[10] U.S. Patent No. 5,843,390 describes a catalytic filter for removing contaminants such as NO_X from a fluid stream. This filter employs composite fibers containing catalytic particles that are chipped into staple fibers and made into a catalytic felt material. This filter can remove macro particles, such as dust, before the dust can clog active filter sites, and effectively convert undesirable contaminants catalytically. However, this filter has a costly manufacturing process, and improved performance is still needed.

[11] As noted above, various catalytic materials for filtering contaminants from a fluid stream have been disclosed; however, such materials are subject to many forms of failure, deterioration, or clogging. Thus, there is a continuing need for catalytic filter materials that can effectively remediate contamination while remaining durable and providing sufficient flow rate to be useful as filters.

SUMMARY

[11a] In one aspect, provided herein is a catalytic composite, comprising:

a catalytic layered assembly comprising:

a porous catalytic fluoropolymer film having an upstream side and a downstream side; and

one or more felt batts comprising a first felt batt positioned adjacent the upstream side of the porous catalytic fluoropolymer film; wherein the porous catalytic fluoropolymer film comprises a plurality of perforations;

wherein each perforation of the plurality of perforations has a diameter of 0.1 mm to 3 mm; and

wherein a percent open area of the porous catalytic fluoropolymer film is from 0.14% to 50%.

[11b] In another aspect, provided herein is a filter comprising the catalytic composite as described herein.

[12] In one example, the present disclosure relates to a catalytic composite. The catalytic composite includes a catalytic layered assembly that includes a porous catalytic fluoropolymer film having a first, upstream side and a second, downstream side; and one or more felt batts. A first felt batt is positioned adjacent the upstream

side of the porous catalytic fluoropolymer film to form the catalytic composite, and the fluoropolymer film is perforated to enhance air permeability of the fluoropolymer film without degrading the suitability of the catalytic composite for catalyzing the reduction or removal of chemical contaminants in a fluid flowing therethrough. Each felt batt can be formed of fleece formed from PTFE staple fiber. The composite can be connected together by a plurality of perforations formed by a needle punching process, by a needling process, or both. The porous catalytic fluoropolymer film can be perforated by punching at a diameter corresponding to a punch diameter from 0.3 to 6.5 mm; or by needling at a diameter corresponding to a needle diameter from 0.1 to 3.0 mm. Each felt batt can be formed of a fluoropolymer such as, but not limited to, a PTFE felt, a PTFE fleece, an ePTFE felt or

fleece, or a fluoropolymer staple fiber woven or nonwoven. The catalytic composite may also include multiple porous catalytic fluoropolymer films.

[13] The composite can include additional layers, such as a scrim positioned on the downstream side of the porous catalytic fluoropolymer film, a second felt batt positioned downstream of the porous catalytic fluoropolymer layer and/or downstream of the scrim, and a porous protective layer disposed on an upstream side of the first felt batt for blocking particulate ingress. The porous protective layer can be an expanded polytetrafluoroethylene (ePTFE) membrane or other suitable porous expanded ePTFE layer.

[14] The catalytic composite can, according to some examples, include perforations in the porous catalytic fluoropolymer film alone; or in some cases, multiple layers may be perforated together. For example, in one example, the fluoropolymer film, felt batt, and other layers may be connected together by way of the needling and/or needle punching operations that perforate the fluoropolymer film. The fluoropolymer film can have a perforation pattern resulting in an open area of the fluoropolymer film from 0.14% to 50%. A resulting permeability of the catalytic composite can result in a flow rate in the range of 0.9 to 21.3 m/min at 124.5 Pa.

[15] In one example, the present disclosure relates to a catalytic composite formed of a perforated porous membrane that is filled with a catalytic material and perforated.

[16] In one example, the present disclosure relates to a method of forming a catalytic composite as described above. The catalytic composite can be formed by forming a catalytic layered assembly, by layering a porous catalytic fluoropolymer film with a first felt batt on a first side of the porous catalytic fluoropolymer film. The layered assembly can be connected together to form a multilayered composite, and the fluoropolymer film can be perforated such that the multilayered composite has a minimum air permeability of at least 0.9 m/min at 124.5 Pa.

[17] The method can include steps of adding layers prior to the connecting step, e.g., adding a scrim to the catalytic layered assembly on a second side of the porous catalytic fluoropolymer film opposite the first side, adding a second felt batt to the layered assembly adjacent the scrim and opposite the porous catalytic fluoropolymer film; and/or adding a porous protective membrane to the layered assembly adjacent the first felt batt and opposite the porous catalytic fluoropolymer film.

[18] Connecting the layered assembly together to form the multilayered composite can include connecting the catalytic layered assembly together via the perforation step, via an adhesive, via a heat treatment step, or any suitable combination of these steps. For example, in at least one example, the catalytic layered assembly is set via a heat treatment step that includes heat treating the multilayered composite at a temperature in the range of 290˚C to 330˚C for at least 1 minute, or until the assembly has reached thermal stability.

[19] Perforating the fluoropolymer film can include a needle punching process, a needling process, or a combination of the two. For example, a perforation pattern can be needled into the fluoropolymer film to an open area of at least 0.2%. Alternatively, the perforation pattern may be needle punched into the multilayered composite to an open area of at least 0.2%. Further, the needling or needle punching steps may be performed on the layered assembly, including other assembled layers, resulting in perforations of the fluoropolymer film along with minor deformation / perforation of the adjacent layers, which may connect the layers.

[20] In one example, the present disclosure relates to a catalytic article that includes a perforated porous polymeric membrane containing therein a catalytic material. The perforated porous polymeric membrane contains a plurality of pores; and the catalytic material at least partially fills the pores of the porous membrane. In some specific examples, the porous membrane has a microstructure including, or in some cases

substantially made up of, fibrils. The catalytic material can be enmeshed in the fibrils of the microstructure. In various examples, the catalytic material extends from into the pores of the porous membrane.

[21] In one example, the present disclosure relates to a method of using a catalytic filter that includes a catalytic composite as described above. For example, in one example a catalytic filter is provided that includes a catalytic composite as described above. The catalytic filter is placed in a fluid stream and oriented with the scrim upstream of the fluoropolymer film with respect to a flow direction of the fluid stream, and the fluid stream is passed through the catalytic filter to remove chemical and/or particulate contaminants therefrom.

[22] These and other examples, along with many of their advantages and features, are described in more detail in conjunction with the below description and attached figures.

BRIEF DESCRIPTIONS OF THE DRAWINGS

[23] The accompanying drawings are included to provide a further understanding of the disclosure and are incorporated in and constitute a part of this specification, illustrate embodiments, and together with the description serve to explain the principles of the disclosure.

[24] FIG. 1 is a schematic illustration of a composite filter material that includes a perforated, porous catalytic fluoropolymer film assembled with an upstream felt batt, in accordance with one embodiment of the present disclosure;

[25] FIG. 2 is a schematic illustration of a second composite filter material that includes a perforated, porous catalytic fluoropolymer film assembled with a scrim, with upstream and downstream felt batts, and a protective porous membrane;

WHAT IS CLAIMED IS:

1. A catalytic composite, comprising:

a catalytic layered assembly comprising:

a porous catalytic fluoropolymer film having an upstream side and a downstream side; and

one or more felt batts comprising a first felt batt positioned adjacent the upstream side of the porous catalytic fluoropolymer film; wherein the porous catalytic fluoropolymer film comprises a plurality of perforations;

wherein each perforation of the plurality of perforations has a diameter of 0.1 mm to 3 mm; and

wherein a percent open area of the porous catalytic fluoropolymer film is from 0.14% to 50%.

2. The catalytic composite of claim 1, wherein the one or more felt batts comprises fleece wherein the fleece comprises PTFE staple fiber.

3. The catalytic composite of any of the preceding claims, wherein the catalytic layered assembly is connected together by the plurality of perforations.

4. The catalytic composite of any of the preceding claims, further comprising a porous protective layer disposed on an upstream side of the first felt batt, wherein the porous protective layer is configured to block particulate ingress.

5. The catalytic composite of any of the preceding claims, wherein the porous catalytic fluoropolymer film comprises an expanded polytetrafluoroethylene (ePTFE) film.

6. The catalytic composite of any of the preceding claims, wherein the porous catalytic fluoropolymer film comprises catalytic particles suspended in an ePTFE matrix.

7. The catalytic composite of any of the preceding claims, wherein the one or more felt batts comprises a fluoropolymer.

8. The catalytic composite of any of the preceding claims, wherein the catalytic composite has an air permeability corresponding to a flow rate in the range of 0.6 to 21.3 m/min at 124.5 Pa.

9. A filter comprising the catalytic composite of any of the preceding claims.

10. The catalytic composite of any of the preceding claims, wherein the porous catalytic fluoropolymer film has a perforation density of 1 to 64 perforations per cm^2 of the porous catalytic fluoropolymer film.

11. The catalytic composite of any of the preceding claims, wherein the porous catalytic fluoropolymer film has a perforation density of 185 to 558 perforations per cm^2 of the perforated porous catalytic fluoropolymer film.

12. The catalytic composite of any of the preceding claims comprising two or more felt batts, the two or more felt batts comprising:

the first felt batt positioned adjacent the upstream side of the porous catalytic fluoropolymer film; and

a second felt batt positioned on a downstream side of the porous catalytic fluoropolymer film.

13. The catalytic composite of claim 12, further comprising a scrim positioned on the downstream side of the porous catalytic fluoropolymer film between the porous catalytic fluoropolymer film and the second felt batt.

14. The catalytic composite any of the preceding claims, wherein multiple layers of the catalytic composite are perforated and comprise the plurality of perforations.

15. The catalytic composite of any of the preceding claims, wherein the first felt batt is perforated and comprises the plurality of perforations.

16. The catalytic composite of claim 13, wherein the scrim is perforated and comprises the plurality of perforations.

17. The catalytic composite of claim 13, wherein the first felt batt and the scrim are perforated and comprise the plurality of perforations.