No more laundry?

An innovative and economical fabrication technique developed by HKU Scientists could make the dream come true!

衣物免洗終能實現?
港大科學家發明研發出理想化的防水防油物料

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Material property depends on substance and structure; we develop microfluidic technology to precisely tailor/create structures at micro/nano-scales.

材料的性質取決於所用物質和物質的結構；我們發展微流控技術以在微納米量級上精准調控物質結構。

Artificial blood vessels
人工血管
Embolic microparticles
栓塞微球
Liquid-repellent surfaces
疏液表面
Micro/nano-droplet-manipulation surfaces
微納液滴操控表面
Spider-web-like microfibers
蜘蛛網式空腔纖維
Thermal waves/resonance heat-transfer media
熱波熱共振傳熱介質

Zhu & Wang, Lab on A Chip, 2017
**Liquid-repellent surfaces** 防水防油表面

**In nature 自然界實例**

Superhydrophobic lotus leaf 超疏水荷葉

Water strider 水黽

Fog collection by desert beetles 沙漠甲蟲收集水

https://www.youtube.com/watch?v=D1lh0vjNFdk  
https://www.youtube.com/watch?v=4CU8gYYkwSw  
Planet Earth II, Episode 4: Deserts, BBC

**Applications 應用**

Daily life 日常生活

Military equipment 軍事設備

https://www.youtube.com/watch?v=rEEdyBkD1YE  
https://buzzorange.com/2017/01/12/aircraft-carrier-liaoning/
Requirements for high-performance liquid-repellent surfaces
高性能防水防油表面的要求

- Robust liquid repellency
- 良好的防水防油性
- Long-term durability
- 耐久性
- Large-scale fabrication
- 大面积製備
- Low-cost fabrication
- 成本低廉

https://www.youtube.com/watch?v=i3jA40arq9Y
**Background**

**Challenges**

- Trade-offs between liquid repellency and mechanical durability
  防水防油性和強韌度難相容

- Mutually exclusive fabrication of large-scale manufacturing and precise control over surface structures
  大面積製備和精確控制表面結構二者互斥

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**Roughing surfaces**

製造表面結構

Low mechanical stability

低強韌度

Weak liquid repellency

防水防油性差

**Bottom-up** 自下而上

**Top-down** 自上而下

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Large-scale

面積大

Low-cost

成本低

Random structures

結構隨機

Well-ordered structures

結構均勻

Laborious

過程複雜

Difficult to scale up

難以大面積製備

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*Chem. Soc. Rev.*, 2016, **45**, 323

*Adv. Mater.*, 2014, **26**, 2029

Background 背景

Bio-inspired design of surface structure 仿生學表面設計

Cuticles of springtails 跳蟲表皮

Our design: interconnected micro-cavities with re-entrant profiles. 設計思路：互連的凹角微腔結構

Bio-inspired design resolves effectively the conflict between mechanical stability and liquid repellency: 仿生學設計有效地解決了強韌度和防水防油性之間的矛盾：

interconnectivity endows the surface with enhanced mechanical stability; re-entrant structure yields robust liquid repellency. 互相連接提高強韌度；凹角特點加強疏液性能。

PloS One, 2011, 6, e25105
High-throughput droplet generation (~ 1.5 L h⁻¹) 量產液滴（1.5升/小時）

Droplet microfluidics 液滴微流控技術
Fabrication of functional materials 製備功能材料

Droplet microfluidics enables low-cost fabrication of large-scale surface structures with high precision and controllability.
液滴微流控技術可實現低成本大面積並具有精確結構的表面製備
Microfluidic droplet generation  生產微流控液滴

Single emulsion 單乳液

Double emulsion (single-core)  雙重乳液（單核）

Double emulsion (double-core)  雙重乳液（雙核）

Triple emulsion 三重乳液

Double emulsion (triple-core)  雙重乳液（三核）
Diverse microfluidic emulsions 多種微流控乳液

- **Single emulsion 單乳液**
- **Janus emulsion 雙面乳液**
- **Double emulsion 雙重乳液**
Self-assembly of Micro-droplets 微液滴自動組裝

Fabrication process 製備過程

- Emulsion Deposition 乳液沉積
- Solvent Evaporation 溶劑揮發
- Template Removal 範本去除

FFT image

Large-scale well-ordered porous surface 具有均勻結構的大面積多孔表面
Robust liquid repellency 良好的防水防油性

Contact angle >90° for both water and oils 水和油的接触角均高于90°

Water 133.6°  Glycerol 131.8°  Olive oil 126.2°  Soybean oil 124.9°  2% SDS 109.0°
Paraffin oil 103.3°  DMC 97.3°  Hexadecane 94.8°  1,4-dioxane 90.8°  2-octanol 90.7°
Enhanced mechanical stability
強韌度被增強

Abrasion test (over 21-fold enhancement)
摩擦測試結果（強韌度增強至少21倍）
Concluding Remarks 總結

Design 設計

- Bioinspired design resolves effectively the conflict between the liquid-repellency and the mechanical stability
- 仿生學設計新型結構解決了疏液性和耐用性的矛盾

Fabrication 製造

- Microfluidic-droplets-based fabrication offers low-cost and scalable production of well-defined structures with precision and controllability
- 微流控液滴技術實現低成本大面積製備結構控制的表面
Many Thanks

謝謝