CLAIMS

What is claimed is:

1. A gripping apparatus comprising:

a palm member;

a plurality of finger members configured to couple to the palm member, each of the plurality of finger members comprising:

a plurality of phalange members arranged in series along a longitudinal axis of the finger member, each phalange member being formed of an elastomer;

a multilayer finger membrane configured to encapsulate the plurality of phalange members, the multilayer finger membrane being formed of multiple material layers, comprising a strain limiting layer configured to limit the multilayer finger membrane from stretching; and

a coupling end portion configured to couple to the palm member and comprises an opening configured for fluid communication with a vacuum system,

wherein each of the plurality of finger members is configured to bend based on vacuum pressure actuation generated by the vacuum system via the opening of the coupling end portion of the finger member

wherein the multilayer finger membrane comprises a first flexible membrane layer and a second flexible membrane layer, and the strain limiting layer is embedded between the first and second flexible membrane layers.

2. The gripping apparatus according to claim 1, wherein

the strain limiting layer comprises a plurality of first cut-outs, the plurality of first cut-outs enabling a robust embedment of the strain limiting layer in the multilayer finger membrane.

3. The gripping apparatus according to claim 2, wherein the first flexible membrane layer and the second flexible membrane layer are each a soft silicone layer, and the strain limiting layer is a fiberglass fabric layer.

4. The gripping apparatus according to any one of claims 1 to 3, wherein for each of the plurality of finger members, each of the plurality of phalange members of the finger member comprises a first side wall and a second side wall on an opposite side of the phalange member with respect to the first side wall, and a through hole configured for fluid communication with the vacuum system, wherein the through hole of the phalange member extends from the first side wall to the second side wall.

5. The gripping apparatus according to claim 4, wherein for each of the plurality of finger members, the through hole of each of the plurality of phalange members of the finger member are at least substantially aligned with the longitudinal axis of the finger member.

6. The gripping apparatus according to claim 4 or 5, wherein for each of the plurality of finger members, each of the plurality of phalange members of the finger member further comprises a first side portion and a second side portion opposite to the first side portion, and the first side portion and the second side portion are bonded to the multilayer finger membrane of the finger member.

7. The gripping apparatus according to claim 6, wherein for each of the plurality of finger members,

the first side portion and the second side portion of each of the plurality of phalange members of the finger member comprises a first opening and a second opening, respectively, and

the multilayer finger membrane of the finger member comprises, for each of the plurality of phalange members of the finger member, a first opening and a second opening corresponding to the first opening and the second opening of the phalange member.

8. The gripping apparatus according to claim 7, wherein the first and second side portions are bonded to the multilayer finger membrane of the finger member at the first and second openings of the first and second side portions and the corresponding first and second openings of the multilayer finger membrane, respectively.

9. The gripping apparatus according to any one of claims 4 to 8, wherein for each of the plurality of finger members, for each pair of immediately adjacent phalange members of the plurality of phalange members of the finger member, the second side wall of a first phalange member of the pair and the first side wall of a second phalange member of the pair are configured to define a space therebetween when the finger member is at a relaxed state so as to provide the space for the second side wall of the first phalange member and the first side wall of the second phalange member to move towards each other when the finger member is in a bending state, wherein the finger member is configured to receive vacuum pressure at the space between each pair of immediately adjacent phalange members for causing the multilayer finger membrane to deform around the plurality of phalange members of the finger member to create a net bending motion of the finger member towards an object.

10. The gripping apparatus according to claim 9, wherein the space has a substantially V-shaped cross-section when the finger member is at the relaxed state.

11. The gripping apparatus according to any one of claims 1 to 10, wherein the palm member comprises:

a plurality of palm block members arranged in series, each palm block member being formed of an elastomer;

a multilayer palm membrane configured to encapsulate the plurality of palm block members, the multilayer palm membrane being formed of multiple material layers, comprising a strain limiting layer configured to limit the multilayer palm membrane from stretching; and

a first coupling end portion configured to couple to a robotic component and comprises an opening configured for fluid communication with the vacuum system,

wherein the palm member is configured to bend based on vacuum pressure actuation generated by the vacuum system via the opening of the first coupling end portion of the palm member.

12. The gripping apparatus according to claim 11, wherein each the plurality of palm block members of the palm member comprises a first side wall and a second side wall on an opposite side of the palm block member with respect to the first side wall, and a through hole configured for fluid communication with the vacuum system,

wherein the through hole of the palm block member extends from the first side wall to the second side wall.

13. The gripping apparatus according to claim 11 or 12, wherein each of the plurality of palm block members of the palm member further comprises a first side portion and a second side portion opposite to the first side portion, and the first side portion and the second side portion are bonded to the multilayer palm membrane of the palm member.

14. The gripping apparatus according to any one of claims 1 to 13, wherein the plurality of finger members is coupled to a first valve, and the palm member is coupled to a second valve, wherein the first valve and the second valve are configured to independently regulate the flow of fluid to the plurality of finger members and the palm member.

15. The gripping apparatus according to any one of claims 1 to 14, wherein for each of the plurality of finger members, each of the plurality of phalange members of the finger member further comprises a force sensor configured to detect applied force on the phalange member.

16. The gripping apparatus according to any one of claims 1 to 15, wherein the multilayer finger membrane comprises a flex sensor configured to detect bending of the finger member in medial and lateral directions.

17. A method of forming the gripping apparatus according to any one of claims 1 to 16.

18. The method according to claim 17, further comprising forming the plurality of phalange members and the multilayer finger membrane by casting.

19. A method of operating the gripping apparatus of any one of claims 1 to 15, the method comprising:

applying a vacuum pressure to the plurality of finger members so as to create a bending motion of the plurality of finger members.

20. The method according to claim 19, further comprising applying a vacuum pressure to the palm member so as to create a bending motion of the palm member.

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