process associated with the production of flexible composite aerogel insulation also presents challenges for the use of rigid fibrous based materials as reinforcement for these composites. Fibrous materials with high binder content and/or materials that are rigid cannot sustain the winding/unwinding process of rolled-good manufacture without sustaining copious amounts of defects in the form of delaminations, buckles and/or tears. Due to substantially improved economics, there is a strong desire to enable the use of lower cost fibrous reinforcements with high binder content for the production of flexible aerogel insulation. To date, these types of reinforcement materials are too rigid to be wound around a mandrel with a small radius without imparting non-conformities in the presence of folds, tears and delaminations. As such, there is a need to develop a process that could enable the winding and subsequent aerogel processing of such material without imparting the damage associated with winding. For the purposes of this patent application, a rigid panel means a panel of practical installable surface area (from 0.1 to 10 m^2) with the ability to hold its own weight without bending to the extent that it interferes in the practical handling and installation of the panel. While one can make rigid panels by attaching non-rigid planar material to another rigid material, the rigid panel as defined above excludes such attached combinations and the rigid panels of the present invention focuses on one or more gel-composite layers attached through adhesives or otherwise being rigid as described above.

The present invention also describes an efficient method to manufacture flat-panel aerogel-based boards using low-cost fibrous substrates or open-cell foam substrates with increased rigidity. Such substrates are not normally amenable to standard processing in a cylindrical vessel for the various processes involved in manufacturing gel composites in rolled good form. Efficient utilization of vessels necessitates the manufacture of fiber reinforced aerogel materials in rolled good form in order to maximize the volume of a cylindrical vessel and reduce the fixed costs associated with production. As such, the fiber reinforcements used to reinforce aerogels need to have sufficient flexibility to sustain winding and unwinding. Materials with excess rigidity and/or materials with high binder content do not normally process well and typically result in the manufacture of aerogel composites with excessive defects in the form of folds, buckles, delaminations and tears (Figure 1). The final product formed using such rigid reinforcements is thus not amenable to the production of flat-panel board stock, a preferred product form for building and construction applications. The excessive amount of defects in such products diminishes thermal performance, material integrity and severely complicates any fabrication process.

We have discovered that the longitudinal segmentation (across the width of the blanket) of rigid non-woven fiber reinforcement or open-cell foam reinforcement enables sufficient flexibility so that the product can be wound/unwound with minimal delamination or buckling. In another embodiment, a facing sheet is integrated on one side of the blanket to provide additional tensile strength. Segmented non-woven blankets may be prepared by various methods including scoring the non-woven partially across its thickness, attaching separate segments to a face sheet, thus creating a segmented sheet connected together by the face sheet, scoring the non-woven sheet all the way and attaching a face sheet or any other practical ways known in the art. The terms segmentation and scoring are used interchangeably in this document to refer to the process of making segmented sheets in which segments are held together by a face sheet. Alternatively, the scoring (cutting) is performed for less than the thickness of the sheets such that the segmented sheet is still in one piece and held together by the portions through the thickness not cut by the scoring process. Certain scored non-woven sheets are available in the market. An example is a mineral wool non-woven, Isoroll MW from Isolparma S.r.l. The segmented non-woven sheet is carried by a face sheet/veil through the fiber-reinforced aerogel composite production process and the subsequent fabrication of rigid panel see schematic in Figures 2 and 6. The non-woven fiber reinforcement can be efficiently wound in a cylindrical form and any gel-infused sheets manufactured therefrom may be unwound into a flat board-like shape with little to no damage. This allows for the efficient casting of a wet gel/fiber composite using a flat conveyor belt and the winding of the final wet-gel composite to enable efficient utilization in processes involving the use of cylindrical vessels. Alternatively, segmented non-woven sheet may be pre-wound with another non-permeable layer adjoining its major surface and a gel precursor may be infused into the fiber matrix along the axis of the winding, subsequently unwound after gel formation and further processed to produce a dry segmented gel composites. More importantly, most of the visible air gaps in the gel composite as produced in the cylinderical form, between adjoining segments, effectively disappear upon unwinding into flat stock, ensuring that thermal performance of a typical aerogel-fiber composite is maintained. The final material can be unwound into a near perfect flat panel, enabling the efficient production of rigid panels or aerogel-based boards suitable for building and construction applications. What was surprising and unexpected was that when wound (either as wet or dry gel), the gaps, i.e. gaps between two adjoining segments separated in a clean line without shattering the wet or dried gel. Aerogels and other dried gels made from the gel precursors described in the present invention are fragile material that when subjected to any stress are prone to crack and shatter. However,

CLAIMS

1. A process of manufacturing a segmented, reinforced dried aerogel composite sheet comprising the steps of:

providing a segmented reinforcement sheet comprising a segmented fiber reinforcement sheet or a segmented open cell foam reinforcement sheet, wherein the segmented reinforcement sheet has a length, a width, and a thickness, and the segmented reinforcement sheet comprises separate segments attached to a face sheet, wherein the separate segments are connected together by the face sheet to create a segmented reinforcement sheet segmented through the thickness across the width of the segmented reinforcement sheet;

combining the segmented reinforcement sheet with a gel precursor;

gelling the gel precursor in the segmented reinforcement sheet to make a segmented reinforced gel composite sheet; and

drying the segmented reinforced gel composite sheet to make a segmented, reinforced dried aerogel composite sheet.

2. The process of claim 1 further comprising applying an adhesive to at least one face of the segmented, reinforced dried aerogel composite sheet and attaching the segmented reinforced dried aerogel composite sheet to another planar material.

3. The process of claim 1, further comprising the steps of:

providing the segmented, reinforced dried aerogel composite sheet of claim 1 with at least two major surfaces and multiple segmented cross-sectional surfaces;

applying an adhesive to at least one surface of said segmented, reinforced dried aerogel composite sheet; and

attaching said segmented, reinforced dried aerogel composite to another dried aerogel composite sheet.

4. The process of claim 1, wherein the segmented reinforcement sheet has a facing layer or a facing sheet attached thereto.

5. The process of claim 4, wherein the facing layer or the facing sheet comprises fibers.

6. The process of claim 1, wherein the segmented fiber reinforcement sheet comprising non-continuous fibers.

7. The process of claim 1, further comprising the step of incorporating additives into the gel precursor, selected from the group consisting of titanium dioxide, iron oxides, carbon black, graphite, aluminum hydroxide, phosphates, borates, metal silicates, metallocenes, molybdates, stannates, carbonates, zinc oxides, aluminum oxides, antimony oxides, magnesiumzinc blends, magnesium-zinc-antimony blends, silicon carbide, molybdenum silicide, manganese oxides, iron titanium oxide, zirconium silicate, zirconium oxide, iron titanium oxide (ilmenite), chromium oxide and a combination thereof.

8. The process of claim 1, further comprising the step of adding at least a binder to the fibers of the segmented fiber reinforcement sheet or wherein the segmented fiber reinforcement sheet comprises at least one binder.

9. The process of claim 1, wherein at least a segment of the segmented reinforcement sheet is rigid.

10. The process of claim 1, wherein the gel precursor comprises a material selected from the group consisting of zirconia, yttria, hafnia, alumina, titania, ceria, silica, polyacrylates, polystyrenes, polyacrylonitriles, polyurethanes, polyimides, polyfurfural alcohol, phenol furfuryl alcohol, melamine formaldehydes, resorcinol formaldehydes, cresol formaldehyde, phenol formaldehyde, polyvinyl alcohol dialdehyde, polycyanurates, polyacrylamides, epoxies, agar, and agarose and combinations thereof.

11. The process of claim 1, wherein the segmented fiber reinforcement sheet comprising materials selected from the group consisting of mineral wool, glass wool,

fiber glass, polyester, polyolefin terephthalates, poly(ethylene) naphthalate, polycarbonates, cellulose fiber, aliphatic polyamides, cotton based polyester-polyurethanes, Carbon based fibers, graphite, polyacrylonitrile (PAN), oxidized PAN, uncarbonized heat treated, fiberglass based material, E-glass, silica based fibers, quartz, Polyaramid fibers, polyolefins, polypropylene fibers, fluoropolymers, polytetrafluoroethylene (PTFE), Silicon carbide fibers, ceramic, Acrylic polymers, fibers of wool, silk, hemp, leather, suede, poly(p-phenylene-2,6-benzobisoxazole) (PBO), Liquid crystal material, Polyurethanes, polyamaides, Wood fibers, Boron, Aluminum, Iron, Stainless Steel fibers, polyether ether ketone (PEEK), polyether sulfone (PES), polyetherimide (PEI), polyether ketone (PEK), poly(p-phenylene sulfide) (PPS) and combinations thereof.

12. The process of claim 2, wherein the adhesive is selected from the group consisting of potassium water glass, sodium water glass, cement and alkali-activated aluminosilicates, polyethylene, polyoxydiphenylene-pyromellitimide, polyurethane, polyester, natural rubber, synthetic rubber, chlorosulfonated polyethylene synthetic rubber, plastic alloys, polytetrafluoroethylene (PTFE), polyvinyl halides, polyester, polychloroprene, acrylics, nitriles, ethylene propylene diene terpolymer (EPDM), polytrimethylene terephthalate, viton, vinyls, vinyl-acetate, ethylene-vinyl acetate, styrene, styreneacrylates styrene-butadienes, polyvinyl alcohol, polyvinylchloride, acrylamids, phenolics and combinations thereof.

13. The process of claim 1, wherein the thermal conductivity of the dried segmented, reinforced aerogel composite sheet is less than 25 mW/mK at ambient conditions.

14. The process of claim 1, further comprising the steps of rolling of the segmented reinforced gel composite sheet prior to the drying step to produce a roll having an axis, and wherein the rolling of the segmented reinforced gel composite sheet is such that any gaps formed between the segments of the reinforced gel composite sheet face away from the axis of the roll.

15. A segmented, reinforced dried aerogel composite sheet comprising a segmented reinforcement sheet; and a dried aerogel, wherein the segmented reinforcement sheet comprises a segmented fiber reinforcement sheet or a segmented open cell foam reinforcement sheet, wherein the segmented reinforcement sheet has a length, a width and a thickness, and the segmented reinforcement sheet comprises separate segments attached to a face sheet, and the separate segments are connected together by the face sheet to create a segmented reinforcement sheet segmented through the thickness across the width of the segmented reinforcement sheet, and wherein the dried aerogel is continuous through at least one segment of the segmented reinforcement sheet, and at least one gap exists between at least two adjoining segments with discontinuity in both the dried aerogel and the segmented reinforcement sheet.

16. The segmented, reinforced dried aerogel composite sheet of claim 15, further comprising fillers selected from the group consisting of titanium dioxide, iron oxides, carbon black, graphite, aluminum hydroxide, phosphates, borates, metal silicates, metallocenes, molybdates, stannates, carbonates, zinc oxides, aluminum oxides, antimony oxides, magnesium-zinc blends, magnesium-zinc-antimony blends, silicon carbide, molybdenum silicide, manganese oxides, iron titanium oxide, zirconium silicate, zirconium oxide, iron titanium oxide (ilmenite), chromium oxide and a combination thereof.

17. The segmented, reinforced dried aerogel composite sheet of claim 15, wherein the segmented fiber reinforcement sheet comprises at least a binder in the fiber.

18. The segmented, reinforced dried aerogel composite sheet of claim 15, wherein the segmented reinforcement sheet has a facing layer or a facing sheet attached thereto.

19. The segmented, reinforced dried aerogel composite sheet of claim 18, wherein the facing layer comprises fibers.

20. The segmented, reinforced dried aerogel composite sheet of claim 15, wherein the segmented fiber reinforcement sheet comprises non-continuous fibers.

21. The segmented, reinforced dried aerogel composite sheet of claim 15, further comprising additives selected from the group consisting of titanium dioxide, iron oxides, carbon black, graphite, aluminum hydroxide, phosphates, borates, metal silicates, metallocenes, molybdates, stannates, carbonates, zinc oxides, aluminum oxides, antimony oxides, magnesium-zinc blends, magnesium-zinc-antimony blends, silicon carbide, molybdenum silicide, manganese oxides, iron titanium oxide, zirconium silicate, zirconium oxide, iron titanium oxide (ilmenite), chromium oxide and a combination thereof.

22. The segmented, reinforced dried aerogel composite sheet of claim 15, wherein at least a segment of the segmented reinforcement sheet is rigid.

23. The segmented, reinforced dried aerogel composite sheet of claim 15, wherein the dried gel comprises a material selected from the group consisting of zirconia, yttria, hafnia, alumina, titania, ceria, silica, polyacrylates, polystyrenes, polyacrylonitriles, polyurethanes, polyimides, polyfurfural alcohol, phenol furfuryl alcohol, melamine formaldehydes, resorcinol formaldehydes, cresol formaldehyde, phenol formaldehyde, polyvinyl alcohol dialdehyde, polycyanurates, polyacrylamides, epoxies, agar, and agarose and combinations thereof.

24. The segmented, reinforced dried aerogel composite sheet of claim 15, wherein the segmented reinforcement sheet comprises a fiber reinforcement sheet comprising materials selected from the group consisting of mineral wool, glass wool, fiber glass, polyester, polyolefin terephthalates, poly(ethylene) naphthalate, polycarbonates, cellulose fiber, aliphatic polyamides, cotton based polyester-polyurethanes, Carbon based fibers, graphite, polyacrylonitrile (PAN), oxidized PAN, uncarbonized heat treated, fiberglass based material, E-glass, silica based fibers, quartz, Polyaramid fibers, polyolefins, polypropylene fibers, fluoropolymers, polytetrafluoroethylene (PTFE), Silicon carbide fibers, ceramic, Acrylic polymers, fibers of wool, silk, hemp,

leather, suede, poly(p-phenylene-2,6-benzobisoxazole) (PBO), Liquid crystal material, Polyurethanes, polyamaides, Wood fibers, Boron, Aluminum, Iron, Stainless Steel fibers, polyether ether ketone (PEEK), polyether sulfone (PES), polyetherimide (PEI), polyether ketone (PEK), poly(p-phenylene sulfide) (PPS) and combinations thereof.

25. The segmented, reinforced dried gel composite sheet of claim 15, wherein the thermal conductivity of the segmented, reinforced aerogel composite sheet is less than 25 mW/mK at ambient conditions.

26. A panel comprising at least two layers of reinforced dried aerogel composites, wherein at least one layer comprises the segmented, reinforced dried aerogel composite sheet of one of claims 15 to 25.

27. The panel of claim 26, further comprising an adhesive is selected from the group consisting of potassium water glass, sodium water glass, cement and alkali-activated aluminosilicates, polyethylene, poly-oxydiphenylene-pyromellitimide, polyurethane, polyester, natural rubber, synthetic rubber, chlorosulfonated polyethylene synthetic rubber, plastic alloys, polytetrafluoroethylene (PTFE), polyvinyl halides, polyester, polychloroprene, acrylics, nitriles, ethylene propylene diene terpolymer (EPDM), polytrimethylene terephthalate, viton, vinyls, vinyl-acetate, ethylene-vinyl acetate, styrene, styreneacrylates styrene-butadienes, polyvinyl alcohol, polyvinylchloride, acrylamids, phenolics and combinations thereof.