resistance is at least about 100,000 mks Rayls.

When used with respect to a multilayer composite, the phrase “reinforcing core” refers to a core whose stiffness is such that the composite can not be rolled up or folded over without damage.

When used with respect to a multilayer composite, the word “unitary” refers to a composite whose layers adhere together sufficiently so that the composite can normally be cut to fit as needed and installed in a vehicle without objectionable delamination.

FIG. 1 is a schematic side sectional view of a multilayer sound absorptive composite 10. Semipermeable airflow-resistive membrane 12 is colored and textured to provide a decorative appearance, and forms the outermost occupant side layer of composite 10. Membrane 12 is adhered via flame-lamination to reinforcing core 18. Core 18 contains a resin-saturated open cell foam structure filled with chopped fiberglass strands 19. Core 18 is adhered via air-permeable thermoplastic adhesive layer 17 to air-permeable film barrier 24. Decorative membrane 12 limits airflow into composite 10 and may have higher airflow resistance per unit of thickness (viz., higher resistivity) than core 18. Barrier 24 prevents air from flowing through composite 10 and forms the outermost vehicle side layer of composite 10. The cavity having depth D1 between the outermost surface of membrane 12 and the innermost surface of barrier 24 forms a sound absorbing space whose acoustic effectiveness is maximized by placing membrane 12 and barrier 24 at opposing outermost surfaces of composite 10 and thus maximizing cavity depth D1 as a percentage of the overall composite thickness T1. Core 18 provides overall stiffness to composite 10, and enables composite 10 to span long distances (e.g., vehicular roof areas) without objectionably sagging.

FIG. 2 is a schematic side sectional view of a multilayer sound absorptive composite 20. Composite 20 is similar to composite 10 except for its use of reinforcing core 27 in place of core 18 and its somewhat greater cavity depth D2 and composite thickness T2 arising from the greater thickness of core 27 compared to core 18. Core 27 has outer fiberglass mat layers 28 on either side of central open cell foam layer 32, forming an “I-beam” structure somewhat analogous to lumber core plywood.

FIG. 3 is a schematic side sectional view of a multilayer sound absorptive composite 30. Composite 30 is similar to composite 20 except for its use of an air-permeable thermoplastic adhesive layer 15 between membrane 12 and core 27 and its somewhat greater cavity depth D3 and composite thickness T3 arising from the thickness of adhesive layer 15. Composite 30 may be made without using flame lamination to adhere membrane 12 to core 27.

A variety of airflow-resistant membranes may be used in the disclosed multilayer composites. The membrane may be formed, for example, from fibrous precursors such as synthetic fibers, natural fibers or blends of synthetic and natural fibers and processed into a nonwoven web using meltblowing, spunbonding or other suitable web processing techniques that will provide a finished semipermeable open structure having an airflow resistance of about 500 to about 4000 mks Rayls. The membrane may also be formed from microdenier continuous filament or staple fiber yarns (viz., yarns having a denier per filament (dpf) less than about 1, e.g., between about 0.2 and about 1 dpf) and processed into a woven or knit fabric using suitable processing techniques to provide a finished semipermeable open structure having an airflow resistance of about 500 to about 4000 mks Rayls. Preferably the membrane airflow resistance is about 500 to about 2000 mks Rayls. The membrane may for example be less than about 1/2 the total composite thickness. Membranes made from microdenier continuous or staple synthetic fibers, and especially synthetic fibers that are split or splittable, may be preferred. Suitable synthetic fibers include multicomponent (e.g., bicomponent) fibers such as side-by-side, sheath-core, segmented pie, islands in the sea, tipped and segmental ribbon fibers. Splitting may be carried out or encouraged using a variety of techniques that will be familiar to those skilled in the art including carding, air jets, embossing, calendering, hydroentangling or needle punching. The membrane is decorative and thus for a headliner may serve as the outermost occupant side layer and may be visible to vehicle occupants. The membrane may be processed in a variety of ways to alter or improve its appearance, tactile properties (e.g., hand), physical properties (e.g., stiffness or drape) and other desired characteristics. Such processing techniques include pigmentation, dyeing, impregnation, immersion, coating, calendering, stretching, embossing, corrugation, brushing, grinding, flocking and other treatments or steps that will be familiar to those skilled in the art. The membrane preferably has an elongation to break sufficient to enable the composite to survive deep cavity molding without objectionable delamination, rupture or adverse permeability changes. A preferred membrane elongation to break is at least about 5% and more preferably at least about 20%. The membrane also preferably has a thermal resistance sufficient to withstand the rigors of the high temperature molding processes that may be employed in manufacturing vehicular headliners and other multilayer sound absorptive composites. Thus it may be preferred to avoid using membranes containing extensive amounts of low-melting polyolefins or other materials that might cause an objectionable air-permeability change (e.g., a substantial decrease) during a molding cycle. The membrane may be treated as described in the above-mentioned application Ser. No. 10/353,752 so that it has a low surface energy, e.g., less than that of an adjacent thermoplastic adhesive layer (if employed), for example less than about 34 dynes/cm², preferably less than about 30 dynes/cm², and more preferably less than about 28 dynes/cm². Lightweight membranes having basis weights less than 300 g/m² are especially
preferred, more preferably than about 200 g/m² and most preferably from about 100 to about 200 g/m². Stiff or flexible membranes may be employed. For example, the membrane may have a bending stiffness B as low as 0.005 Nm or less when measured according to ASTM D1388 using Option A—Cantilever Test. The selection and processing of suitable membrane materials will be familiar to those skilled in the art. Representative membranes or fibers for use in such membranes are disclosed in U.S. Pat. Nos. 5,459,291, 5,824,973, 6,057,256 and 6,145,617; U.S. Published Patent Application Nos. US 2001/0056788 A1 and US 2003/0104749 A1; Canadian Published Application No. 2,350,477 A1; and PCT Published Application No. WO 99/44817 A1. Representative commercially available membranes or fibers include EVOLON™ fabric (commercially available from Freudenberg & Co.); Nos. T-502, T-512 and T-522 segmented splittable bicomponent fibers from Fiber Innovation technology, Inc.; microdenier woven or warp knit fabrics from Guilford Mills, Inc.; splittable bicomponent fibers from Kanebo Ltd., Kuraray Co. Ltd. and Unitika Ltd. and splittable bicomponent fibers and fabrics from Toray Industries, Inc.

A variety of reinforcing cores may be employed in the disclosed composites. As noted above the core has an airflow resistance of at least about 100 mls Rayls. The core may for example have an airflow resistance of about 200 to about 7000 mls Rayls. As also noted above, the core thickness is at least about ½ the total composite thickness. Preferably the core is at least about 3/4 the total composite thickness. The core may have higher stiffness (viz., higher modulus), higher density or higher airflow resistance than the membrane. The core preferably has a thermal resistance sufficient to withstand the rigors of the molding process. Thus it may be preferred to avoid using cores containing excessive amounts of low-melt polyolefins or other materials that might cause an objectionable air-permeability change (e.g., a substantial decrease) during a molding cycle. The core may for example have a relatively uniform structure such as is shown in FIG. 1, or an I-beam construction in which more dense skin layers flank a less dense central layer such as is shown in FIG. 2 and FIG. 3. Suitable cores include those described in U.S. Pat. Nos. 5,536,556, 5,549,776, 5,565,259, 6,150,287, 6,214,456 B1 and 6,238,507 B1 and Canadian Published Application No. 2,350,477 A1. Representative commercially available cores include AZDEL SUPERLITE™ composites from Azdel, Inc., UROCORE™ and TRU™ from Lear Corp. and ACOUSTICORE™ and POLYBOND™ composites from Johnson Controls, Inc.

A variety of air-impermeable barriers may be employed in the disclosed composites. The barrier may for example have a thickness less than about 2 mm, e.g., less than about 1 mm. Suitable barriers include polymeric films such as polyolefin, polyester or vinyl films and metal foils. One widely-used barrier film that includes an adhesive is INTEGRAL™ 909 adhesive film from Dow Chemical Company.

The membrane, core and barrier are adhered or laminated together to form a unitary composite. Such adhesion or lamination may be accomplished in a variety of ways, and may take place in a single step that addresses all of the layers or in a series of steps that individually address some of the layers. For example, the disclosed sound absorptive multilayer composites may conveniently be made by laying up or applying the individual composite layers in a suitable mold. The layers may be preheated if needed and then compression molded using sufficient heat and pressure to form a unitary composite.

A variety of adhesive measures or adhesive layers may be employed as needed to promote formation of the disclosed unitary composites. For example, the membrane may conveniently be adhered to the core using measures such as compression molding or flame lamination. The core may be adhered to the membrane or barrier using an air-permeable adhesive layer such as a thermoplastic air-permeable adhesive, or by incorporating a suitable polymer in the core (e.g., a thermoplastic urethane) that will form a bond to the membrane or barrier upon heating. Other measures for joining together the various layers and forming a unitary composite will be apparent to those skilled in the art. The finished composite may be air quenched as needed and cut (using, for example, a water jet) to yield the desired completed parts.

A variety of thermoplastic adhesives may optionally be used in the disclosed composites. The multilayer composites may for example contain one or two adhesive layers which may be the same or different. Desirably the adhesive layers will satisfactorily bond together adjacent layers of the composite when processed using typical high temperature molding processes while maintaining adequate air-permeability, and will maintain adequate bonding strength at the expected use temperatures that may be experienced inside a vehicle (e.g., at temperatures of 70° C. or more). Preferred adhesives include copolyesters, polyesters, polyurethanes, polyamides, ethylene vinyl acetate, low density polyethylenes, atactic polypropylenes, propylene/1-butene/ethylene terpolymers, and propylene/ethylene, 1-butene/ethylene, 1-butene/propylene copolymers and copolymers of any of the foregoing. Other useful adhesives include those described in U.S. Pat. Nos. 3,932,328, 4,081,415, 4,692,370, 5,248,719, 5,869,562 and 6,288,149. The adhesive may also be a low basis weight thermoplastic scrim such as SHARNET™ hot melt adhesive web from Bostik-Findley Company. The selection and processing of such adhesives will largely be familiar to those skilled in the art. It may be noted however that although the completed multilayer composite’s sound absorption characteristics will depend in large measure on the known porosity characteristics of the composite’s thicker layers (e.g., those of the semipermeable airflow-resistant membrane and reinforcing core), the sound absorption characteristics may also depend a great deal on more process- dependent factors including the manner in which adhesive layers are applied and the chosen composite molding or laminating techniques.

The disclosed composites may consist of or consist essentially of the recited layers. The disclosed composites may include additional interior or exterior layers, coatings, treatments or other elements if desired. For example, the composite may include one or more reinforcing scrim layers, a vehicle side adhesive layer, fire retardant additives or treatments, antennas, and other layers, coatings treatments or elements that will be apparent to those skilled in the art.

The disclosed sound absorptive multilayer composites preferably have a cavity depth that is at least 75%, more preferably at least 90% and most preferably at least
95% of the total composite thickness. For purposes of making this comparison, the cavity depth may be measured from the air-impermeable barrier innermost side to the membrane outermost side, and the total composite thickness may be measured from the composite vehicle side to the composite occupant side.

[0035] The disclosed sound absorptive multilayer composites can significantly attenuate sound waves passing into or through an interior of the vehicle. The composite is positioned at an appropriate interior location (e.g., near the roof, pillars, firewall, floor pan or door panels) so that it absorbs sound waves and reduces perceived noise levels.

[0036] Various modifications and alterations of this invention will be apparent to those skilled in the art without departing from the scope and spirit of this invention. This invention should not be restricted to that which has been set forth herein only for illustrative purposes.

1. A sound absorptive multilayer composite comprising in order:

a) a semipermeable airflow-resistant decorative membrane having an airflow resistance of about 500 to about 4000 mks Rayls,

b) an air-permeable reinforcing core having an airflow resistance of at least about 100 mks Rayls and a thickness at least about 2/3 the total composite thickness, and

c) an air-impermeable barrier.

2. A composite according to claim 1 wherein the composite has a cavity depth at least 90% of the total composite thickness, with the cavity depth being measured from the air-impermeable barrier innermost side to the membrane outermost side.

3. A composite according to claim 1 wherein the composite has a cavity depth at least 95% of the total composite thickness, with the cavity depth being measured from the air-impermeable barrier innermost side to the membrane outermost side.

4. A composite according to claim 1 wherein the membrane has an airflow resistance of about 500 to about 1500 mks Rayls.

5. A composite according to claim 1 wherein the membrane is colored or textured to provide a decorative appearance.

6. A composite according to claim 1 wherein the membrane comprises a nonwoven web.

7. A composite according to claim 1 wherein the membrane comprises knit or woven fabric comprising microdenier yarns.

8. A composite according to claim 1 wherein the membrane comprises multicomponent fibers.

9. A composite according to claim 1 wherein the membrane comprises split or splittable bicomponent fibers.

10. A composite according to claim 1 wherein the core has a thickness at least about 3/4 the total composite thickness.

11. A composite according to claim 1 wherein the core has an airflow resistance less than about 2000 mks Rayls.

12. A method for making a multilayer sound absorptive composite comprising:

a) providing a stack of layers comprising in order an air-impermeable barrier, an air-permeable reinforcing core having an airflow resistance of at least about 100 mks Rayls and a thickness at least about 1/2 the final composite thickness, and a semipermeable airflow-resistant decorative membrane having an airflow resistance of about 500 to about 4000 mks Rayls, and

b) laminating the stack of layers together under sufficient heat and pressure to form a unitary sound absorptive multilayer composite.

13. A method according to claim 12 wherein the composite has a cavity depth at least 90% of the total composite thickness, with the cavity depth being measured from the air-impermeable barrier innermost side to the membrane outermost side.

14. A method according to claim 12 wherein the composite has a cavity depth at least 95% of the total composite thickness, with the cavity depth being measured from the air-impermeable barrier innermost side to the membrane outermost side.

15. A method according to claim 12 wherein the membrane has an airflow resistance of about 500 to about 1500 mks Rayls.

16. A method according to claim 12 wherein the membrane is colored or textured to provide a decorative appearance.

17. A method according to claim 12 wherein the membrane comprises a nonwoven web.

18. A method according to claim 12 wherein the membrane comprises knit or woven fabric comprising microdenier yarns.

19. A method according to claim 12 wherein the membrane comprises multicomponent fibers.

20. A method according to claim 12 wherein the membrane comprises split or splittable bicomponent fibers.

21. A method according to claim 12 wherein the core has a thickness at least about 3/4 the total composite thickness.

22. A method according to claim 12 wherein the core has an airflow resistance less than about 2000 mks Rayls.

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