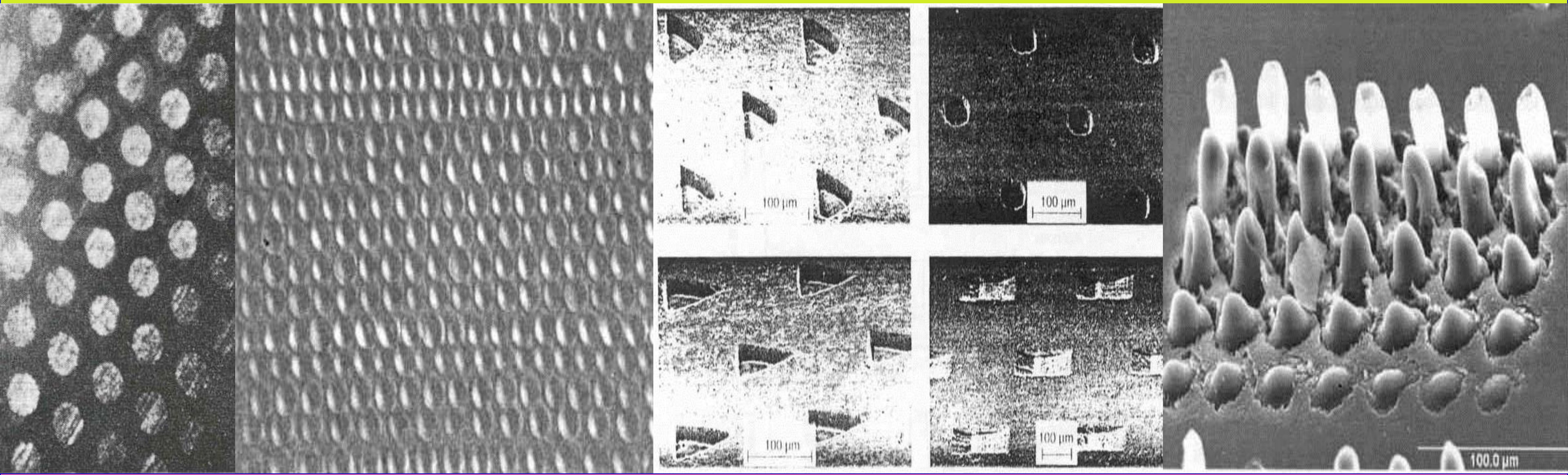
Surface Texturing: Principles and Design



Stephen M. Hsu

Surfaces: why live with random surface roughness?

Surface engineering

- Continuous & discrete textures (friction control)
- Thin soft films (lubrication)
- Thin hard films (durability)
- Surface chemistry protecting films (reliability)

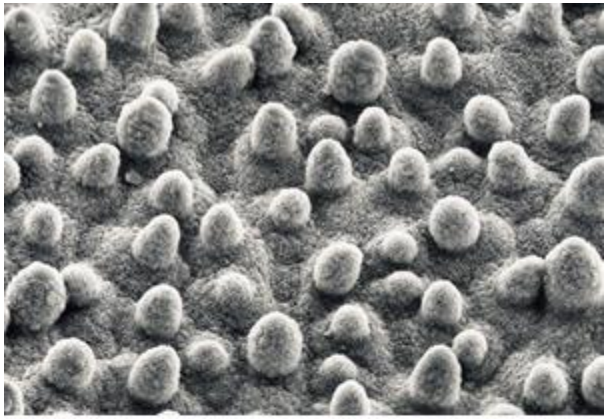
Motivation: to reduce friction & increase durability in energy transmission components and engines

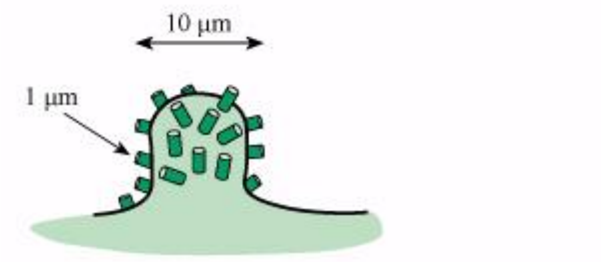
Is it possible to achieve 5% reduction in friction and 30% increase in energy transmission efficiency using surface textures, thin films, and surface chemistry?

Surface texturing

- Operating regime classification & mechanisms
  - High speed, low load (15 MPa, 1 m/s)
  - High speed, high load contacts (800 MPa, 1-2 m/s)
  - Low speed, high load contacts (1-3 GPa, <1/m/s)
- The issue of scale
  - mm scale features
  - Microscale features
  - Nanometer scale features

Symbol of Purity
The Lotus Leaf

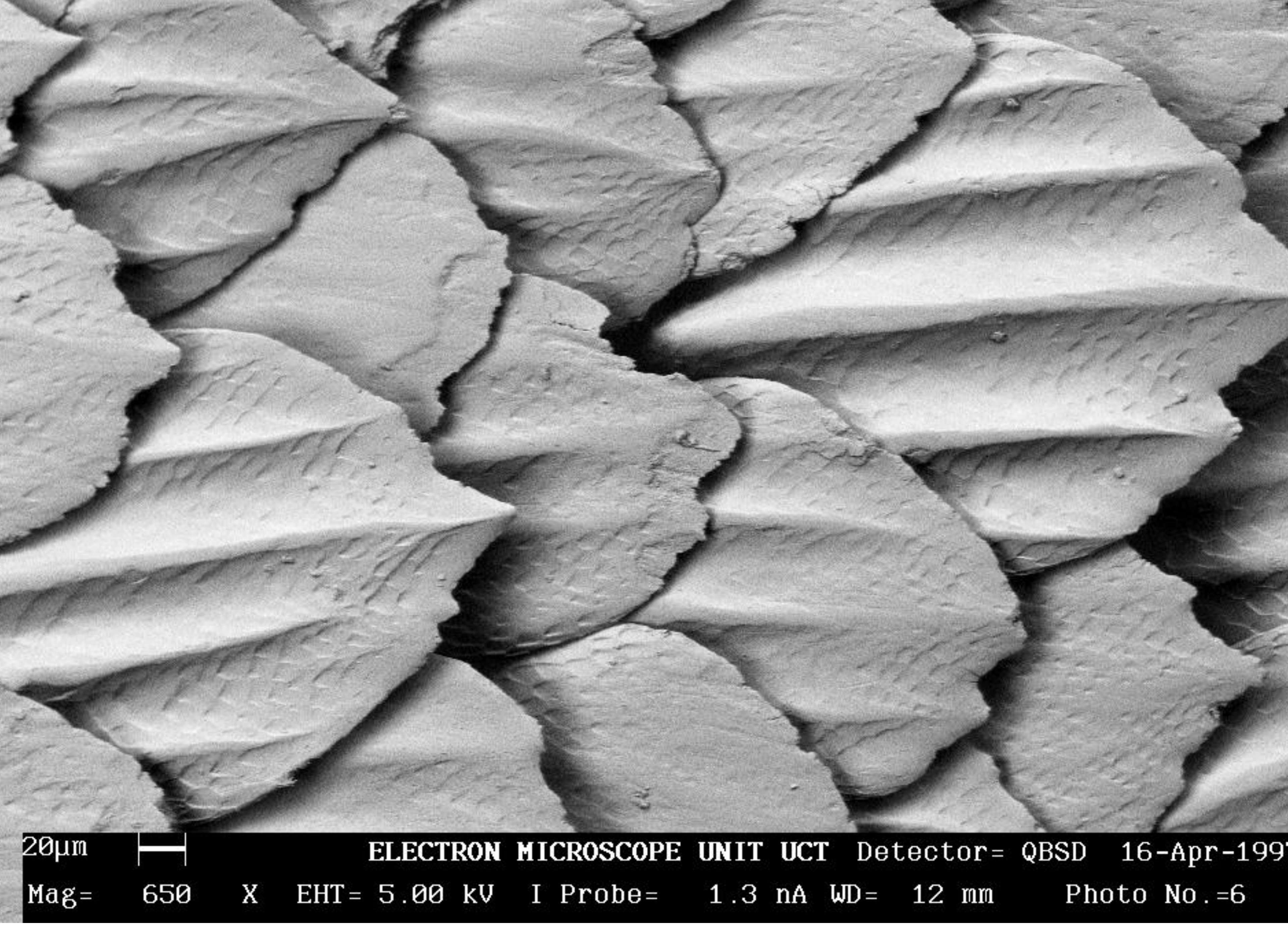




“The white lotus, born in the water and grown in the Water, rises beyond the water and remains unsoiled By the water” (ancient Indian Buddhist text)

Symbol of Purity

Sharks have used **surface texture** to lower friction for > 200 M years.
Parallel placoid riblets guide fluid flow and prevent sideway turbulence across skin.
Riblets do not grow with fish.
Sharks typically swim 5-20 km/h, max ~ 40. Riblets may help in glides after spurts


20µm
ELECTRON MICROSCOPE UNIT UCT Detector= QBSD 16-Apr-199
Mag= 650 X EHT= 5.00 kV I Probe= 1.3 nA WD= 12 mm Photo No.=6

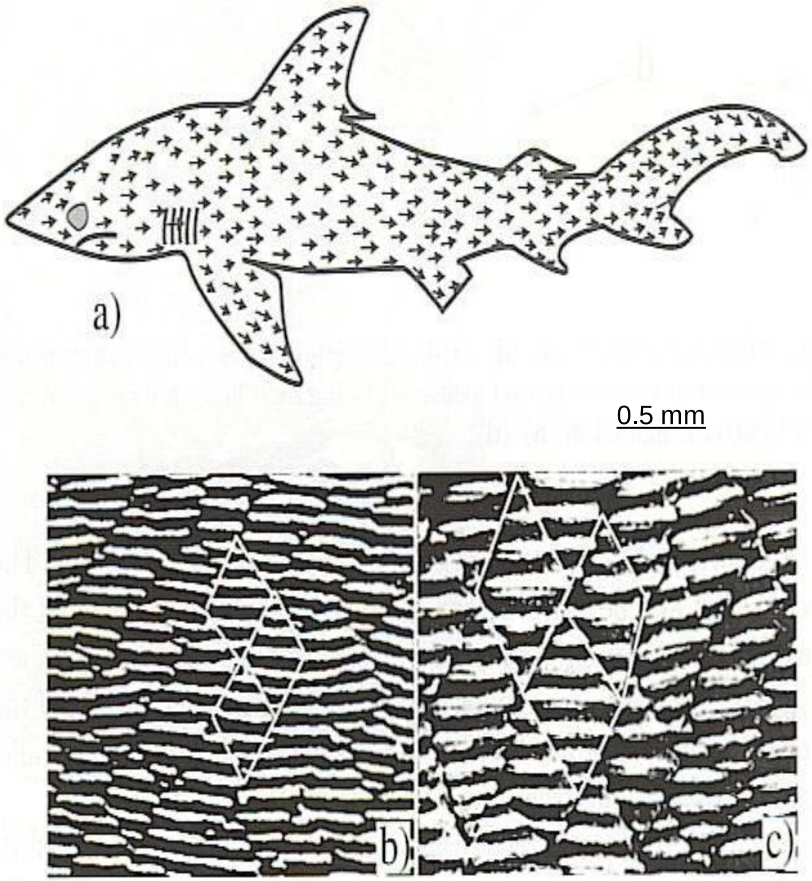


Fig. 3.2. Shark skin surface. (**a**) Directionality of the riblet groove pattern in the shark *Isurus oxyrhynchus*. (**b**) Scale surface of the shark *Sphyrna lewini*. (**c**) Scale surface of the shark *Etmopterus spinax*.

Scherge & Gorb, Biological Micro-and Nanotribology, Springer 2001, 83

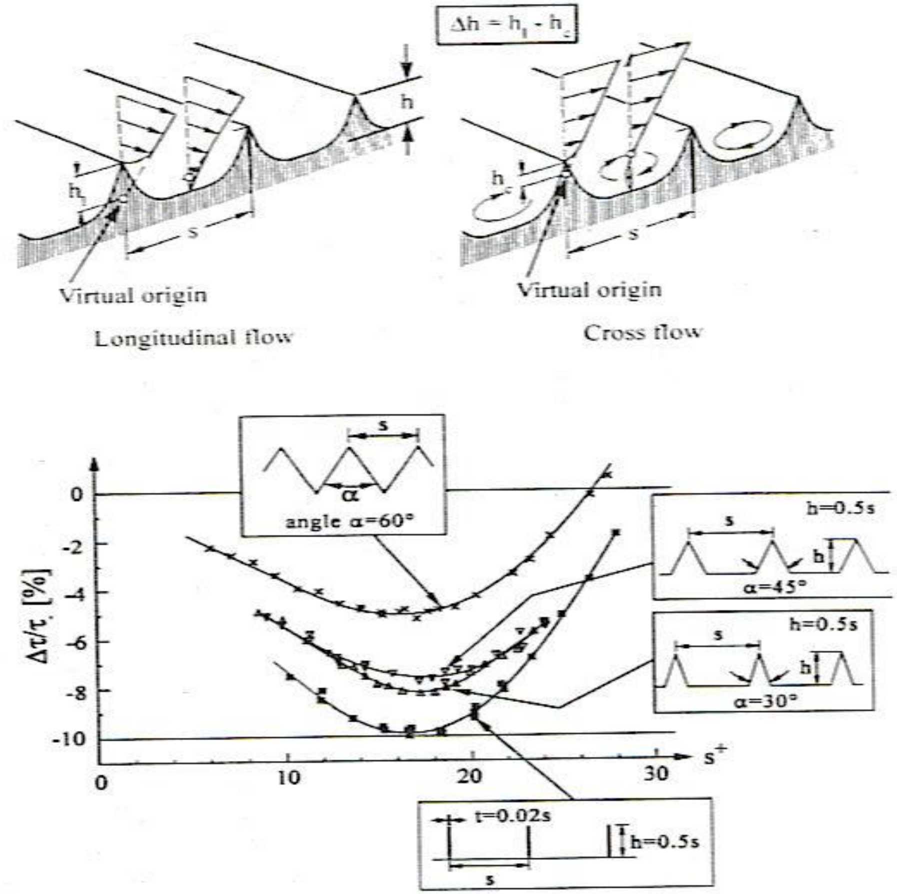
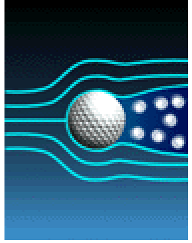


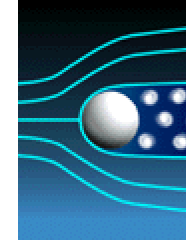
Fig. 3 Above: Longitudinal and cross-flow on a ribbed surface; below: drag reduction performance of various rib geometries

Bechert et al, Naturwissensch. 2000, 87, 157

Turbulent flow, less separation, less drag

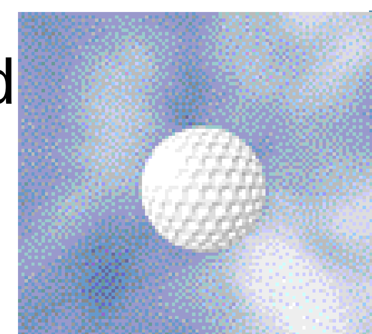


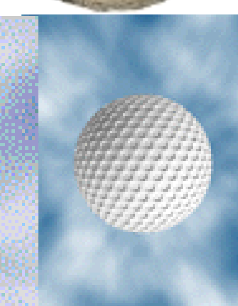
Laminar flow, larger separation, larger drag



Golf Balls and Dimples

- Since 1618 “featheries” balls used, goose feathers stuffed inside cowhide pouch, seams inside
- 1848 – smooth gutta percha balls introduced; did not fly as well as “featheries”; after 1880 they were given texture to fly equally as well
- Dimples (in rows) introduced in 1905 (standard 336 in US, 330 in UK); round ones are standard, hexagonal ones may be better





Biomimetics?

- 3M has made ribbed films modeled on the shark skin of fluoropolymers and coated upper fuselage and wings on a Cathay Pacific Airbus A340. Early tests (1999) showed drag reduction of 1% = 1 ton fuel per 7,000 miles or savings of about $ 100,000/year

- But biomimetics may not always work. Gray calculated in 1936 that dolphins were not strong enough to swim as fast as they do. That led to the belief that the skin had some unusual properties which facilitated flow and that nature had the optimal solution to all problems (*Gray's Paradox*).