

2. 나노섬모 자연구조물 및 응용분야

2.1 Stereocilia (부동섬모)

가 (1, 2). 가 Stereocilia (hair cell) Stereocilia

3 가 3 Tip Stereocilia

Stereocilia Rice W. E. Brownell, Rockefeller A. J. Hudspeth, Minnesota P. Santi, Oregon R. G. Walker, Nottingham K. P. Steel가 Stereocilia가 (compact)가 , (noise) 가 (sensitivity), 가 Flabio N^[1] Stereocilia Nanotube Array 가

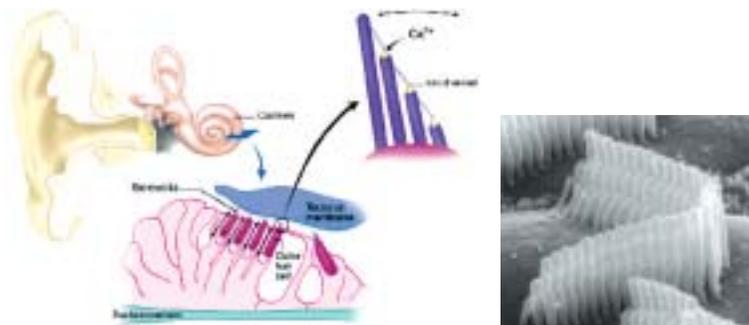


그림 1. 달팽이관속의 Stereocilia

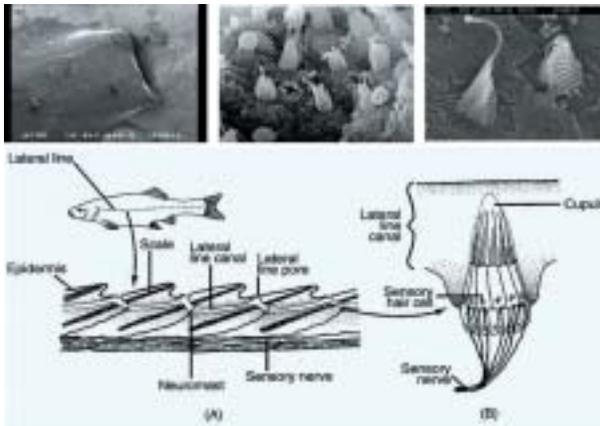


그림 2. 물고기 측선의 Stereocilia의 구조

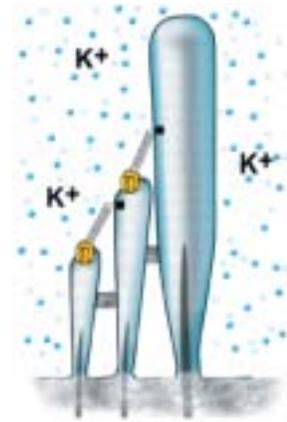


그림 3. Stereocilia의 모식도

2.2 Nano Seta (나노강모)

Gecko() 가 . 가 van der Waals 2000 Nature (4)^[2]. Gecko Setae 가 , 가 . Gecko (seta) Adhesion Tape Glue Gripper 가 .

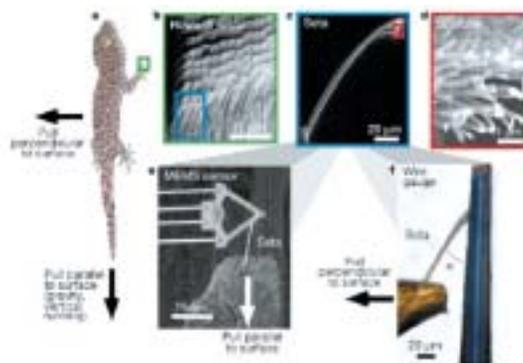


그림 4. Gecko Setae에 관한 실험적 관찰

2.3 Nano Turf (나노돌기)

1991 Wilhelm Barthlott 가 . 가

5, 6 가 가 2
 (hydrophobic) 가 (6) Lotus-effect가
 가
 가 (self cleaning) 가
 100 가



그림 5. 연꽃잎과 그 위에 먼지가 묻어있는 물방울



그림 6. 연꽃잎 표면 확대 사진과 Self-cleaning의 원리

(drag force)
 vortices [3]. Speedo 33 27
 (7).



그림 7. 상어 비늘 및 이를 이용하여 제작된 수영복

3. 나노섬모 자연모사 기술동향

, Multi Scale Multi Physics

3.1 해석기술

Scale (continuum equation) Multi Scale Macro Multi Physics MD (molecular dynamics) . Multi

가 . Multi Physics

가

A. Salt^[4] Stereocilia Cochlear Fluid(lymph) Endocochlear
 Potential Duncan RK^[5] Stereocilia Bundle
 Svrcek - seiler WA^[6] Brownian Motion Stereocilia
 8 2 가 가

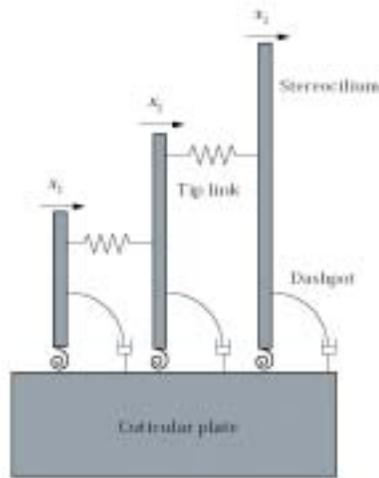


그림 8. Stereocilia의 수학적 모델

Kondrachuk, A.V.^[7] Stereocilia

9

. J.H. Walther^[8]

10

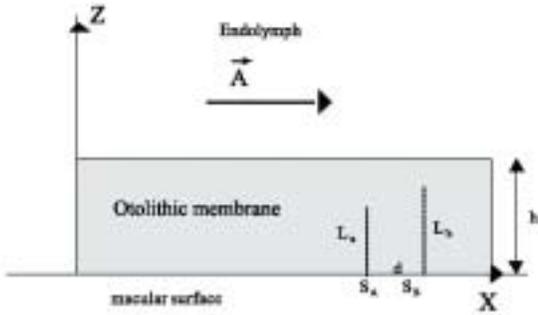


그림 9. Stereocilia의 점탄성 모델

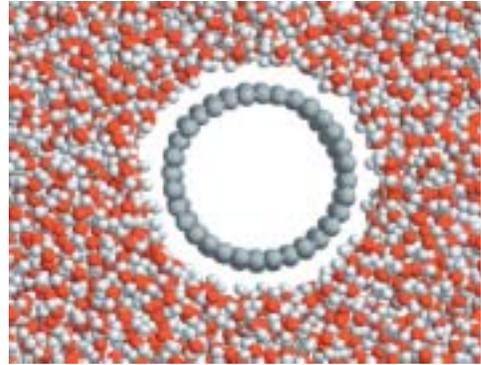


그림 10. Stereocilia 분자동역학 해석 모델

32 측정기술

(1) Stereocilia

AFM(atomic force microscope) SEM(scanning electron microscopy)

가			Stereocilia	가
· Langer MG ^[9]	SEM			· Silver RB ^[10]
Microscopy, SEM				Confocal Light
· Furness DN ^[11]				가
TEM(transmission electron micrograph)				· Valk ^[12]
TEM	,	11, 12	Stereocilia	Guinea Pig
			Glycocalyx	Stereocilia
				SEM
				Link

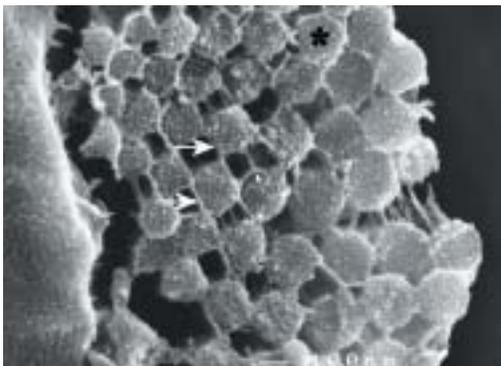


그림 11. Stereocilia의 SEM 관찰 사진

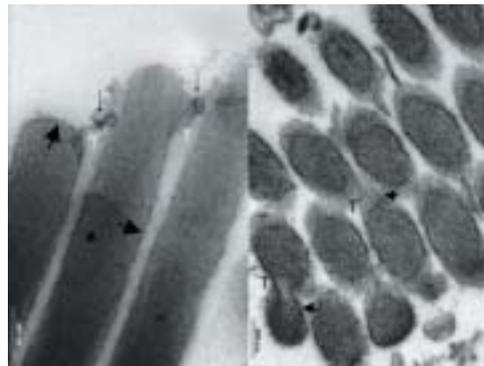


그림 12. Stereocilia의 TEM 관찰 사진

Langer^[13] Postnatal Rats
 Stereocilia $2.5 \pm 6 \times 10^{-3}$ N/m
 (13, 14).

AFM Tip
 , Stereocilia

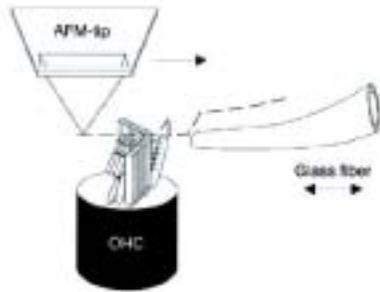


그림 13. 전달력을 측정하기 위한 OHC 번들의 배열

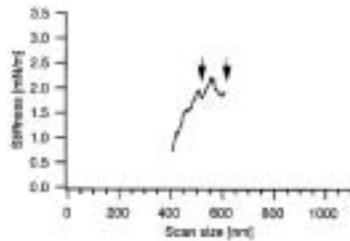


그림 14. Stereocilia의 강성 측정 결과

Frederix^[14] AFM Biomolecule
 . AFM Biomolecule
 (15, 16).

, Sub - nano Scale

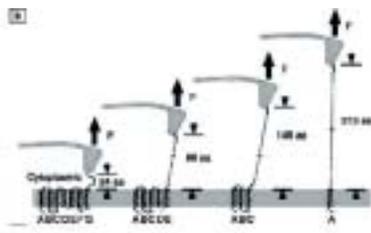


그림 15. Biomolecule의 단분자 조작

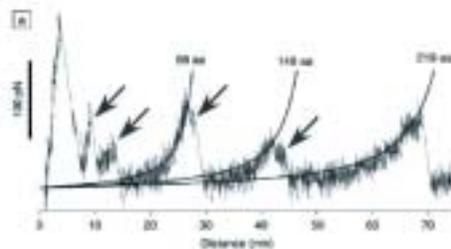


그림 16. Biomolecule의 상호작용력 측정 결과

(2) Nano Seta

Urbakh^[15] Gecko Single Seta 1,000
 16 uN 가 70 uN . Gecko Binding
 Unbinding Force Mili - second Binding Unbinding Process가 (17).

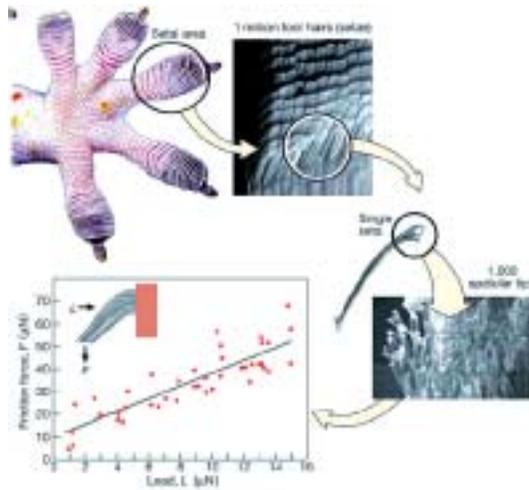


그림 17. Measurement of Adhesion and Friction for Gecko Foot-hair

Hui^[16]

가 Pull - off
 , PDMA Polyimide
 가
 (18, 19).

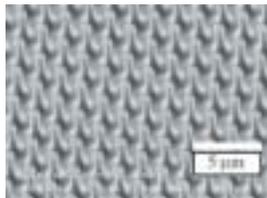


그림 18. Patterned Polyimide for Nano Seta

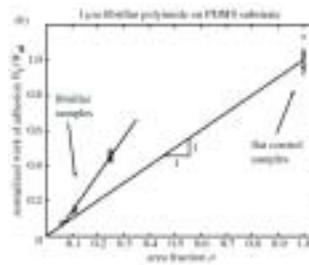


그림 19. Measurement of Adhesion Energy

Mettin Sitti^[17]

Gecko Foot - hair
 Pore Membrane
 (100 nN)

Adhesion

AFM Probe

가 Gecko Foot - hair
 (20, 21).

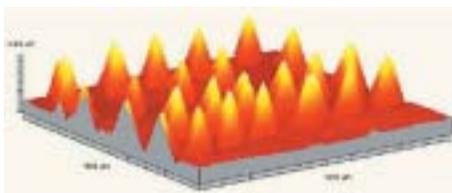


그림 20. Patterned PDMS for Nano Seta

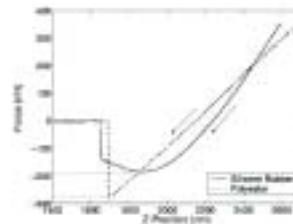


그림 21. AFM에 의한 Nano Seta의 접착력

(3) Nano Turf

MIT 50nm 2 μ m CNT
(22). Quere

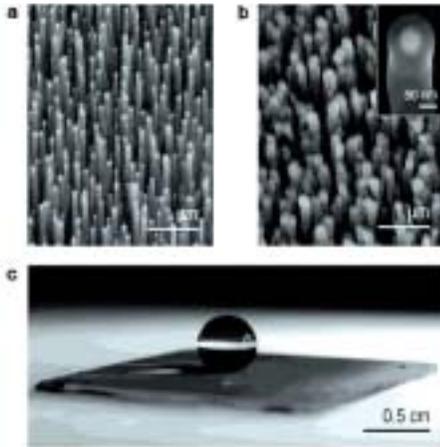


그림 22. 탄소 나노 튜브의 SEM 사진 및 표면 소수성

Roughness가

(23).

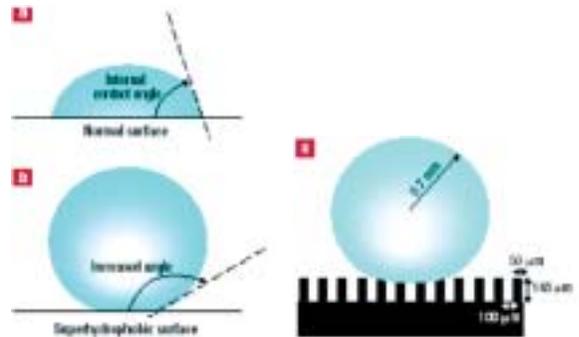


그림 23. 소수성과 나노구조물이 유체방울에 미치는 영향

Illinois
Wetting

Roughness가

No - slip/slip

Roughness가

(24).

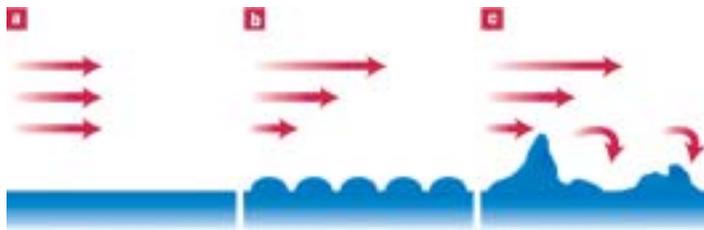


그림 24. 표면 경계에 따른 유동분포

3.3 공정기술

Stereocilia 가

가

CNT

SAM(Self Assembled Monolayer)

가

Open

가

가

Stereocilia

(25).

1998

Hot - Filament PECVD

, New York

Stanford Dai Thermal CVD Porous Si Fe
 CVD Thermal
 NASA F. Noca CNT Stereocilia (electrical
 potential)
 Li^[18] AAO CNTs (26) J. Liang^[19]
 (AAO)

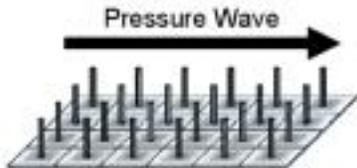


그림 25. 나노튜브를 이용한 Stereocilia 모사 개념도

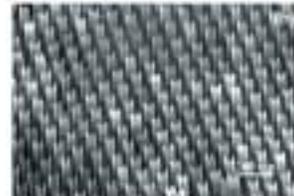
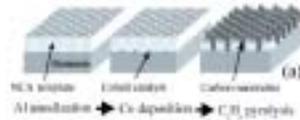


그림 26. AAO를 이용한 CNT어레이의 제작

Bell

Gombert^[20] UV Embossing 350nm 7µm 20
 27 1 Moth-eye

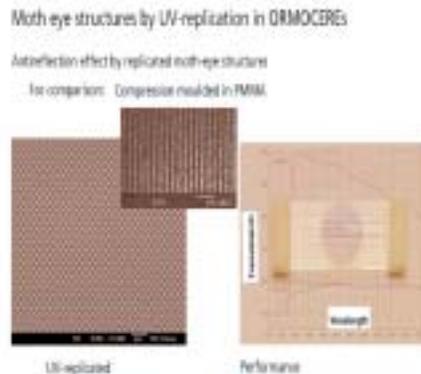
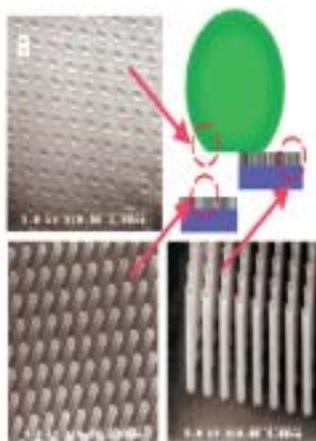


그림 27. 전자빔 노광과 실리콘 건식 식각공정을 통해 제작된 실리콘 나노 포스터(좌), Embossing 공정을 통해 제작된 Moth-eye Structure: UV 경화성 수지(우)

Morariu^[21] Anodic Aluminum Oxide(AAO) Plate 가 200nm
 30 μ m 가 Polystyrene , KOH
 AAO (28).

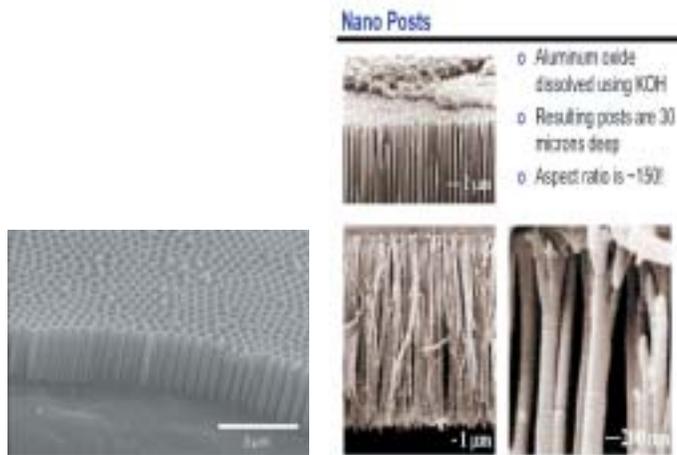


그림 28. AAO 템플레이트의 전자현미경 사진 및 Polystyrene을 사출한 결과

POSTECH^[22] AAO Template PDMS
 (29)



그림 29. SAM으로 개질된 AAO Plate를 이용하여 제작된 PDMS Replica

4. 결 론

- 가

❁ 참고 문헌

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