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(54) Titre : MATERIAU DE REVETEMENT NANOCOMPOSITE ETIRABLE ET STRUCTURES ASSOCIEES
(54) Title: STRETCHABLE NANOCOMPOSITE SKIN MATERIAL AND RELATED STRUCTURES

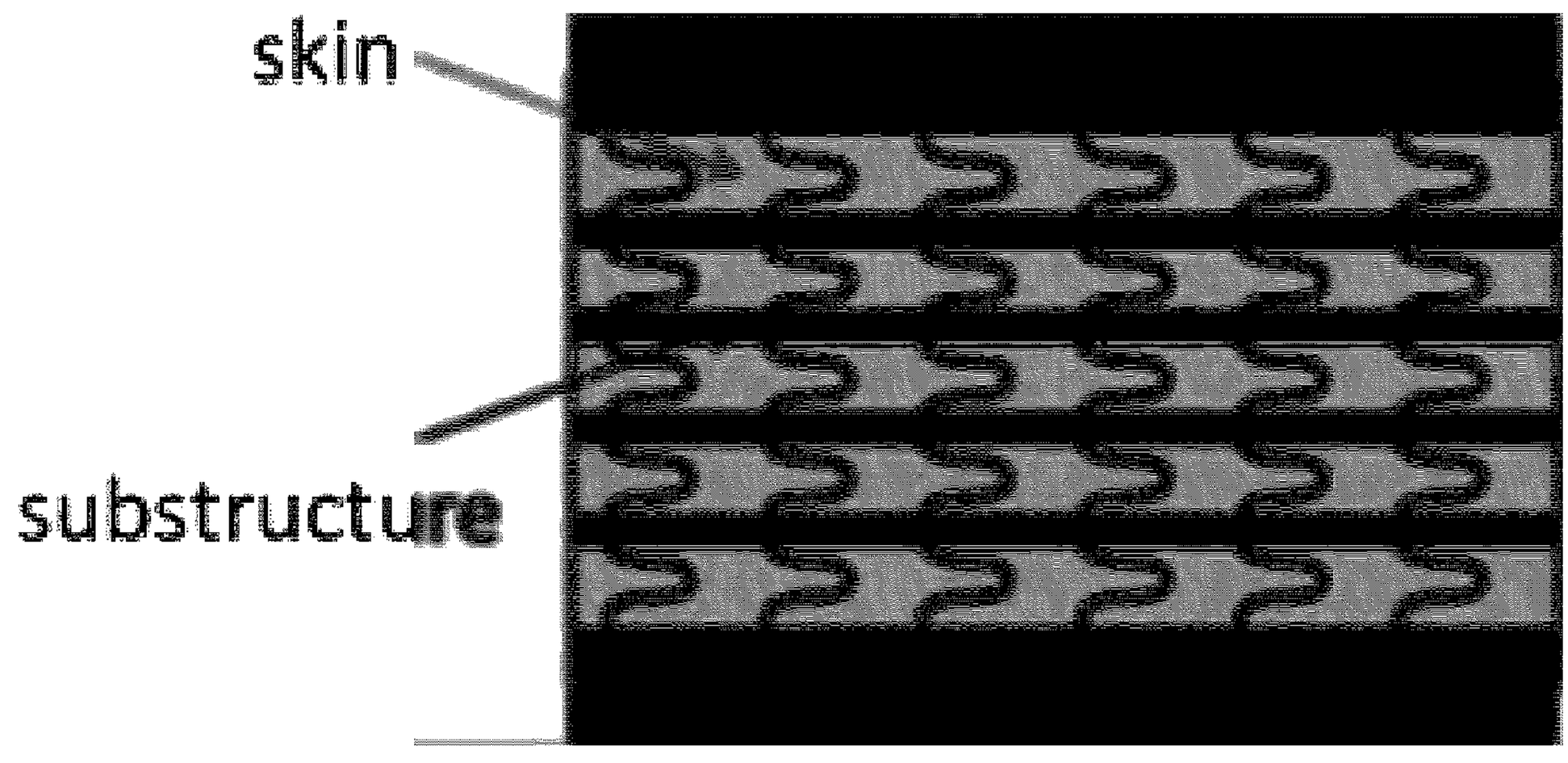

FIG. 9A

(57) Abrégé/Abstract:
A stretchable multiple-layer nanocomposite material is provided and includes at least a nanocomposite material layer comprising a network of nanotubes modified with an elastomeric polymer; and at least one additional layer laminated with the nanocomposite material layer. The number of nanocomposite layers and additional layers, the nature and composition thereof, may be varied in a surface direction and/or a thickness direction so as to provide tailored mechanical and physico- chemical properties to a resulting skin that can be used to produce morphing or deployable structures.

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(54) Title: STRETCHABLE NANOCOMPOSITE SKIN MATERIAL AND RELATED STRUCTURES

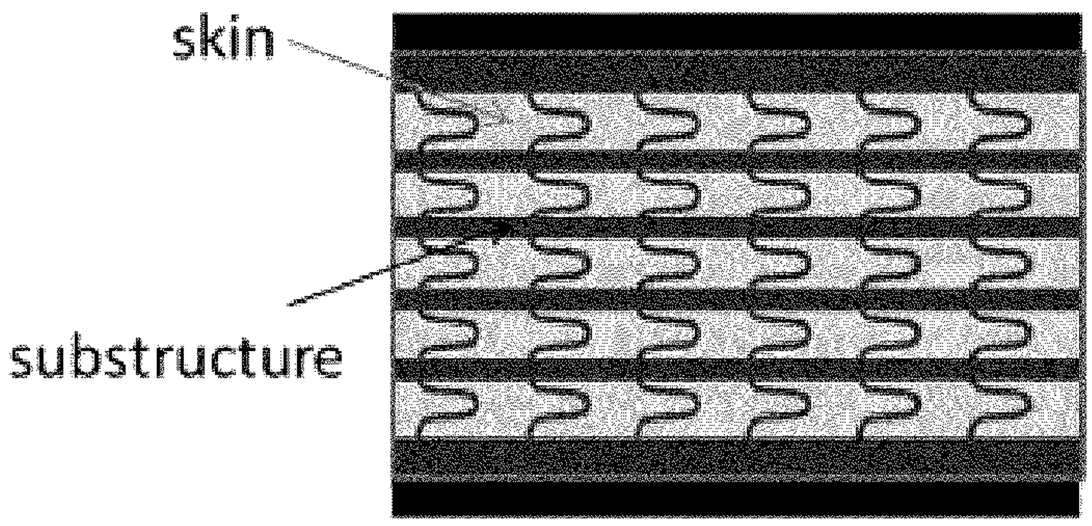

FIG. 9A

(57) Abstract: A stretchable multiple-layer nanocomposite material is provided and includes at least a nanocomposite material layer comprising a network of nanotubes modified with an elastomeric polymer; and at least one additional layer laminated with the nanocomposite material layer. The number of nanocomposite layers and additional layers, the nature and composition thereof, may be varied in a surface direction and/or a thickness direction so as to provide tailored mechanical and physico- chemical properties to a resulting skin that can be used to produce morphing or deployable structures.

[Continued on next page]

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STRETCHABLE NANOCOMPOSITE SKIN MATERIAL AND RELATED STRUCTURES

TECHNICAL FIELD

The technical field generally relates to nanocomposite materials and more particularly to a stretchable nanocomposite skin material and related structures thereof.

BACKGROUND

Nanocomposite materials are good candidates to be used as deformable materials, while offering desirable mechanical resistance properties. Typically, nanotubes are dispersed in polymer or nanotube sheets are subsequently infused with polymer resin to produce a deformable nanocomposite, such as a bendable or stretchable nanocomposite.

Regarding advances in the domain of nanocomposites, US patent application published under No. 2015/147573 provides examples (see examples 32 and 90) showing methods for fabrication of elastomerically deformable carbon nanotube sheets, including deposition of a nanofiber sheet on an elongated elastomeric sheet (porous elastomeric textile or porous silicon rubber sheet), such that the resulting deformable sheet can be elastically relaxed and re-stretched repeatedly to the initial elongation without undergoing a substantial resistance change. Methods may further include overcoating with a second elastomeric sheet. The principle of the method may also be extended to produce elastomerically deformable stacks comprising one or more nanotube electrode sheets that are laminated between sheets of elastomer.

Another example of a deformable nanocomposite material is provided by Martinez-Rubi Y et al. *Nanotube-Buckypaper/Polyurethane Composites with Enhanced Mechanical Properties. 20th International Conference on Composite Materials,*

CLAIMS

1. A stretchable multiple-layer nanocomposite material comprising at least:

a nanocomposite material layer comprising a network of nanotubes modified with an elastomeric polymer; and

at least one additional layer laminated with the nanocomposite material layer.

2. The material of claim 1, wherein the network of nanotubes is provided by a non-woven sheet of nanotubes.

3. The material of claim 2, wherein the nanotubes are randomly oriented within the plane of the nanocomposite material layer.

4. The material of any one of claims 1 to 3, wherein the nanotubes comprise carbon nanotubes, boron-nitride nanotubes, boron-carbon-nitrogen nanotubes, silicon-carbide nanotubes, other nanoparticles, hybrids thereof or a combination thereof.

5. The material of any one of claims 1 to 4, wherein the nanotubes include single-walled nanotubes and multi-walled nanotubes.

6. The material of any one of claims 1 to 5, wherein the nanocomposite material layer has a nanotube content between 5 wt% and 90 wt%.

7. The material of claim 6, wherein the nanotube content is between 10 wt% and 40 wt%.

8. The material of any one of claims 1 to 7, wherein the elastomeric polymer comprises thermoplastic elastomers, thermoplastic polyurethane, rubber, silicone rubber or a combination thereof.

9. The material of any one of claims 1 to 8, wherein the nanocomposite material layer is a first nanocomposite material layer and the at least one additional layer is

another nanocomposite material layer comprising nanotubes differing in nature from the nanotubes of the first nanocomposite material layer.

10. The material of any one of claims 1 to 8, wherein the nanocomposite material layer is a first nanocomposite material layer and the at least one additional layer is another nanocomposite material layer having a nanotube content which is different from the first nanocomposite material layer.

11. The material of any one of claims 1 to 8, wherein the nanocomposite material layer is a first nanocomposite material layer and the at least one additional layer is another nanocomposite material layer similar to the first nanocomposite material layer.

12. The material of any one of claims 1 to 8, wherein the at least one additional layer is a neat polymer layer, a composite polymer layer, or a reinforced polymer layer including at least one elastomeric polymer.

13. The material of claim 12, wherein the elastomeric polymer of the at least one additional layer is the same as the one included in the nanocomposite material layer.

14. The material of claim 12, wherein the elastomeric polymer of the at least one additional layer is different from the one included in the nanocomposite material layer.

15. The material of any one of claims 1 to 14, having mechanical properties varying across a surface area thereof, and wherein at least the nanocomposite material layer has mechanical properties varying across a surface area thereof.

16. The material of claim 15, having a nanotube content varying across the surface area.

17. The material of claim 16, wherein the nanotube content is higher in a specific area of the nanocomposite layer to enhance stiffness of the material.

18. The material of any one of claims 15 to 17, having a polymer content varying across the surface area.

19. The material of claim 18, wherein the polymer content is higher in another specific area of the multiple-layer nanocomposite material to enhance stretchability of the material.

20. The material of any one of claims 15 to 19, wherein the nature of elastomeric polymer changes across the surface area of the material.

21. The material of any one of claims 15 to 20, wherein the nature of the nanotubes changes across the surface area of the material.

22. The material of any one of claims 1 to 21, comprising a plurality of layers which number varies acrossthe surface area of the material.

23. The material of any one of claims 1 to 22, comprising a number of layers tailored to obtain a given material thickness and properties profile adapted for use as a skin material.

24. The material of claim 23, having a nanotube:polymer ratio tailored to provide a given stretchability profile to the skin material for application in a morphing structure or a deployable structure.

25. A skin material for direct application as a skin on a substructure, the skin material comprising a nanotube network modified with a polymer.

26. The skin material of claim 25, wherein the polymer comprises an elastomeric polymer selected to provide stretchability to the skin material.

27. The skin material of claim 25 or 26, comprising a non-woven nanotube layer modified with the polymer.

28. The skin material of claim 27, comprising at least one additional layer which is laminated on the non-woven nanotube layer modified with the polymer.

29. The skin material of claim 28, wherein the at least one additional layer is one or more of a nanocomposite layer.

30. The skin material of claim 29, wherein the at least one additional layer is a layer of neat or reinforced elastomeric polymer comprising thermoplastic polyurethane, silicone rubber, rubber or a combination thereof.

31. The skin material of any one of claims 25 to 30, comprising a plurality of laminated layers tailored to obtain a material thickness between 0.05 mm and 20 mm.

32. The skin material of claim 31, wherein the material thickness is between 0.5 mm and 3 mm.

33. The skin material of any one of claims 25 to 32, having a composition tailored to provide a reversible stretch capacity from 5 to 50% and an elastic modulus from 50 MPa to 10 GPa.

34. The skin material of claim 33, wherein the reversible stretch capacity is of 20% and the elastic modulus is of 500 MPa.

35. The skin material of any one of claims 25 to 34, having a nanotube:polymer ratio tailored to provide a one-time stretch capacity of at least 100% and a stiffness from 50 MPa to 10 GPa.

36. The skin material of claim 35, wherein the one-time stretch capacity is of at least 200% stretch and the stiffness of 500 MPa.

37. A stretchable skin material being the material defined in any one of claims 1 to 24.

38. A skin being directly applied onto a support surface as the material as defined in any one of claims 1 to 36.

39. The skin of claim 38, wherein the nature of the nanotubes included in the material are selected to provide heating, sensing, EMI shielding, neutron shielding properties or a combination thereof to the skin.

40. A morphing structure produced by direct application of a skin material as defined in any one of claims 25 to 37 onto a support structure.

41. The morphing structure of claim 40, being at least a portion of a morphing aircraft, comprising a wing leading edge, a wing trailing edge, a tail fin, a nose cone or a combination thereof.

42. A deployable structure produced by direct application of a skin material as defined in any one of claims 25 to 37 onto a deployable support structure.

43. The deployable structure of claim 42, wherein the deployable support structure reversibly unfolds and/or inflates resulting in stretching of the skin material.

44. The deployable structure of claim 42 or 43, wherein the skin material is maintained in a stretched state by internal air pressure when the support structure is deployed, the internal air pressure being higher than a pressure external to the deployable structure.

45. The deployable structure of any one of claims 42 to 44, being at least a portion of a deployable space habitat or a deployable military habitat.

46. A structure including a sub-structure and a skin as defined in claim 38 or 39 to form at least part of an outer surface of the structure by application onto the sub-structure.

FIGURES

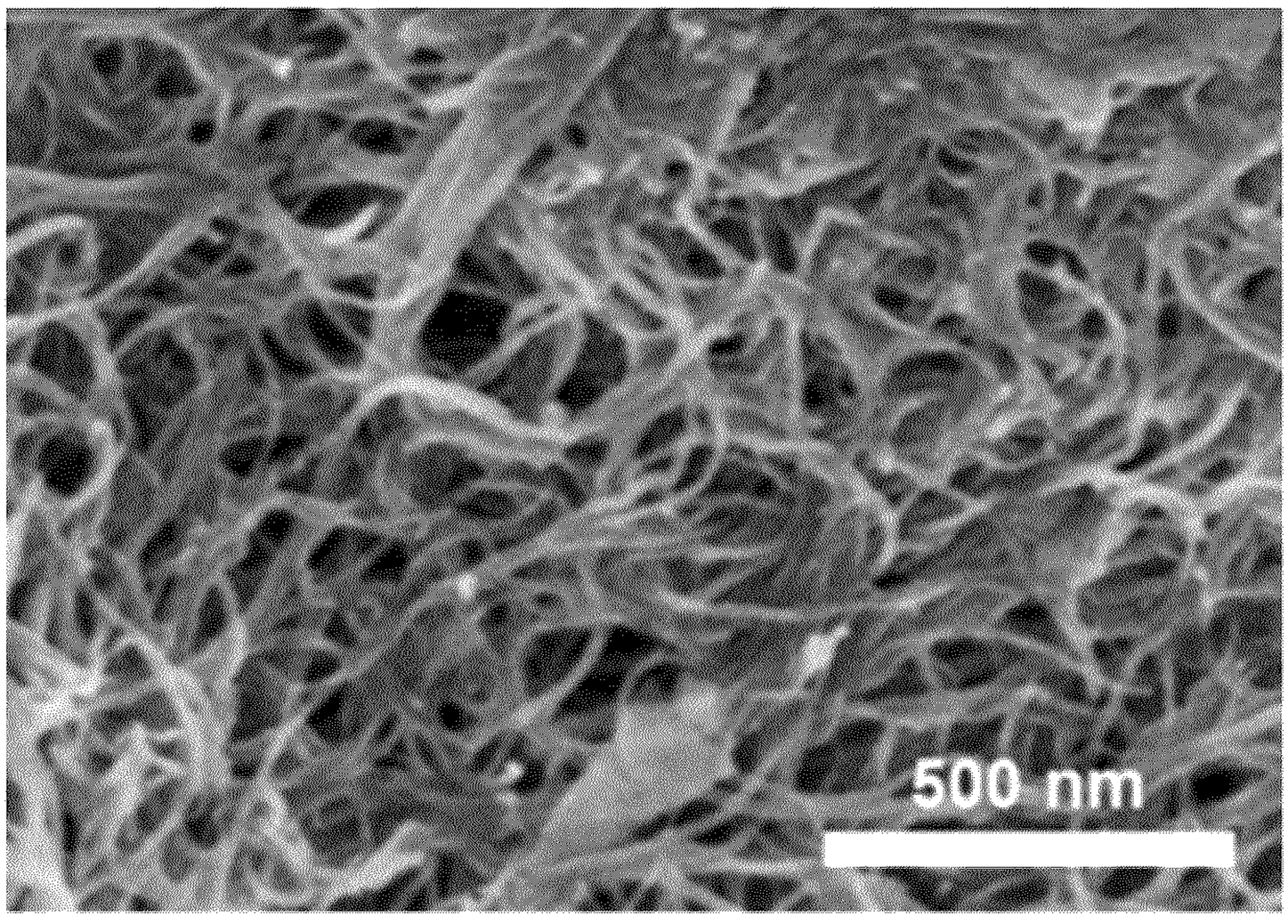

FIG. 1

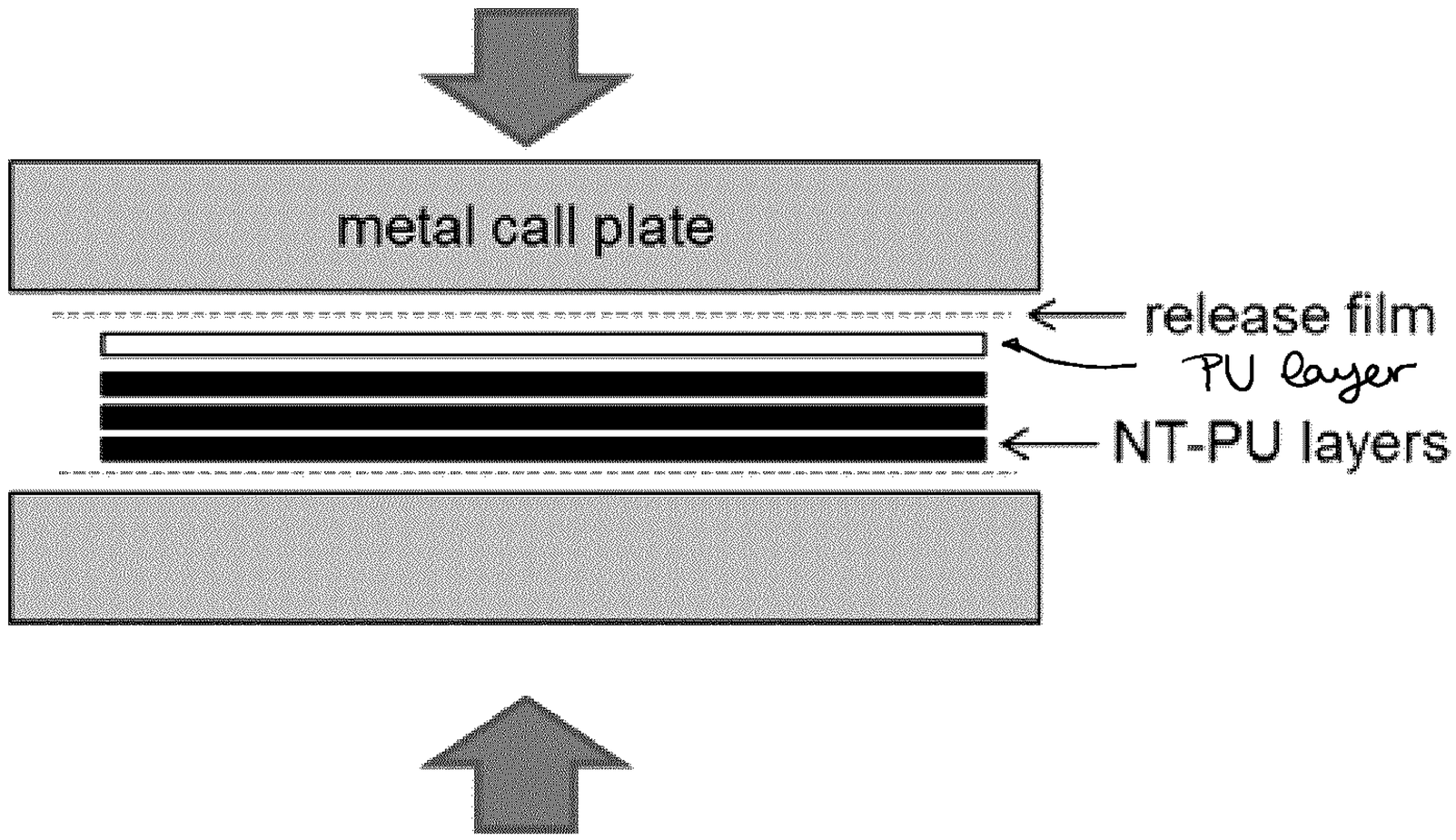
metal call plate
release film
PU layer
NT-PU layers

FIG. 2A

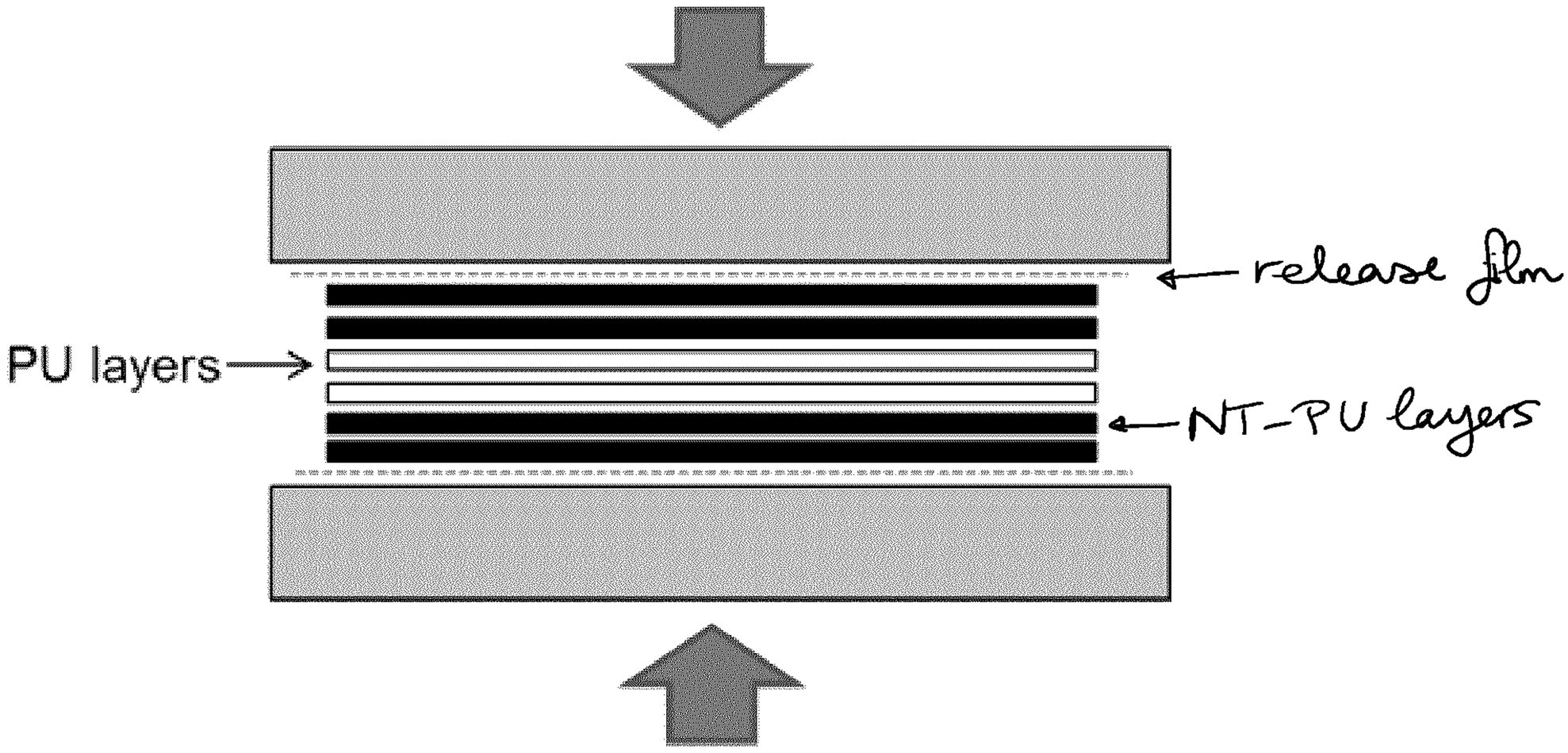
release film
PU layers
NT-PU layers

FIG. 2B

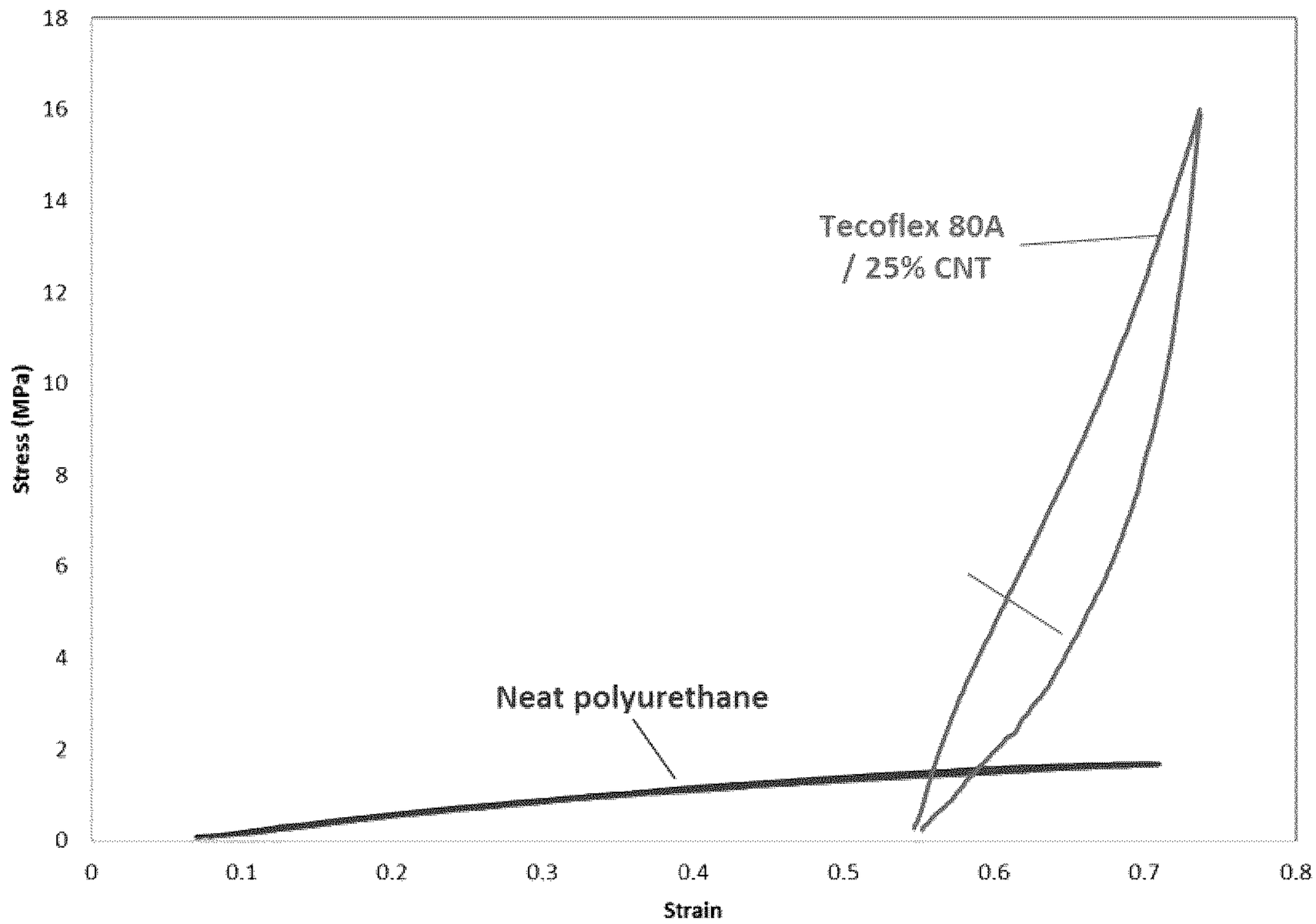
Stress (MPa)
0
2
4
6
8
10
12
14
16
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Strain
Tecoflex 80A
/ 25% CNT
Neat polyurethane

FIG. 3

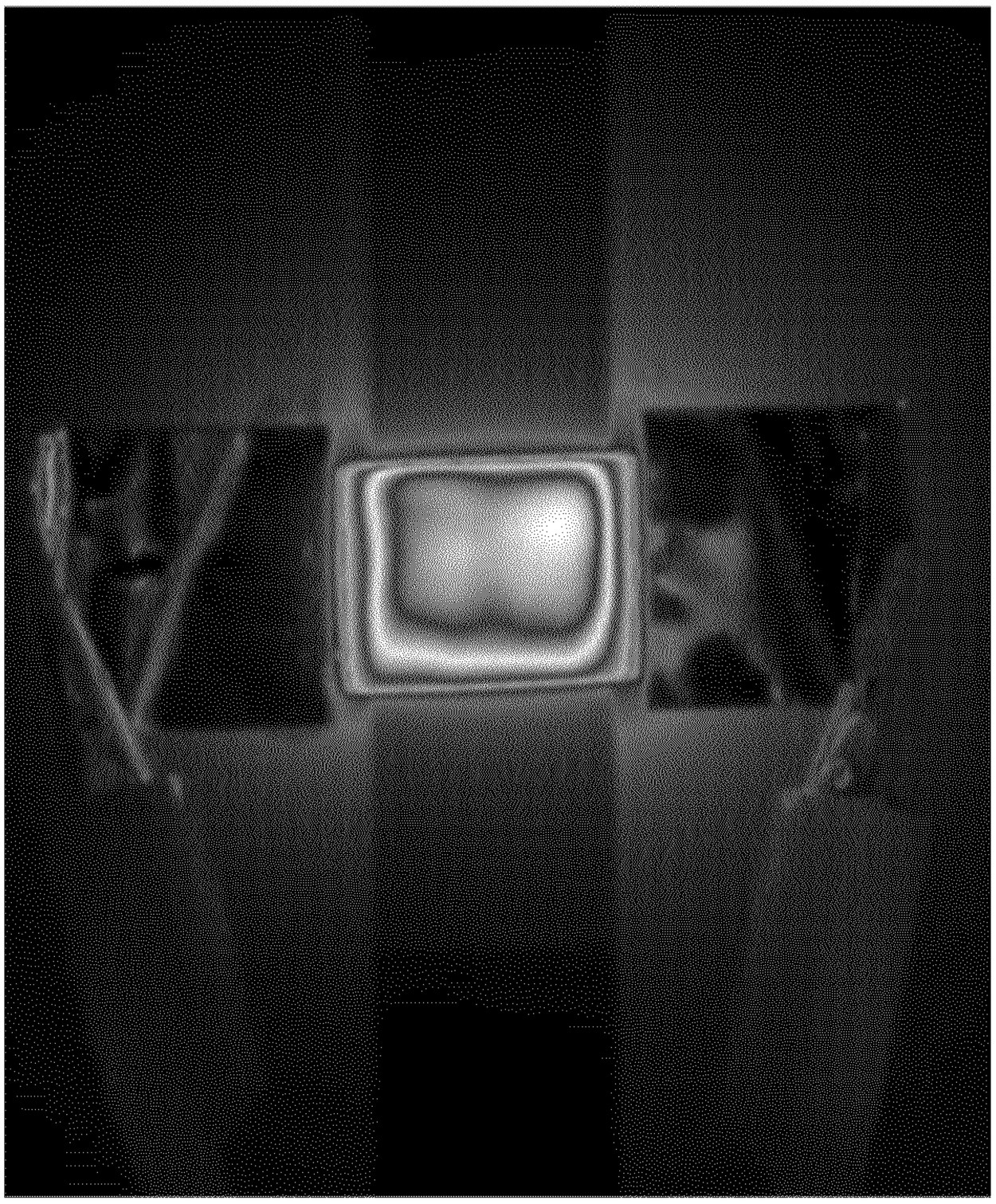

FIG. 4

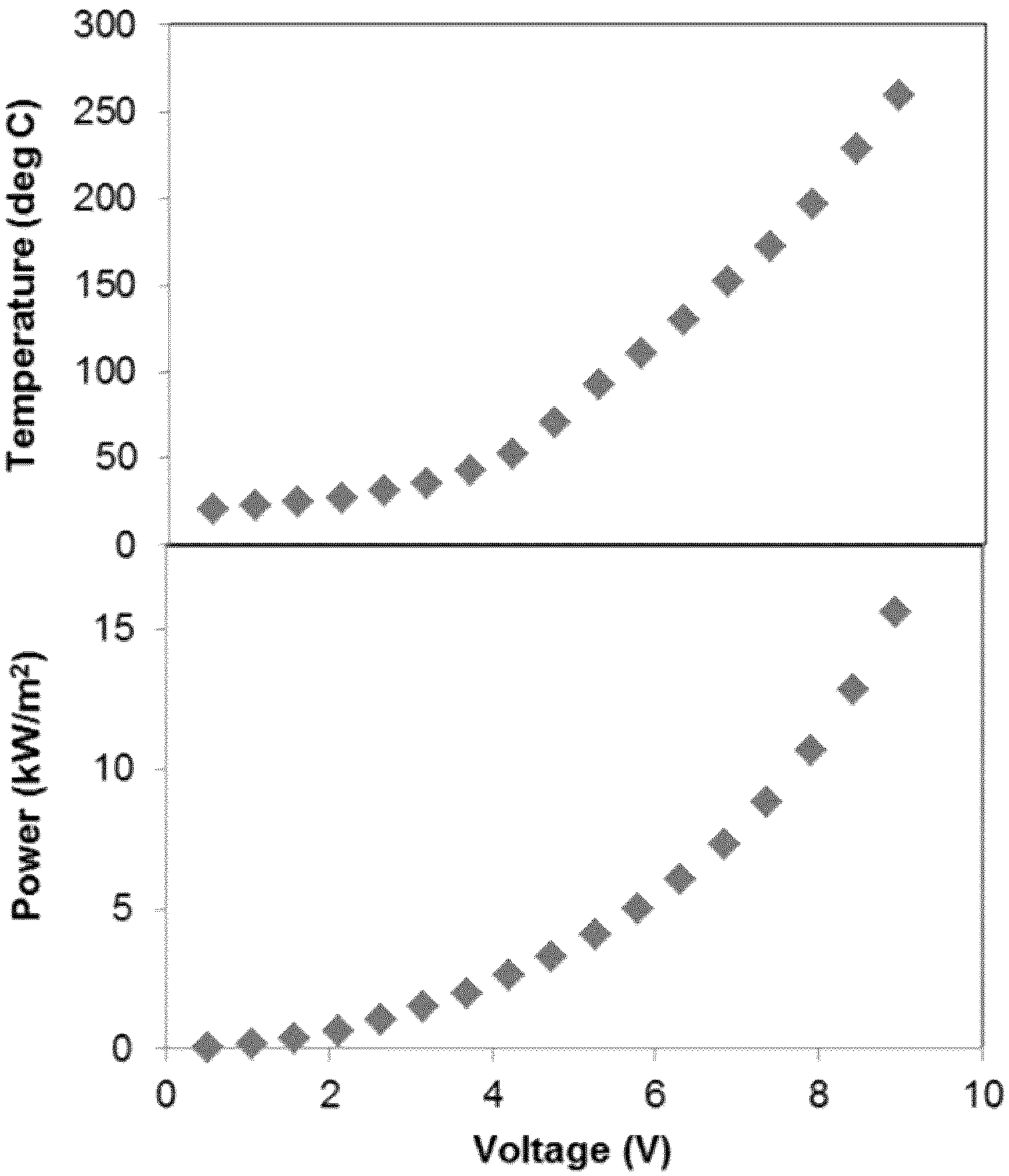
Temperature (deg C)
300
250
200
150
100
50
0
Power (kW/m²)
15
10
5
0
0
2
4
6
8
10
Voltage (V)

FIG. 5

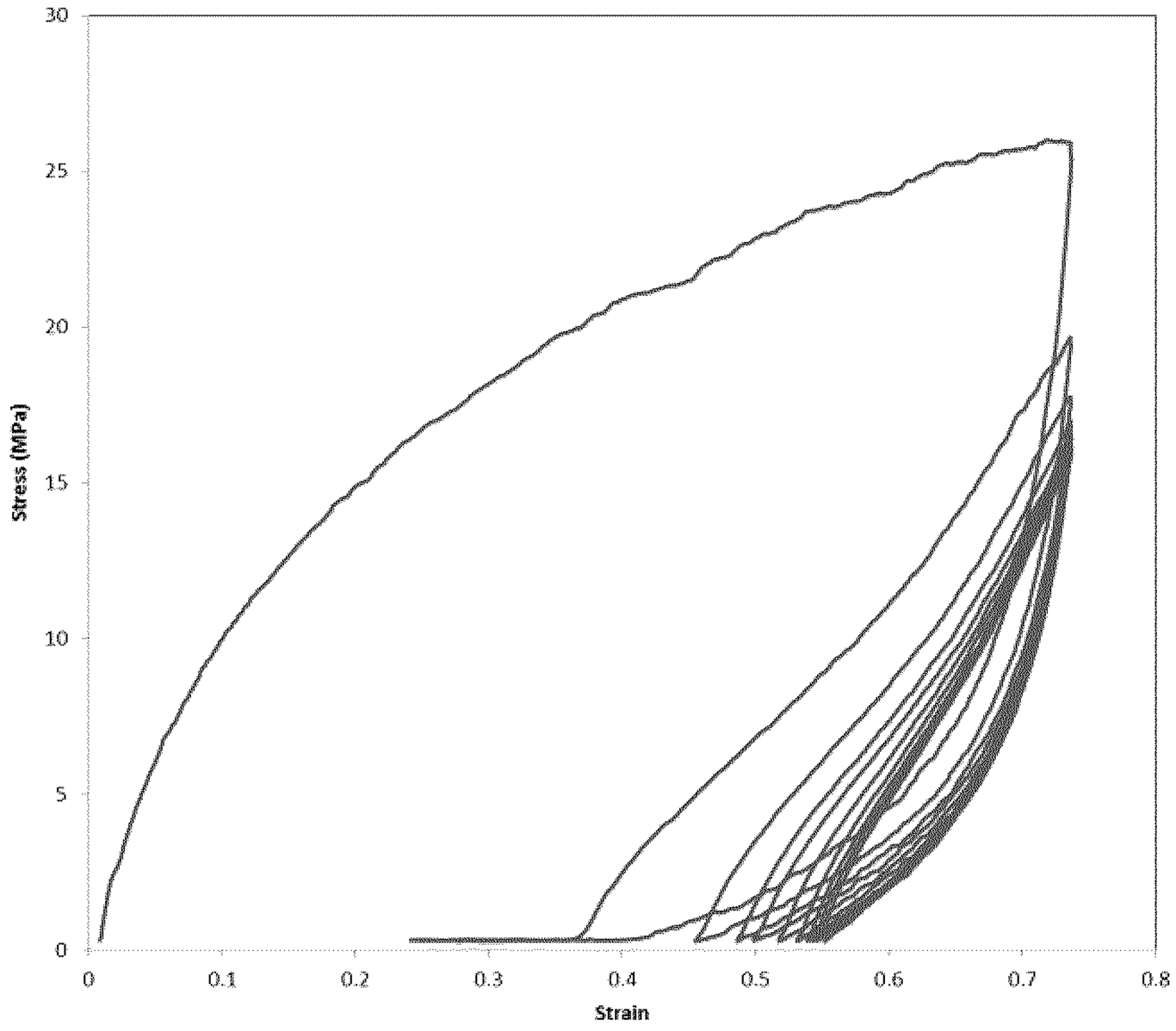
30
25
20
15
10
5
0
Stress (MPa)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Strain

FIG. 6

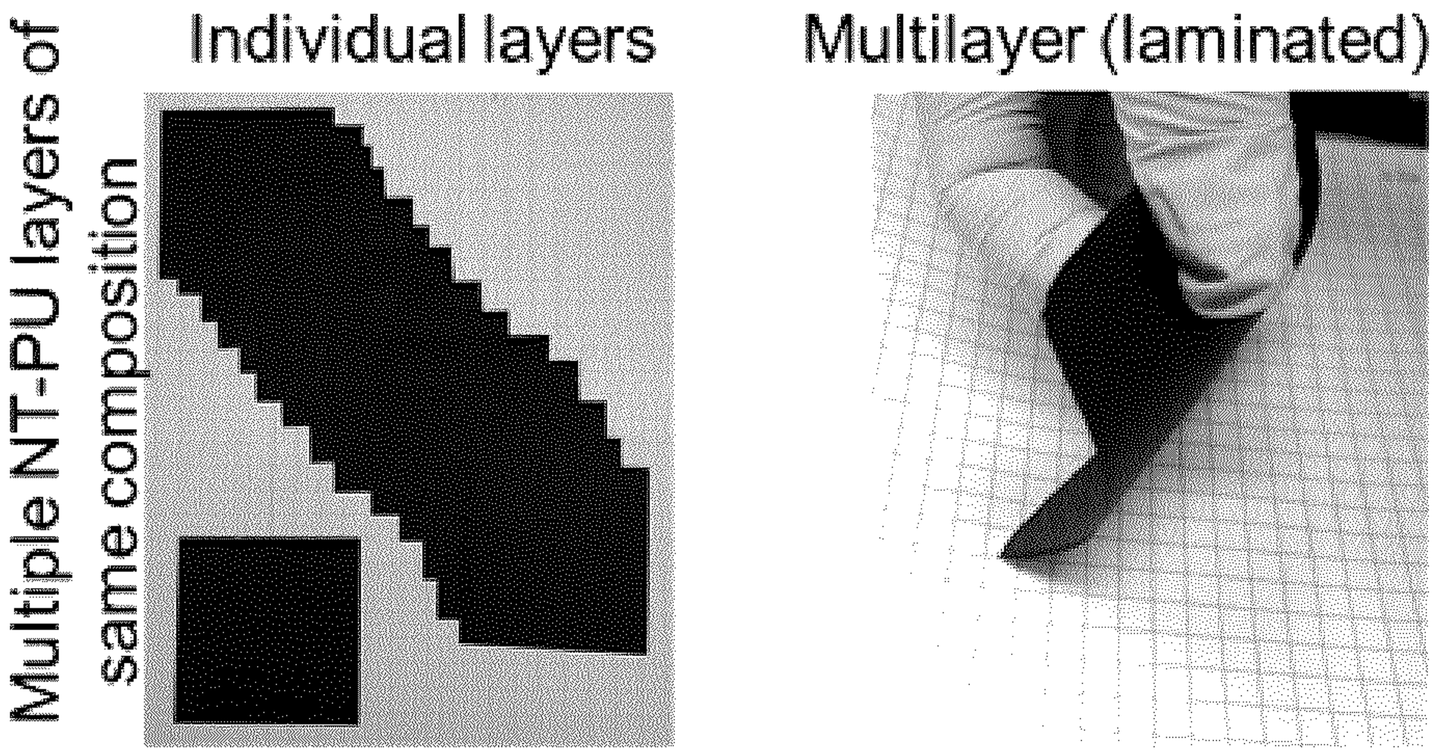
Multiple NT-PU layers of same composition
Individual layers
Multilayer (laminated)

FIG. 7A

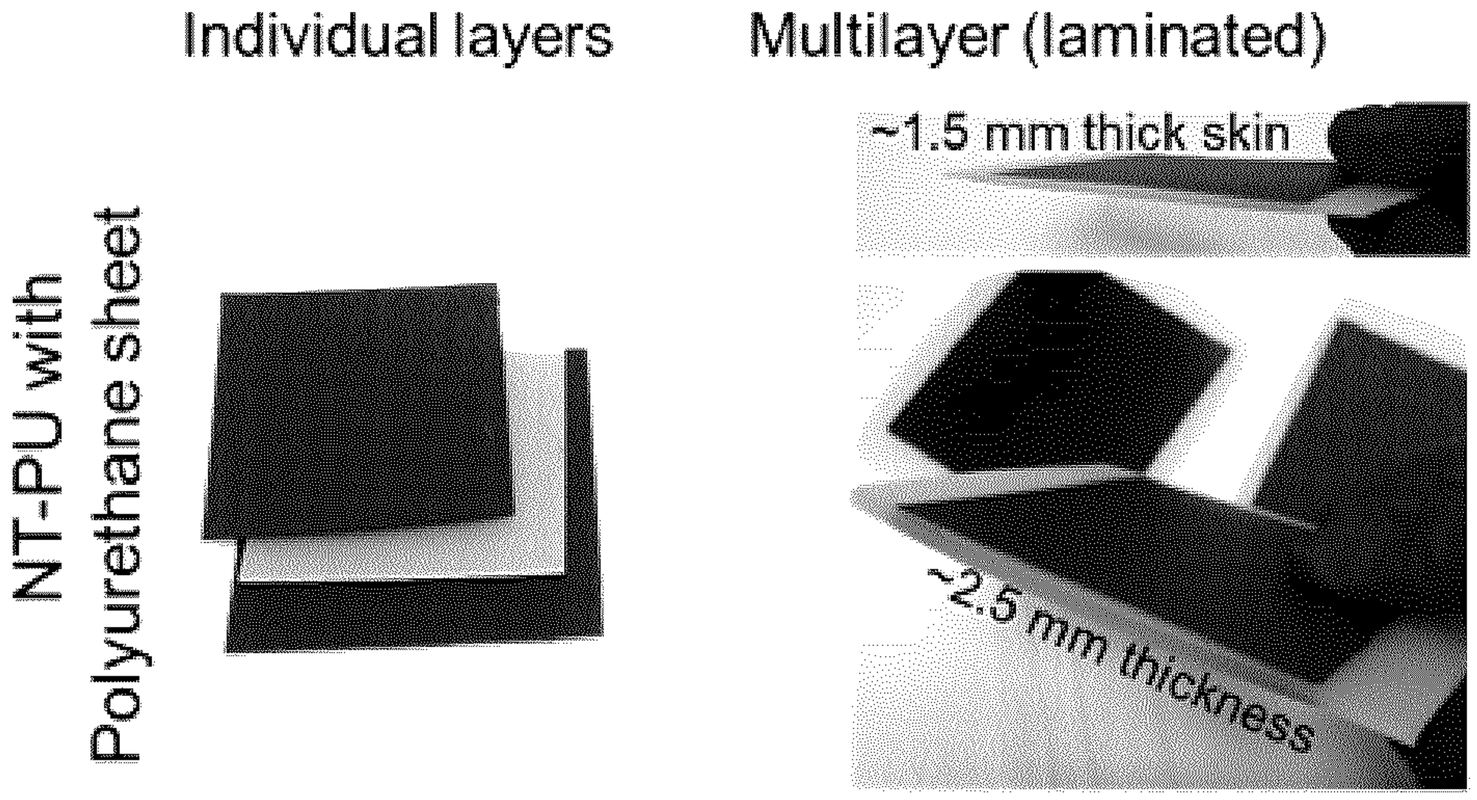
Individual layers
Multilayer (laminated)
NT-PU with
Polyurethane sh
~1.5 mm thick skin
~2.5 mm thickness

FIG. 7B

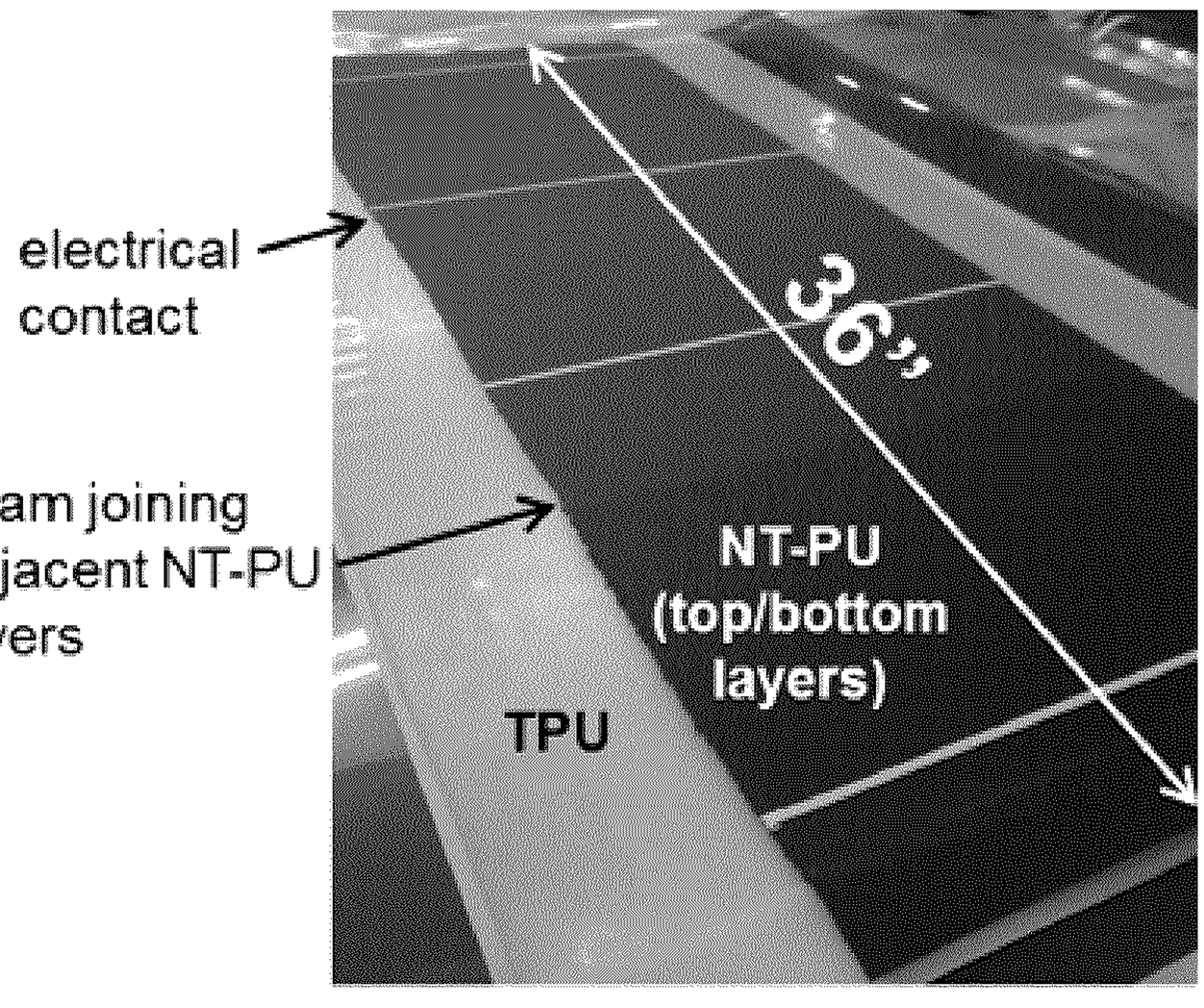
electrical
contact
seam joining
adjacent NT-PU
layers
NT-PU
(top/bottom
layers)
TPU

FIG. 8A

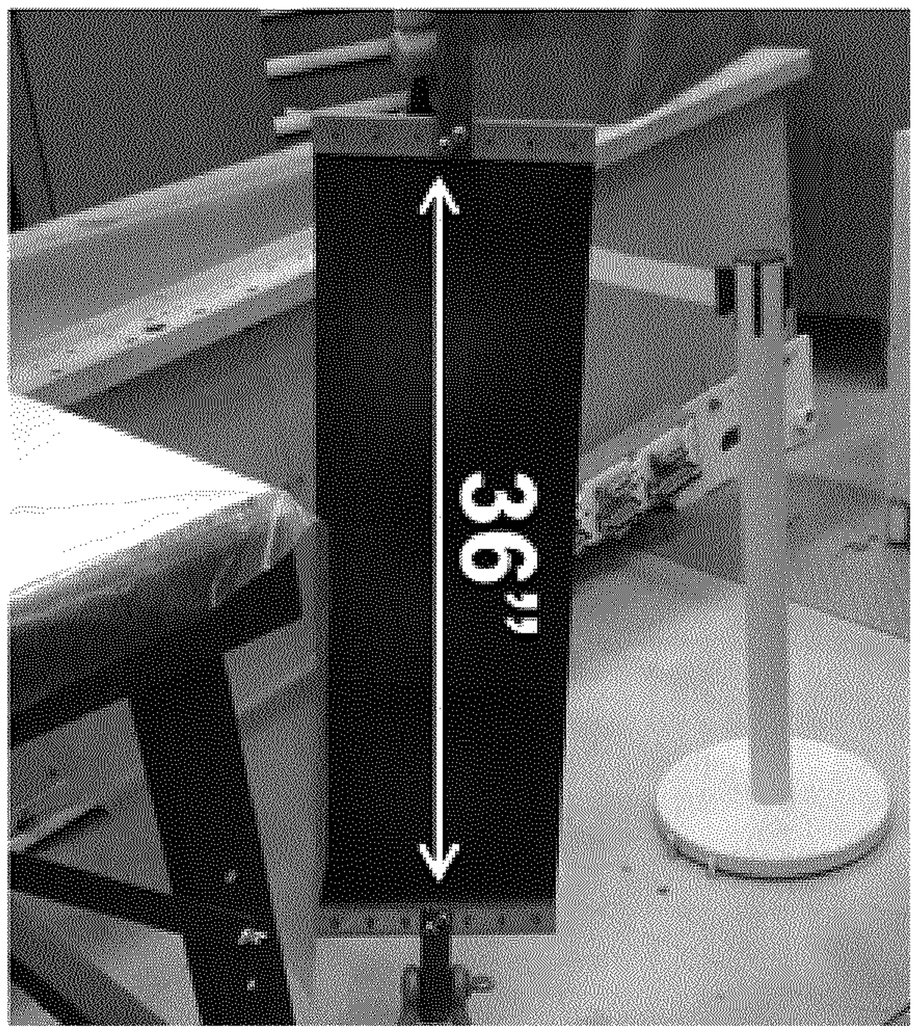

FIG. 8B

FIG. 9A

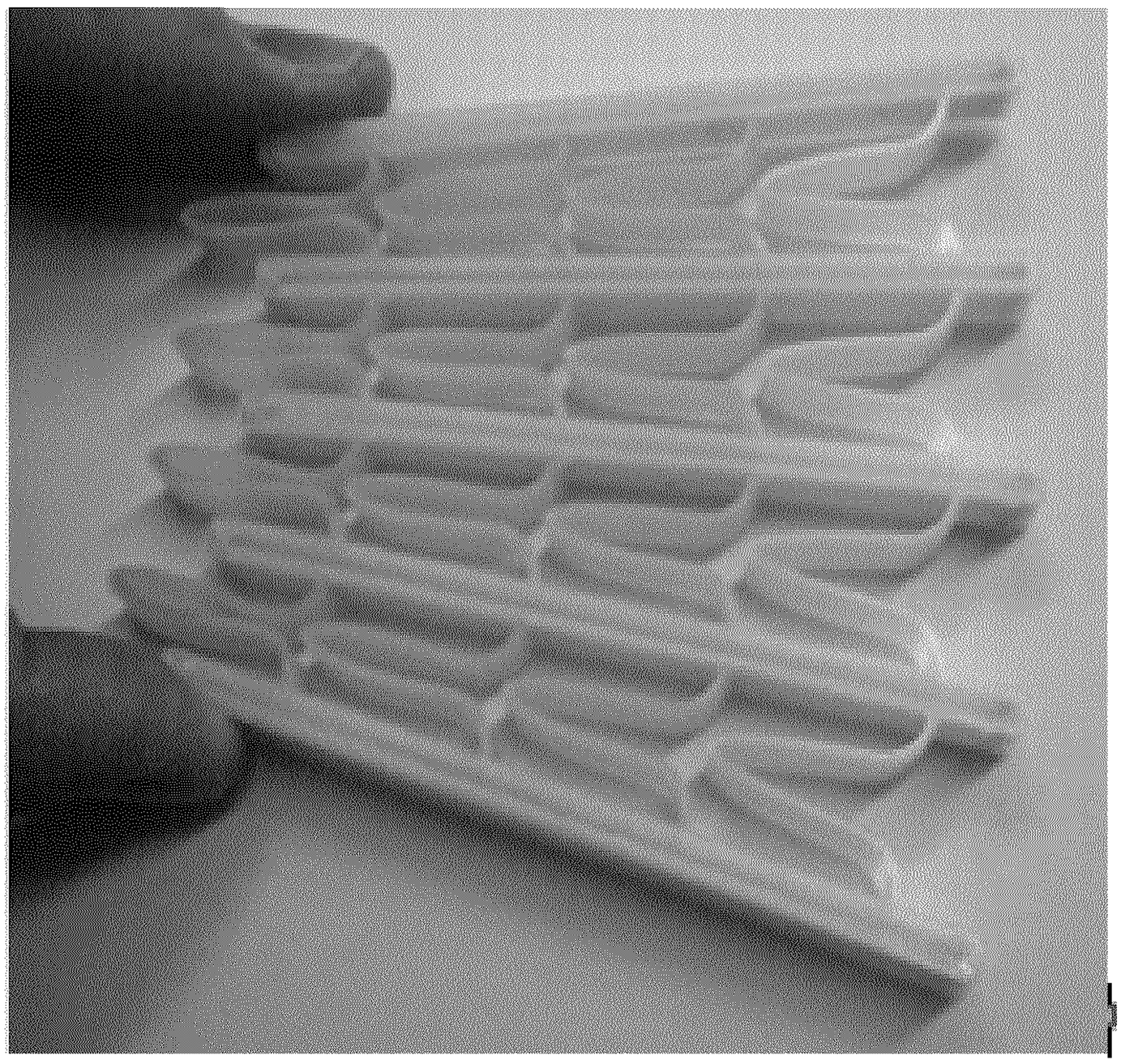

FIG. 9B

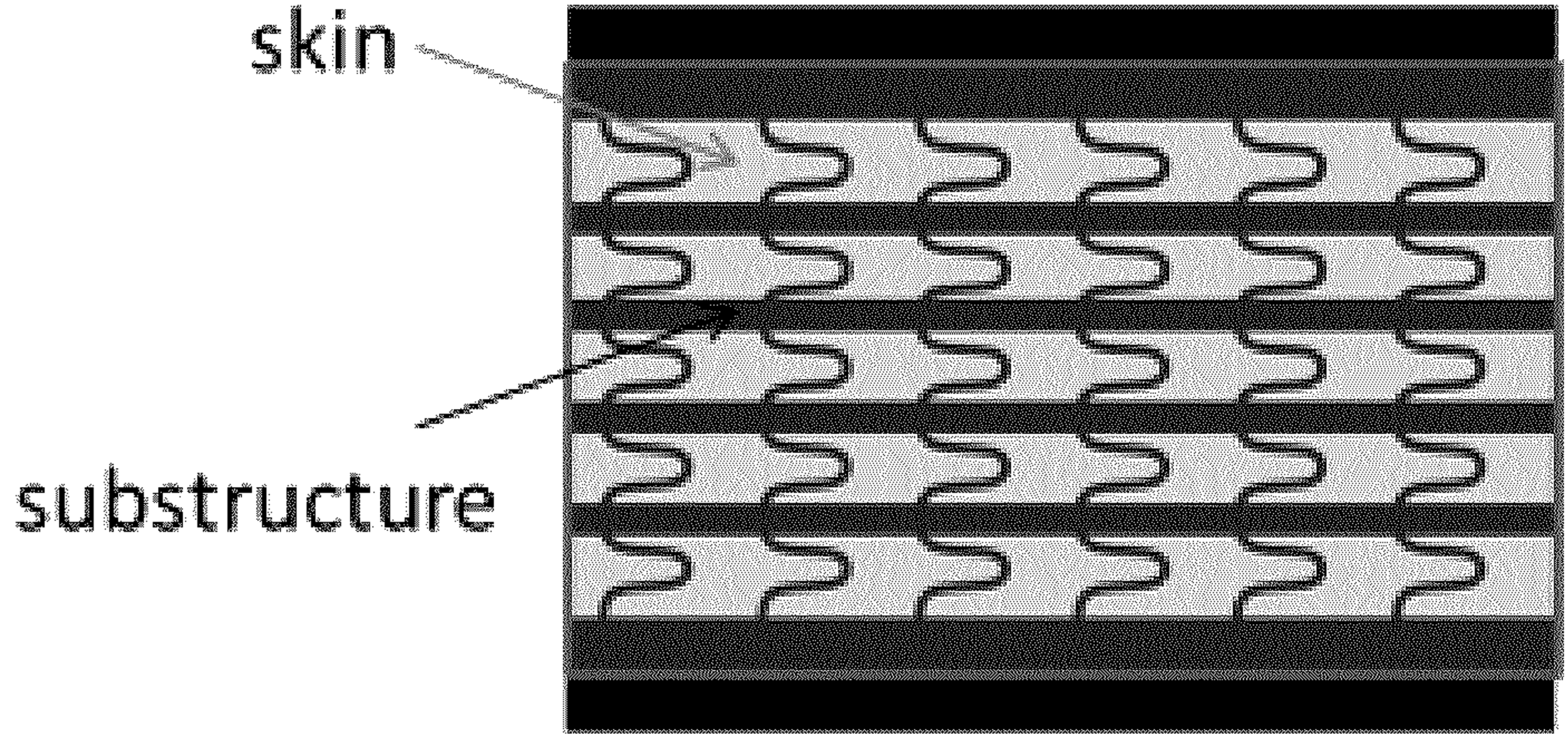

FIG. 9A