Micro- and Nano-structured Surfaces with Tunable Adhesion

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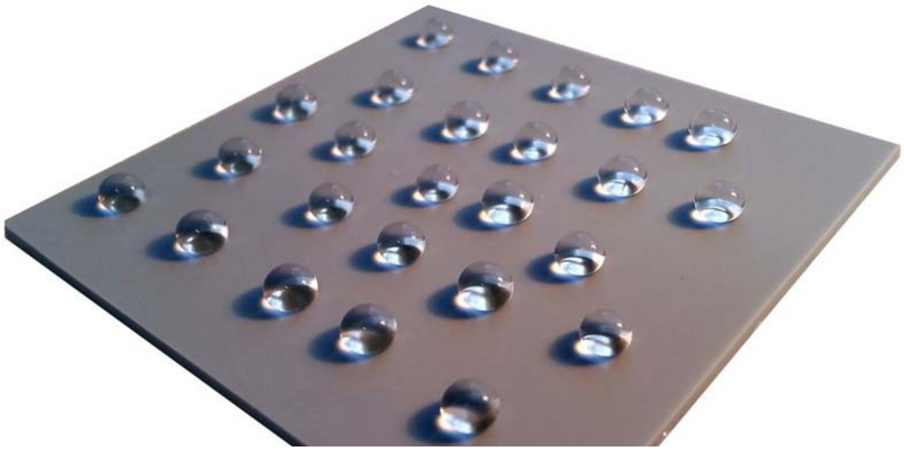
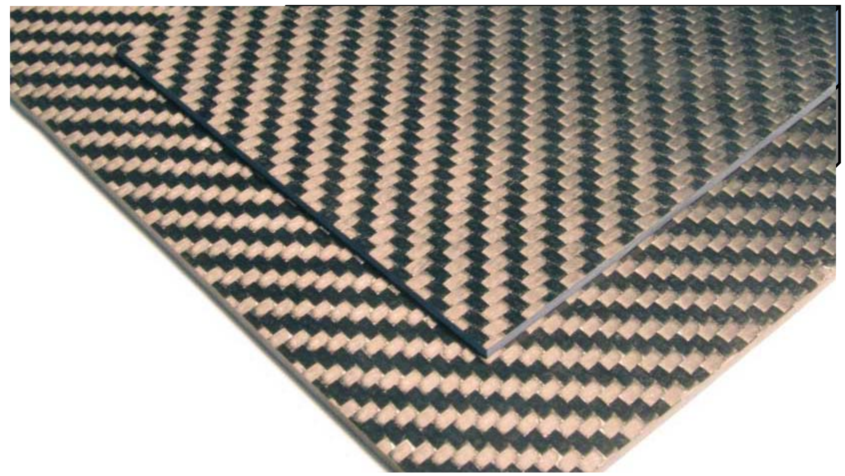
Surfaces and Interfaces – An Opportunity for Nanotechnology

super hydrophobic surface



composites with nanotube-reinforced interfaces



Surfaces/interfaces are thin

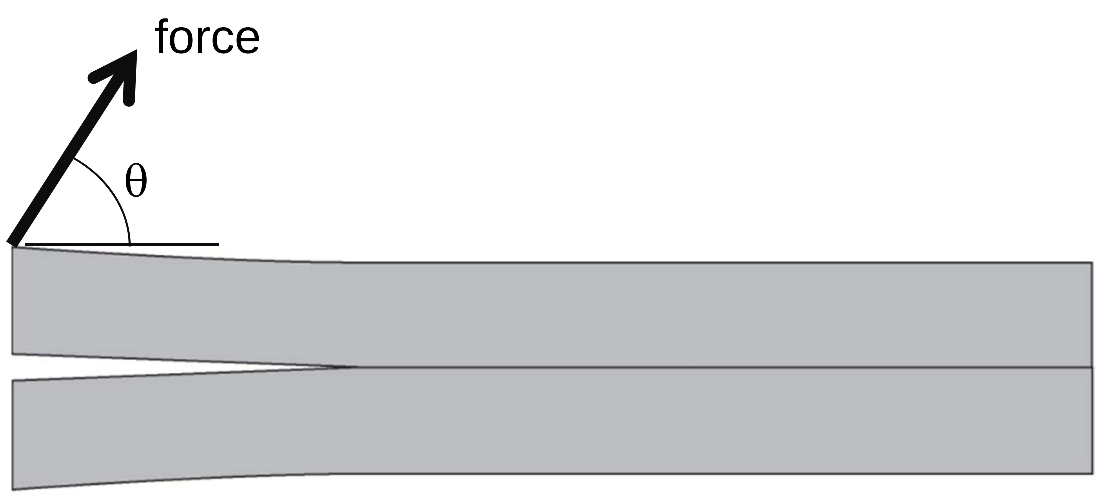
Nanostructures are small

Nanostructures are well-suited for manipulating surface and interface properties

What is tunable adhesion?

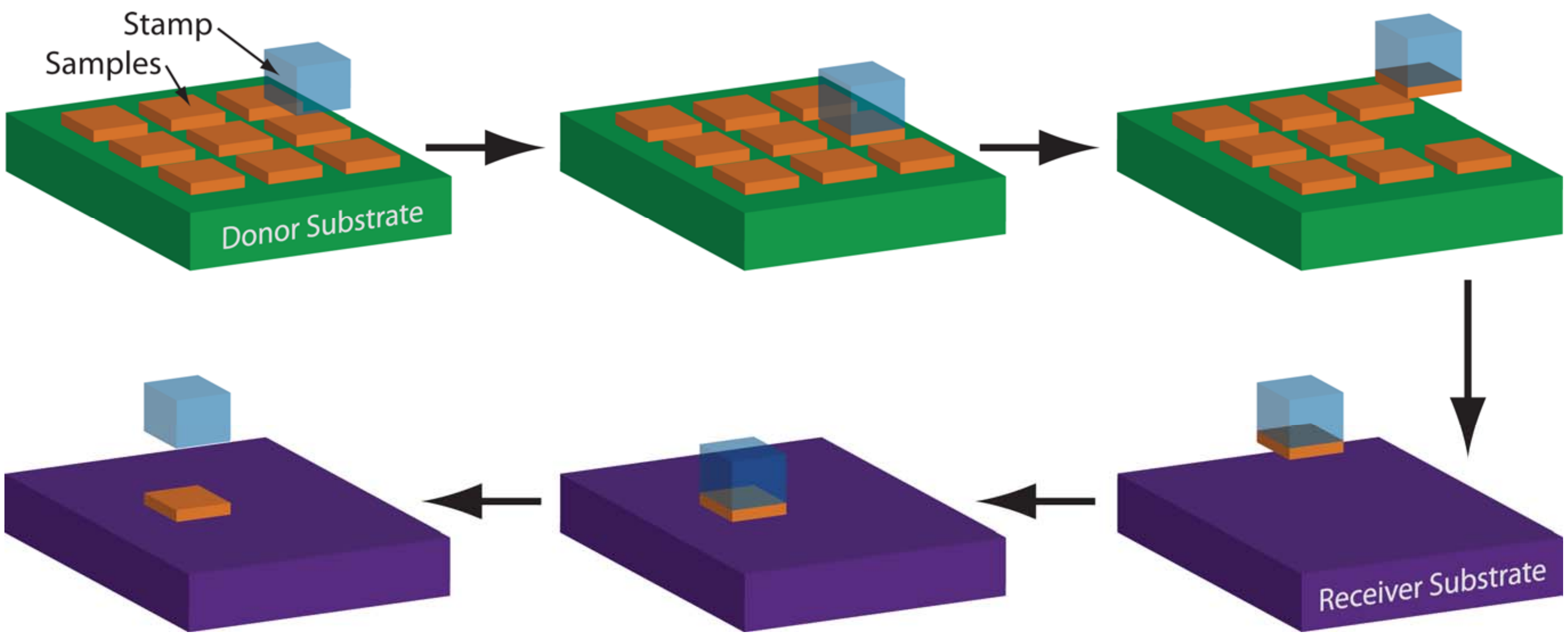
- **Adhesion that can be controllably modulated from strong to weak**
  - Strong adhesion when you need it
  - Weak adhesion when you want to separate an interface

- Many ways to control adhesion: chemistry, temperature, electric fields, etc., but **simplest control approach is the direction of loading**

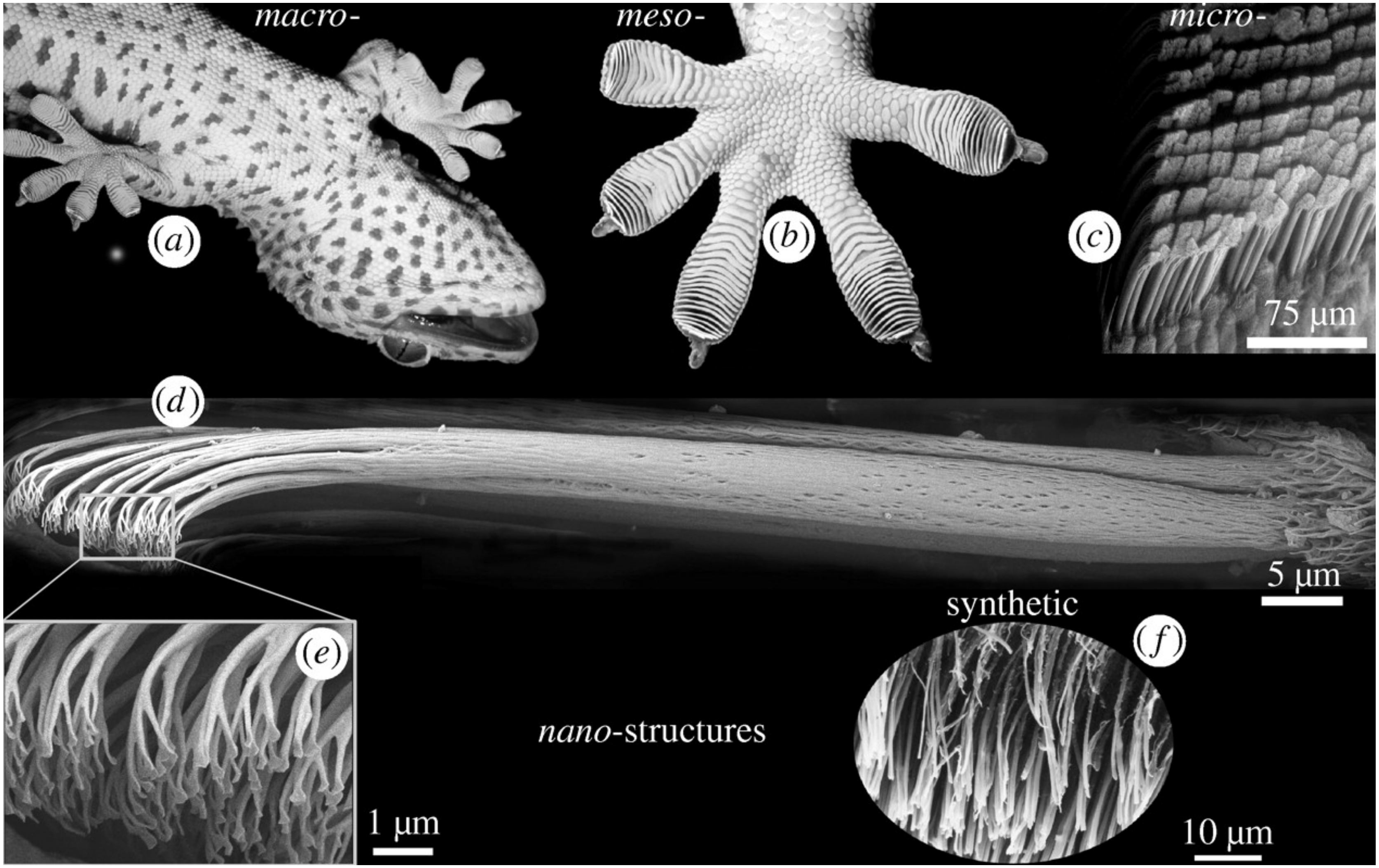


Why are we interested in tunable adhesion?

- Manipulation of micro- and nano- components
- Microtransfer printing of 2-D materials

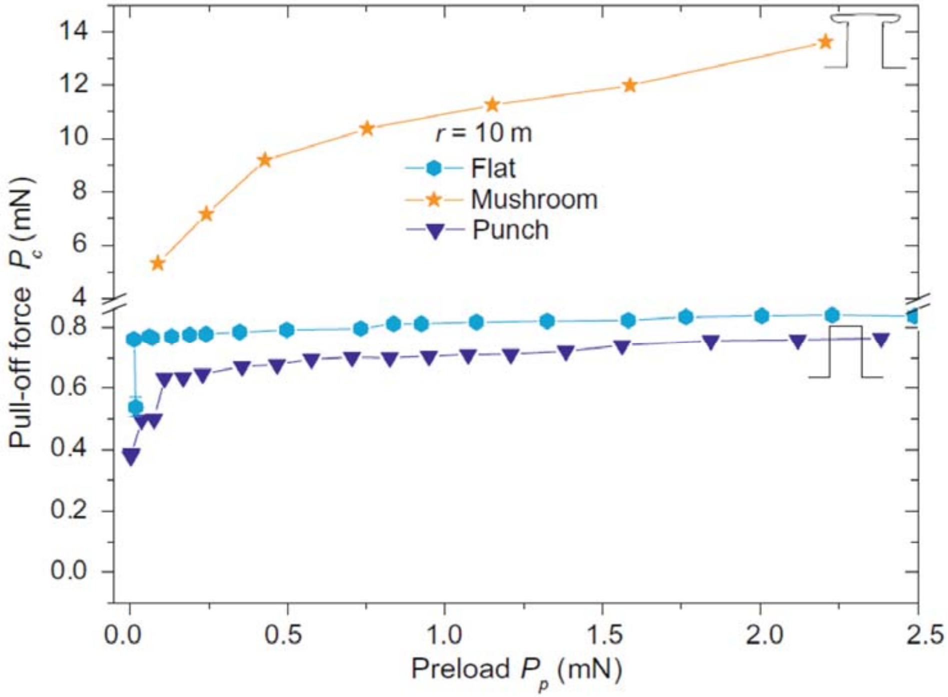


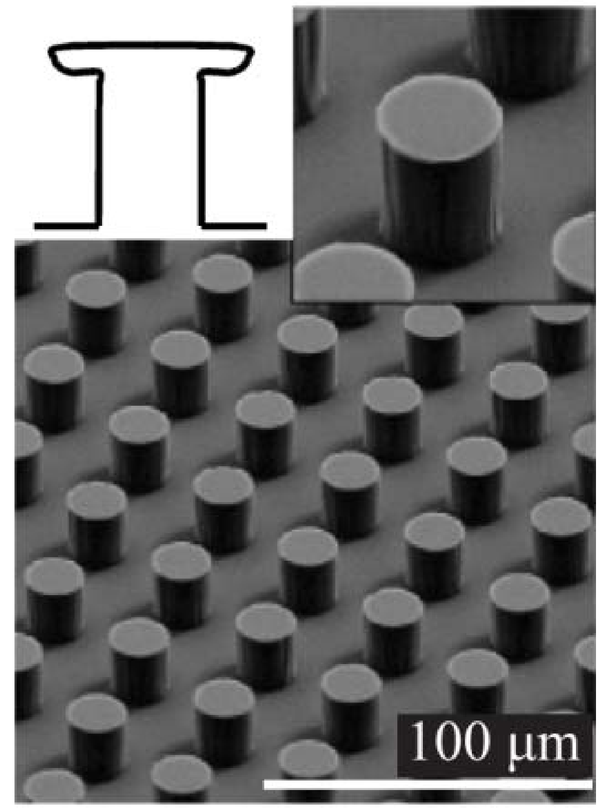
Adhesives based on micro- and nanostructuring

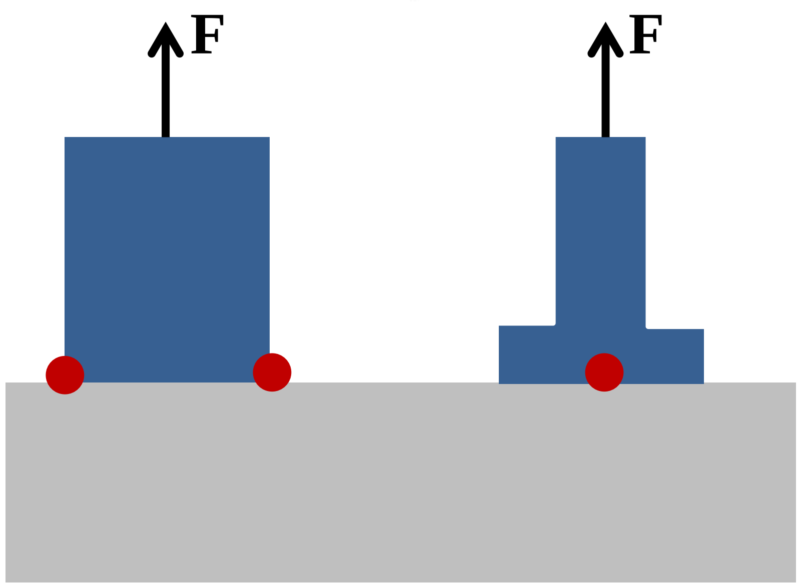


Hierarchical structure that terminates in nanofibers yields strong and tunable adhesion

Adhesion of Mushroom-Shaped Posts

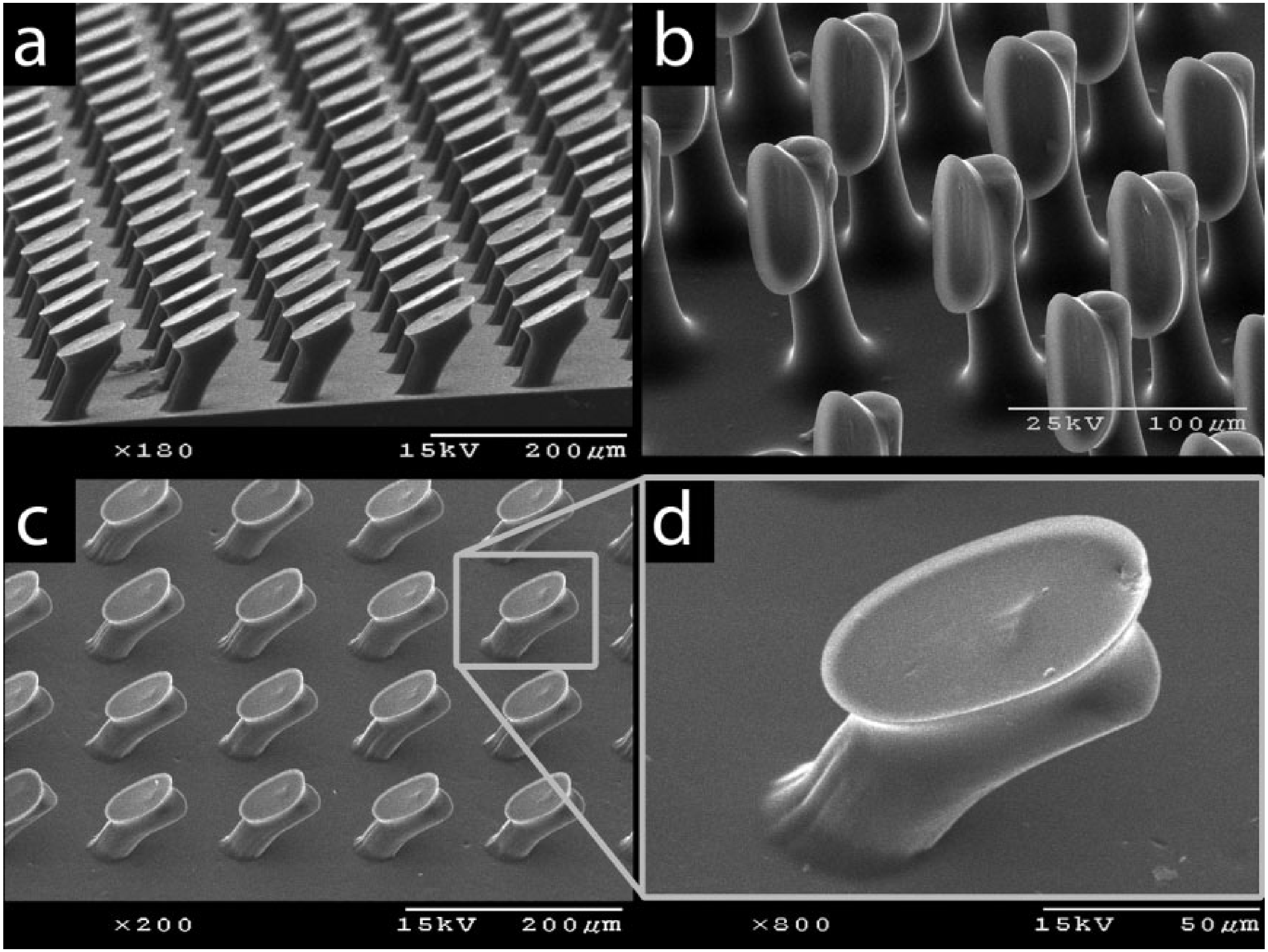






A. del Campo et al, *Langmuir* 23: 10235-43 (2007)
A. Spuskanyuk et al, *Acta Biomaterialia* 4: 1669-76 (2008)

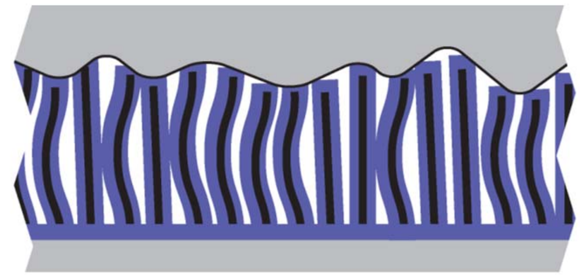
Slanted Mushroom-Shaped Stamps



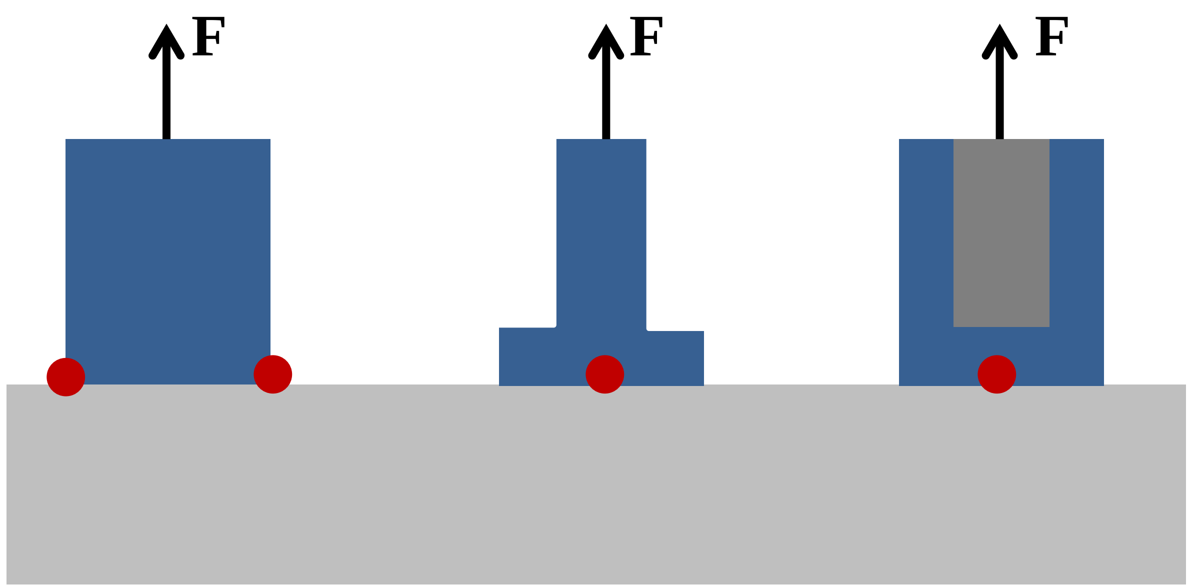
M. Murphy et al, *Small* 5: 170-75 (2009)

Our technology

- **Surface structuring** (e.g., arrays of fibers)
  - **Compliant** – accommodate roughness
  - **Discontinuous** – disrupt crack propagation
  - **Redundant** – not all posts must be adhered



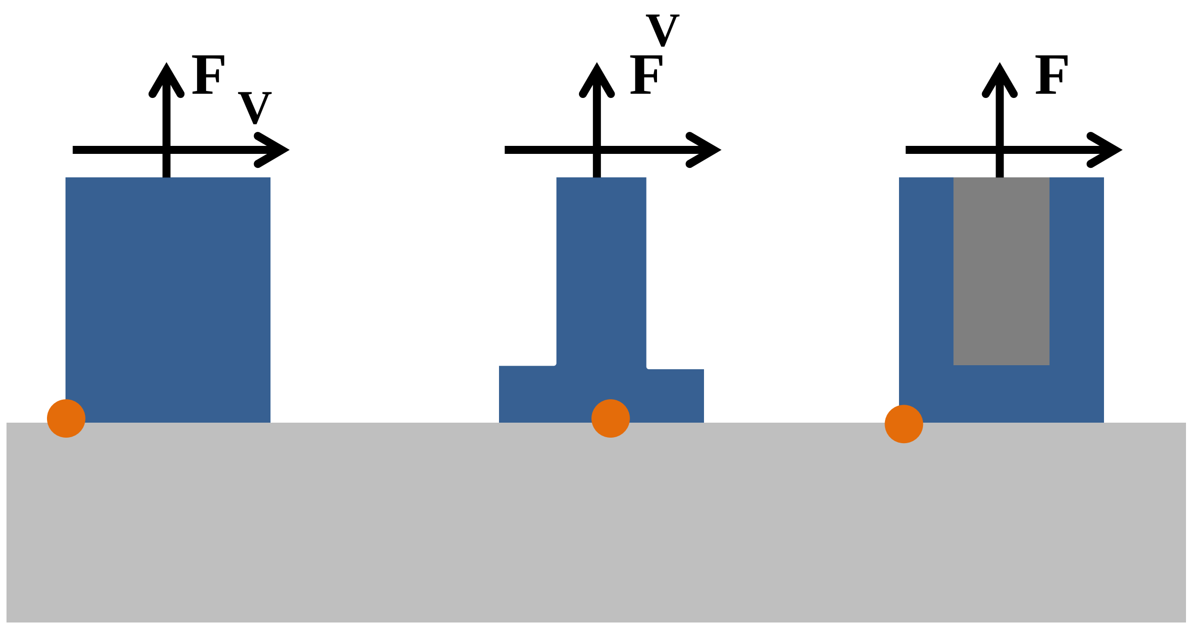
- **Composite fiber structure** to give **high adhesion** and **tunability**



Our technology

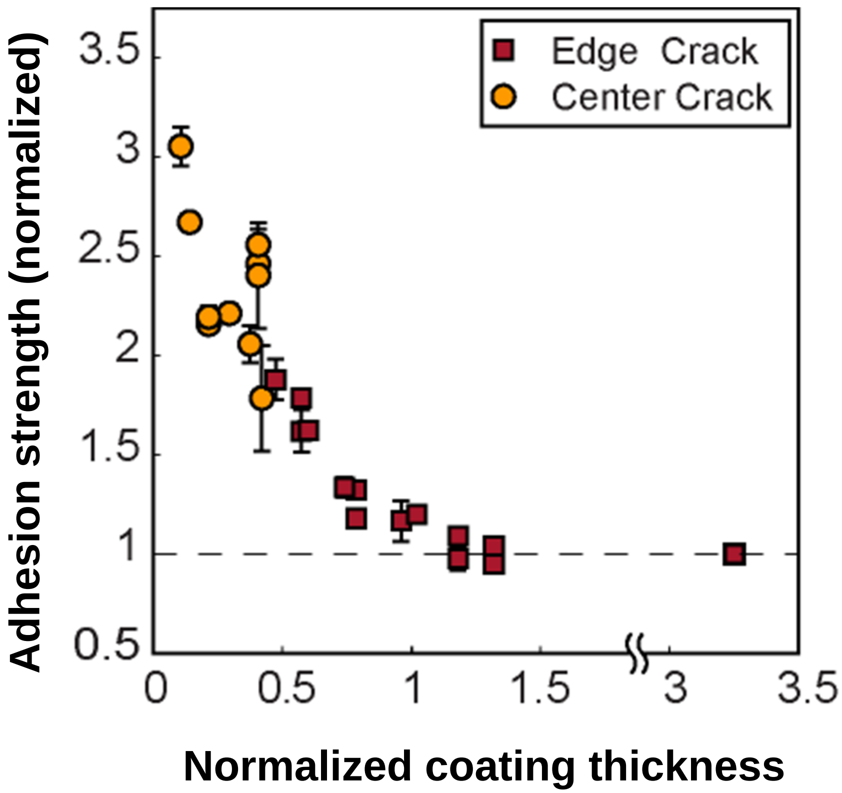
- **Surface structure** (e.g., arrays of fibers) can lead to high adhesion
  - **Compliant** – accommodate roughness
  - **Discontinuous** – disrupt crack propagation
  - **Redundant** – not all posts must be adhered

- **Composite fiber structure** to give **high adhesion** and **tunability**

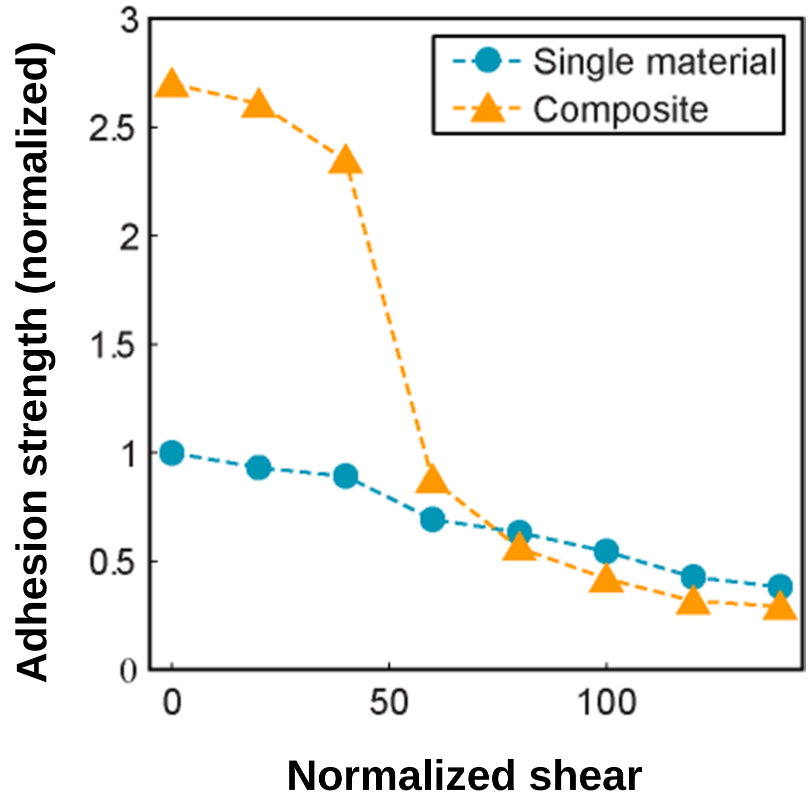


Example data

Adhesion Enhancement



Adhesion Tuning



Some scaling basics – mm, μm, nm

- The composite fiber approach can be used to achieve high tunable adhesion at various length-scales. The mechanics is valid for fibers with dimensions of <u>mm to ~100 nm</u>

- Higher roughness surfaces require smaller fibers
  - smooth and flat surfaces: mm scale fibers OK
  - surfaces of moderate roughness: 10-100 μm fiber size
  - arbitrary rough surfaces: 100 nm-1 μm fiber size

- Reduction in feature size increases redundancy
  - 1 mm: ~500 fibers in 1 in^2 (60% fill)
  - 10 μm: ~5 million fibers in 1 in^2 (60% fill)
  - 100 nm: ~50 billion fibers in 1 in^2 (60% fill)

Potential applications

- **Manufacturing**
- **Robotics**
- **Consumer products**
- **Biomedical**
- **<Insert your idea here>**