its growth substrate. Tearing and buckling can produce poor surface conformality and coverage upon transferring the graphene film to a secondary substrate. Some processes for affecting removal of a graphene film from its growth substrate can also produce undesirable chemical damage to the graphene film, which can degrade its desirable properties.

[0009] One solution for addressing the difficulties posed by unsupported graphene films involves depositing a supporting layer on the graphene film that temporarily provides mechanical stabilization during the transfer process. Poly(methyl methacrylate) (PMMA) layers have been used in this regard. Once transfer to the secondary substrate is complete, the supporting layer is removed from the graphene film, meaning that the supporting layer is sacrificial and does not remain associated with the graphene film in its end deployment configuration. The use of a sacrificial supporting layer to promote transfer of graphene films can be undesirable for a number of reasons including, for example, incomplete layer removal following transfer, chemical damage to the graphene film and/or the secondary substrate during the layer removal process, poor surface conformality of the graphene film to the secondary substrate due to constrainment by the supporting layer, and potential incursion of the supporting layer into perforations within the graphene film. Chemicals used to affect removal of the sacrificial supporting layer can often be particularly incompatible with the polymer materials forming the secondary substrate. Further, the additional processing operations needed to deposit and then remove the sacrificial supporting layer can be undesirable from a time and cost standpoint.

[0010] In view of the foregoing, facile techniques for manipulating graphene films without using a sacrificial supporting layer would be of considerable benefit in the art. The present disclosure satisfies the foregoing need and provides related advantages as well.

SUMMARY

There is provided a process comprising: providing a two-dimensional material adhered to a growth substrate; depositing a supporting layer on the two-dimensional material while the two-dimensional material is adhered to the growth substrate; and releasing the two-dimensional material from the growth substrate, the two-dimensional material remaining in

contact with the supporting layer following release of the two-dimensional material from the growth substrate.

There is also provided a process comprising: providing a graphene or graphene-based film adhered to a growth substrate, the growth substrate comprising a metal; perforating the graphene or graphene-based film to introduce a plurality of pores therein; depositing a supporting layer on the graphene or graphene-based film while the graphene or graphene-based film is adhered to the growth substrate, the supporting layer also comprising a plurality of pores; and releasing the graphene or graphene-based film from the growth substrate, the graphene or graphene-based film remaining in contact with the supporting layer following release of the film from the growth substrate.

There is provided a filtration membrane comprising a perforated graphene or graphene-based material and a supporting layer, the filtration membrane being prepared by the process as disclosed herein.

In one aspect, there is disclosed a membrane comprising: a first layer comprising 1 to 5 layers of a perforated graphene or a perforated graphene-based material formed by chemical vapor deposition that has been subjected to nanoparticle bombardment; a supporting layer in contact with the first layer that comprises a plurality of filaments formed by a wet electrospinning process or a dry electrospinning process; and a secondary substrate comprising a porous polymer, wherein the first layer is positioned between the secondary substrate and the supporting layer or the supporting layer is positioned between the first layer and the secondary substrate.

Another aspect relates to a membrane comprising: a first layer comprising a perforated graphene or a perforated graphene-based material; a porous or permeable supporting layer different from the first layer; and a third layer comprising a porous or permeable secondary substrate, wherein the first layer is positioned between the secondary substrate and the supporting layer or the supporting layer is positioned between the first layer and the secondary substrate.

[0011] In various embodiments, processes for manipulating a two-dimensional material are described herein. In some embodiments, the processes can include providing a two-dimensional material adhered to a growth substrate, depositing a supporting layer on the two-dimensional material while the two-dimensional material is adhered to the growth substrate, and releasing the two-dimensional material from the growth substrate. The two-dimensional material remains in contact with the supporting layer following release of the

CLAIMS

1. A membrane comprising:

a first layer comprising 1 to 5 layers of a perforated graphene or a perforated graphene-based material formed by chemical vapor deposition that has been subjected to nanoparticle bombardment;

a supporting layer in contact with the first layer that comprises a plurality of filaments formed by a wet electrospinning process or a dry electrospinning process; and

a secondary substrate comprising a porous polymer,

wherein the first layer is positioned between the secondary substrate and the supporting layer or the supporting layer is positioned between the first layer and the secondary substrate.

2. A membrane comprising:

a first layer comprising a perforated graphene or a perforated graphene-based material;

a porous or permeable supporting layer different from the first layer; and

a third layer comprising a porous or permeable secondary substrate,

wherein the first layer is positioned between the secondary substrate and the supporting layer or the supporting layer is positioned between the first layer and the secondary substrate.

3. The membrane of claim 2, wherein the graphene or the graphene-based material comprises 1 to 5 layers of graphene or graphene-based material.

4. The membrane of claim 2, wherein the graphene or the graphene-based material is perforated via nanoparticle bombardment.

5. The membrane of claim 2, wherein the graphene or the graphene-based material comprises at least 90% graphene.

6. The membrane of claim 2, wherein the graphene or the graphene-based material is in contact with the supporting layer.

7. The membrane of claim 2, wherein the graphene or the graphene-based material is formed by chemical vapor deposition.

8. The membrane of claim 2, wherein the supporting layer comprises a plurality of filaments formed by a wet electrospinning process or a dry electrospinning process.

9. The membrane of claim 2, wherein the supporting layer comprises a plurality of polymer filaments.

10. The membrane of claim 2, wherein the porous or permeable secondary substrate comprises a porous polymer.

11. The membrane of claim 2, wherein the first layer is positioned between the secondary substrate and the supporting layer.

12. The membrane of claim 2, wherein the supporting layer is positioned between the first layer and the secondary substrate.

13. The membrane of claim 2, wherein the supporting layer comprises pores.

14. The membrane of claim 13, wherein porous supporting layer has a pore size gradient.

15. The membrane of claim 2, wherein the graphene or the graphene-based material is perforated with pores and the supporting layer comprises pores, wherein the pores in the graphene or the graphene-based material are smaller than the pores in the supporting layer.

16. The membrane of claim 2, wherein the supporting layer comprises a porous mat of polymer filaments.

17. The membrane of claim 2, wherein the supporting layer comprises a mat of fibers, the fibers having a diameter between about 10 nm and about 500 nm

18. The membrane of claim 2, wherein the supporting layer comprises a porous film.

19. The membrane of claim 2, wherein the supporting layer comprises a porous polymer film.

20. The membrane of claim 2, wherein the supporting layer the supporting has a thickness between about 500 nm and about 10 μm.

21. The membrane of claim 2, wherein the supporting layer has a thickness of 1 mm or less.

22. The membrane of claim 2, wherein the supporting layer comprises a porous or permeable polymer or a porous or permeable ceramic material.

23. The membrane of claim 2, wherein the graphene or graphene-based film are at least 10-fold smaller than the plurality of pores in the supporting layer.