

The logo features a stylized 'CT' in a blue and green gradient, followed by the text 'Coatings Trends & Technologies SUMMIT' in a bold, black, sans-serif font.

**Coatings Trends  
& Technologies  
SUMMIT**

**UV Cure  
'Shark Skin  
bio-mimicking'  
Antimicrobial  
surfaces for  
Autonomous  
Vehicles?**



# AGENDA

- Autonomous Vehicle (AVs) Revolution?
- History & Development of UV-A Cure Automotive Paints
- Background on Aircraft ‘Shark Skin’ (Riblet) UV Curable Aerospace Coatings
- So what is the connection between Shark Skin Antimicrobial and AV?
- Current Shark Skin (Riblet) Antimicrobial Surfaces in the market
- So where do we go next?
- Conclusions

# Expected release Dates of Autonomous Vehicles (AV)

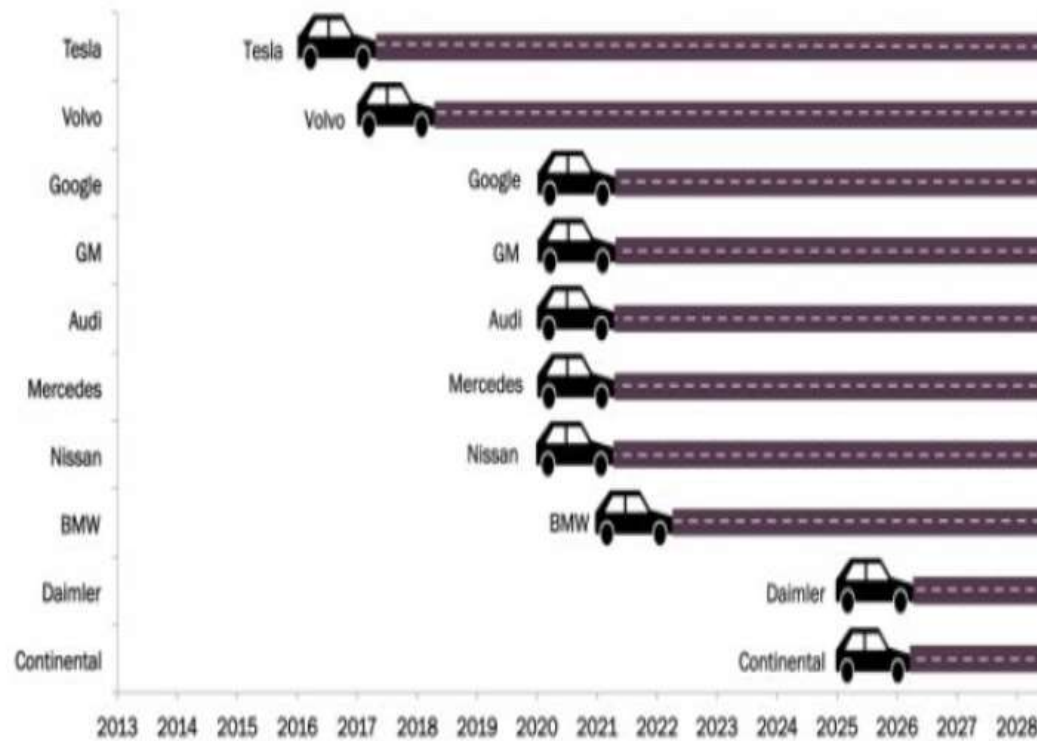


Figure 5: Expected release of Autonomous cars

AI based Autonomous Car, Bin Sulaiman, R., Institute of Arts,  
Science & Technology, Dept. of Computing, Glyndwr University, Wrexham, UK (2018)

# Autonomous Vehicles; Follow the Money

Country: **USA** | Funding: **\$3.6B**

**Argo AI** is a self-driving technology platform company.

Country: **USA** | Funding: **\$3.4B**

**Cruise Automation** is a self-driving car company that develops an autopilot system for existing cars.

Country: **USA** | Funding: **\$3B**

**Waymo is Google's** self-driving technology startup with a mission to make it safe and easy for people and things to move around.

Country: **USA** | Funding: **\$1.5B**

**NURO** is a technology company that aims to accelerate the benefits of robotics for everyday life.

Country: **USA** | Funding: **\$1.3B**

**Pony.ai** is a developer of AI-based robot designed for autonomous driving.

[https://ai-startups.org/top/self\\_driving\\_cars/](https://ai-startups.org/top/self_driving_cars/)

# Stages of Autonomous Vehicles Introduction

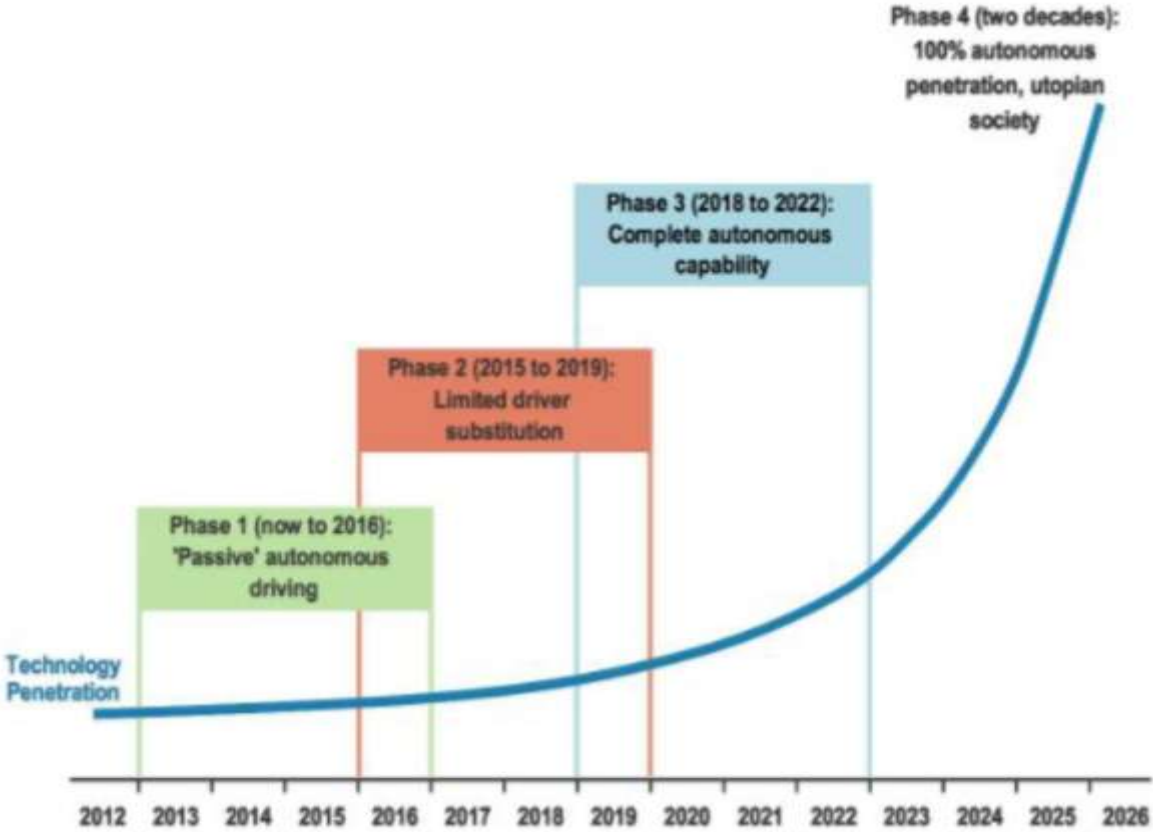


Figure 6: Stages of Autonomous car



# Autonomous Vehicle (AVs) Revolution?

- ❑ Waymo (former Google Div.) is the front-runner in the self-driving race.
  - ❑ It has been ferrying paid passengers around Phoenix for the past year (2019)
  - ❑ These AVs often are running without a “safety driver”
  - ❑ Waymo One (robotaxi service) topped 100,000 trips in 2019
  - ❑ Waymo One has fully driverless vehicles drove over 70,000 miles on US roads
  
- ❑ Zoox (Amazon-owned) has an autonomous robotaxi introduced in December 2019
  - ❑ Fully driverless ( no steering wheel) that can go 75 mph
  - ❑ The AV is built for ride hailing
  - ❑ Passengers face each other
  
- ❑ An endless loop Uber/Tesla/Waymo AVs?
  - ❑ Car ownership is a thing of the past?

[Why 2021 Will Be The Year Self-Driving Cars Go Mainstream \(forbes.com\)](https://www.forbes.com)



# History & Development of UV-A Cure Automotive Paints



- ❑ UV-A lights used to repair stone chips in windshields
- ❑ In 2000 a new technique was developed and introduced that would speed up the use of a automotive primer.
- ❑ In 2005 Clear Coats were introduced
- ❑ This new product brought the use of a UV-A light to cure the primer to American automotive refinish shops
- ❑ Current systems being used in NAFTA & Europe

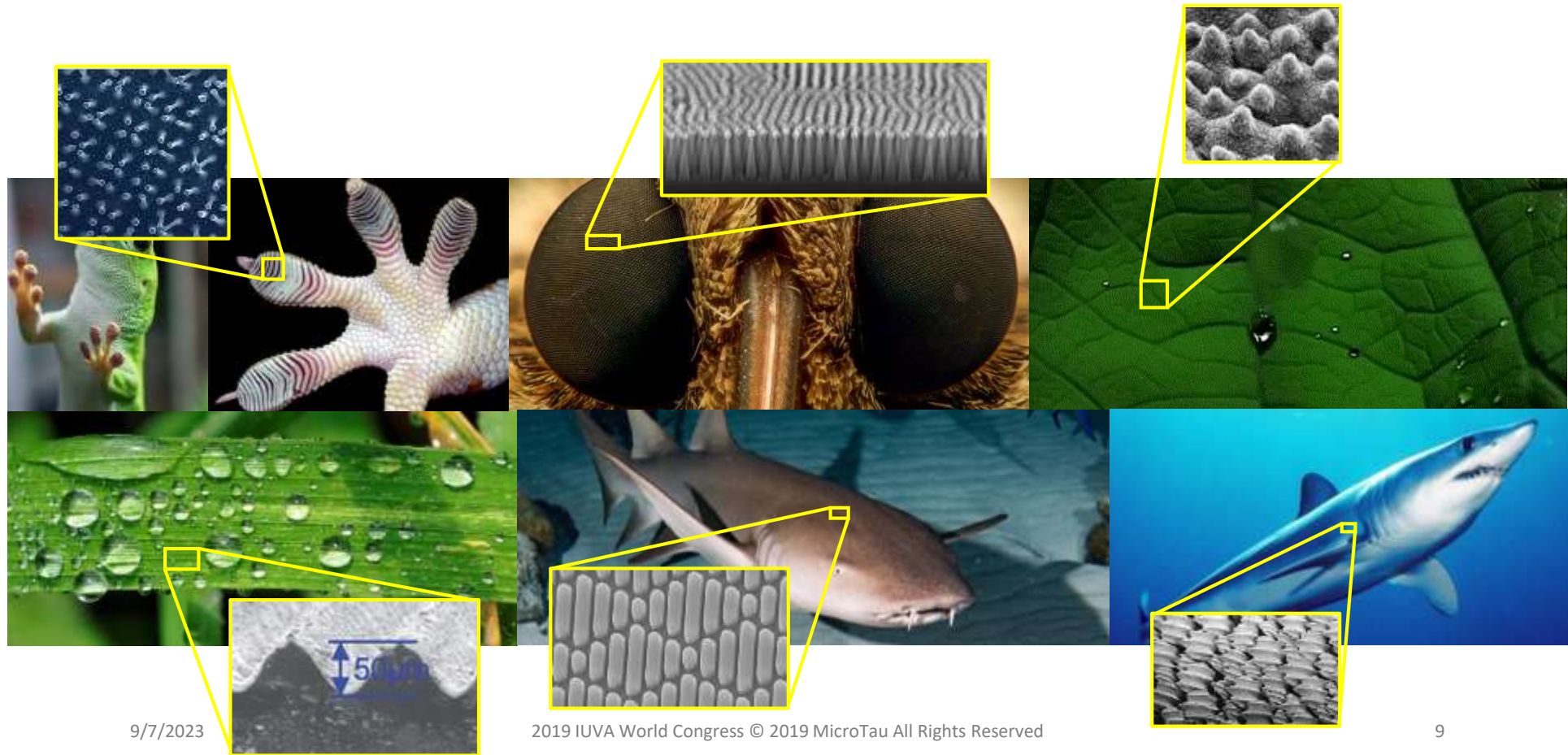
Dvorchak, M. J., Bayer Polymers, LLC, Diffuse UV Cure (UV-A) in the Automotive Coatings Industry: Fact or Fiction?, Focus Conference May 1, 2003



**Background on Shark Skin (riblets)**



# Functional Microstructures



9/7/2023

2019 IUVA World Congress © 2019 MicroTau All Rights Reserved



- ❑ Current USAF technical orders require [min. 72-hr 'dry-to-fly' time](#) for polyurethane topcoat
- ❑ Painting operations in depot and field units typically cause a 'bottleneck' in the work flow
  - ❑ Any one operational base may have up to *dozens* of aircraft and *hundreds* of pieces of support equipment – all need maintenance
  - ❑ Depots collectively paint hundreds of aircraft per year – all require lengthy dry-to-fly time
- ❑ Typical USAF coatings contain 340 – 420 g/L VOC



O'Neil, J., US 8,227,050 Jul. 24, 2012

## History of Shark Skin (Riblet) UV Curable Aerospace Coatings?

# History of Shark Skin (Riblet) UV Curable Aerospace Coatings

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## Air Force Research Lab's Engineered Surfaces, Materials and Coatings (ESMC) Program

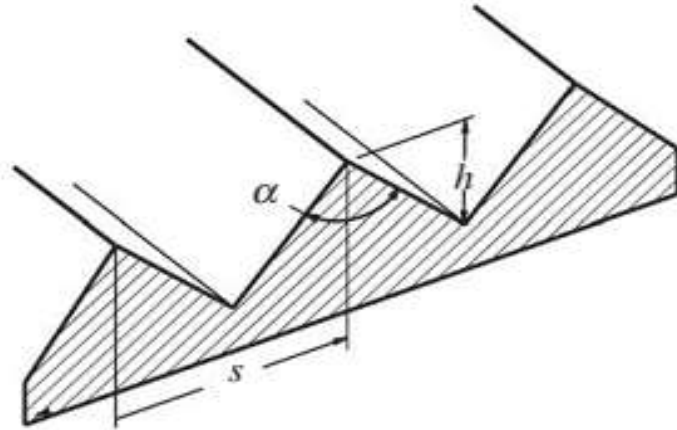


- ❑ USAF C-17, C-5 and C-130 consumed 618 million gal. fuel in 2014
- ❑ Ohio Aerospace Institute (OAI) as prime contractor to Lockheed Martin
- ❑ OAI did an InnoCentive request and received 95 submissions for the potential to obtain \$10,000 to conduct research
- ❑ Out of the 95 submissions 9 were selected and reduced to 3 for the Phase 1 monies in April 2016.
- ❑ Results of this program awarded Micro Tau Phase 2 monies in early 2017

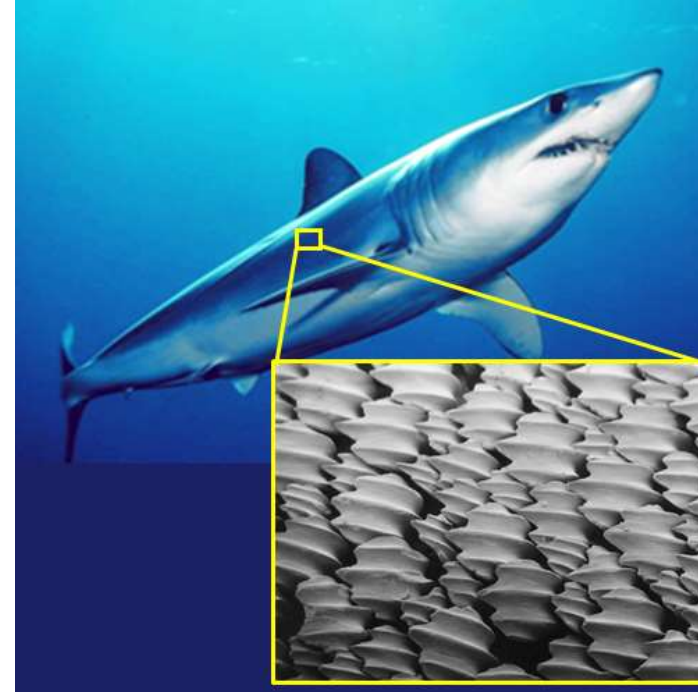
Warwick, G, U.S. Air Force Tackles Fuel-Burn Reduction On Legacy Aircraft, Aviation Week & Space Technology Jan 26, 2017

# Problem

- **Riblets**



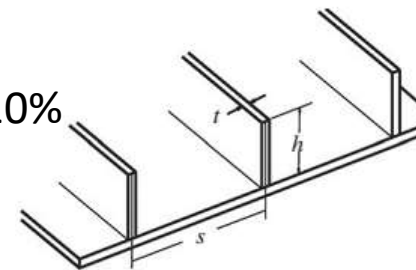
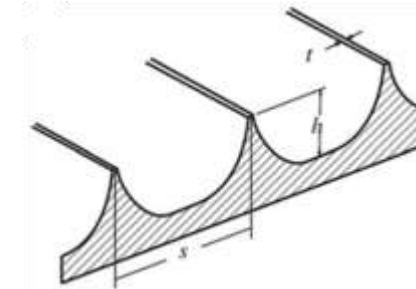
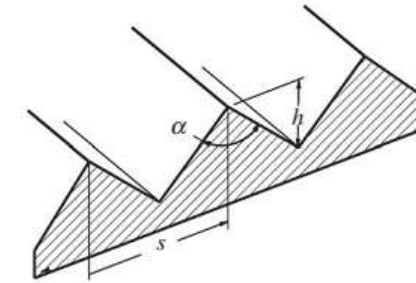
- 5-10% reduction skin friction drag
- 40+ years of evidence



- **Yet to be implemented due to economic viability**

- Application time and cost
- Durability and maintenance
- *Total cost out weighs fuel saving benefits*

# History of Shark Skin (Riblet) UV Curable Aerospace Coatings



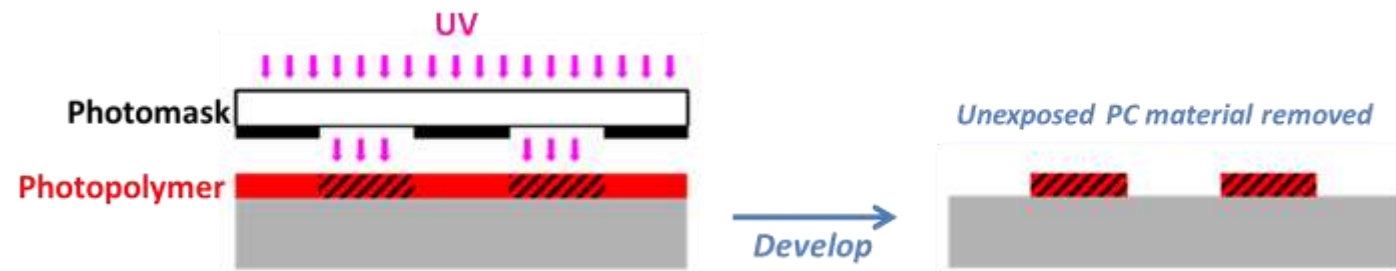
- ❑ Spacing & height  $\sim 50\text{-}150\mu\text{m}$
- ❑ Turbulent drag reduction of up to 10%



# History of Shark Skin (Riblet) UV Curable Aerospace Coatings

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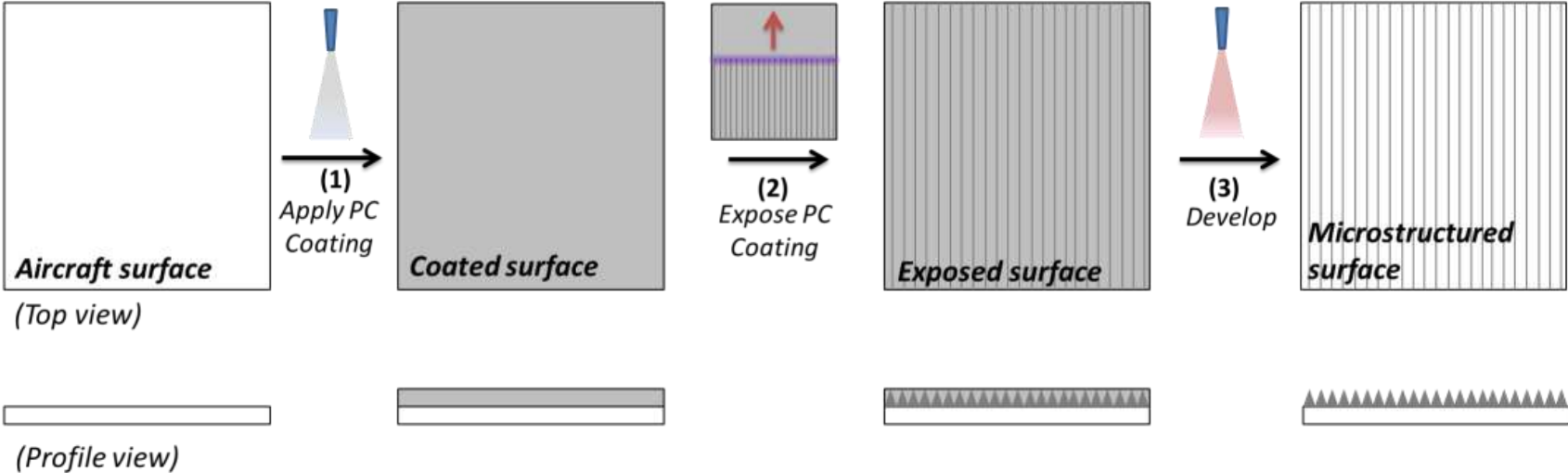
Photolithography (computer chip fabrication)



Bilinsky, H., MicroTau Pty Ltd  
SciTech January 9, 2017

# History of Shark Skin (Riblet) UV Curable Aerospace Coatings

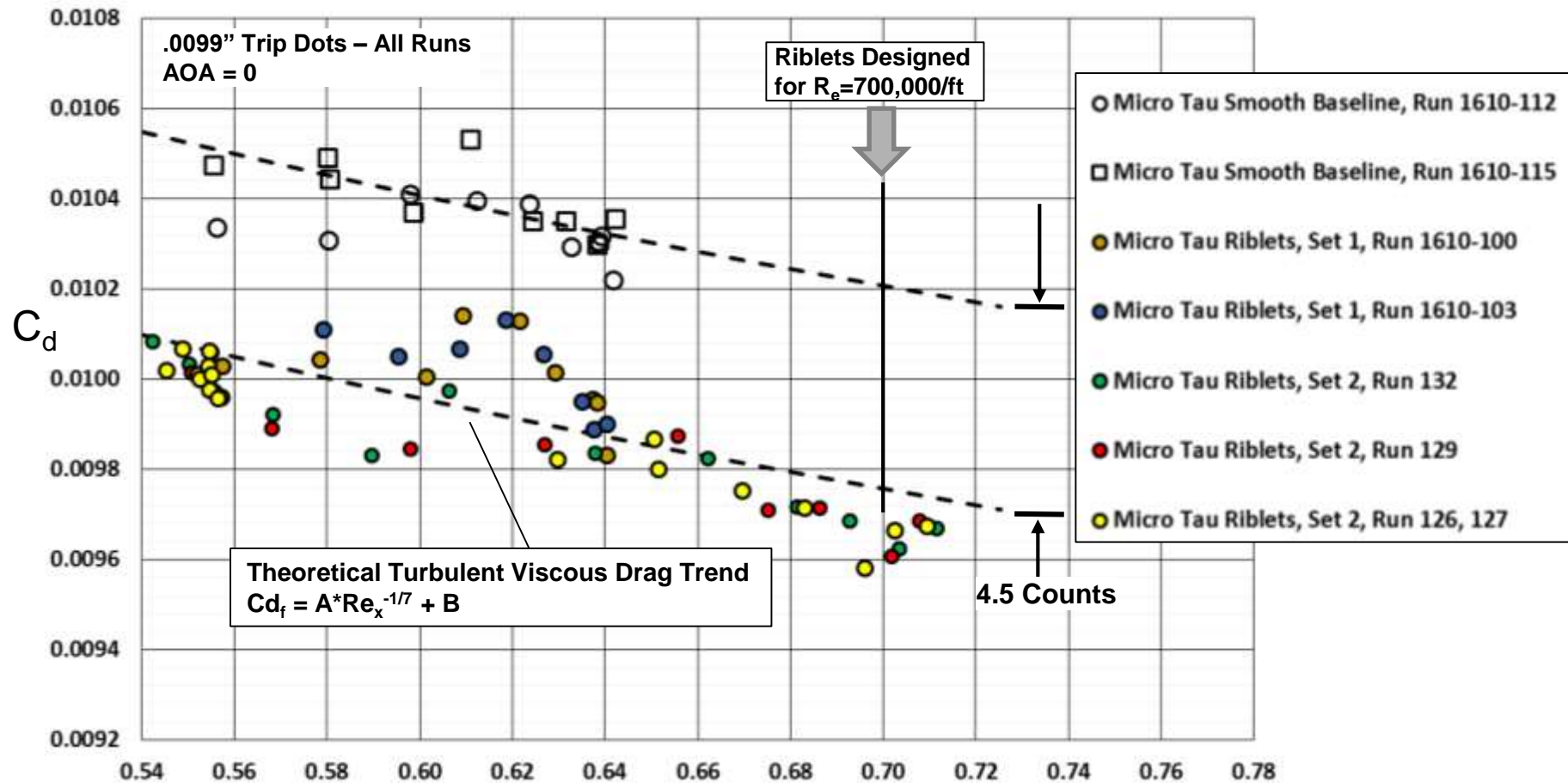
## 3 Step Riblet Microfabrication



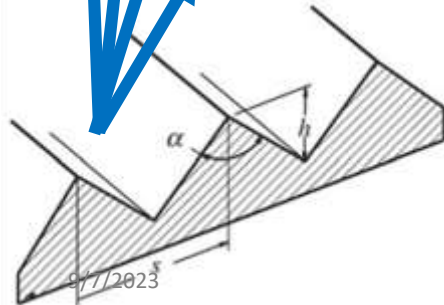
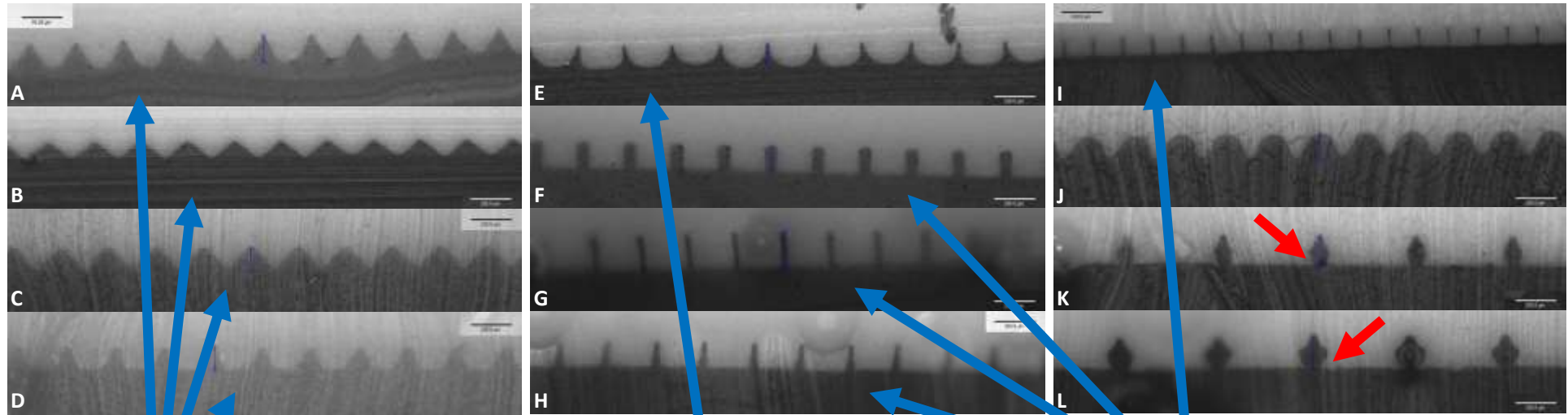
Bilinsky, H., MicroTau Pty Ltd  
SciTech January 9, 2017

# Phase I

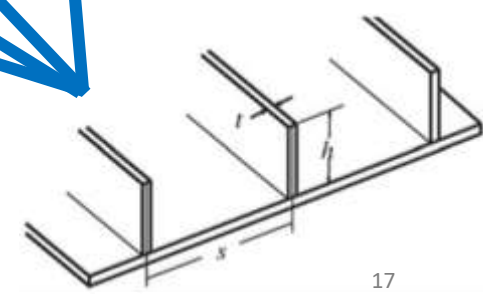
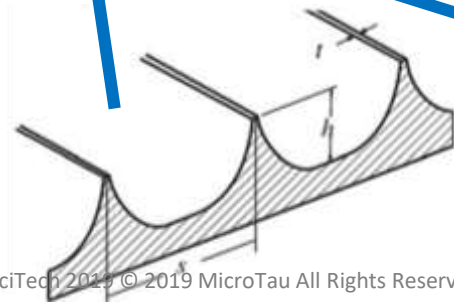
## ■ Wind Tunnel Results



# Riblet (Shark Skin) New Profiles



AIAA SciTech 2019 © 2019 MicroTau All Rights Reserved

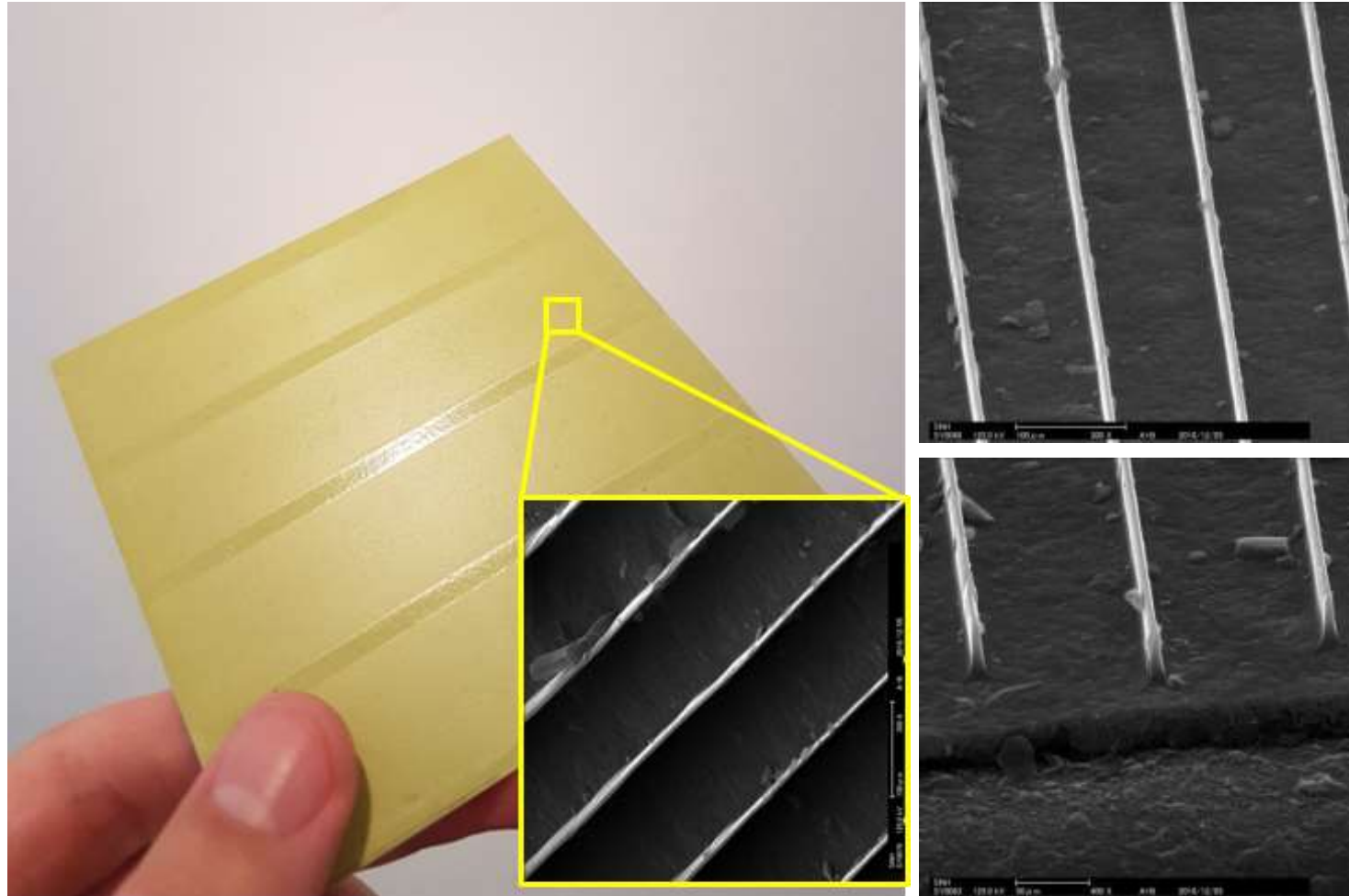






# What the riblets (Shark Skin) look like to the naked eye

- DCM-fabricated riblets

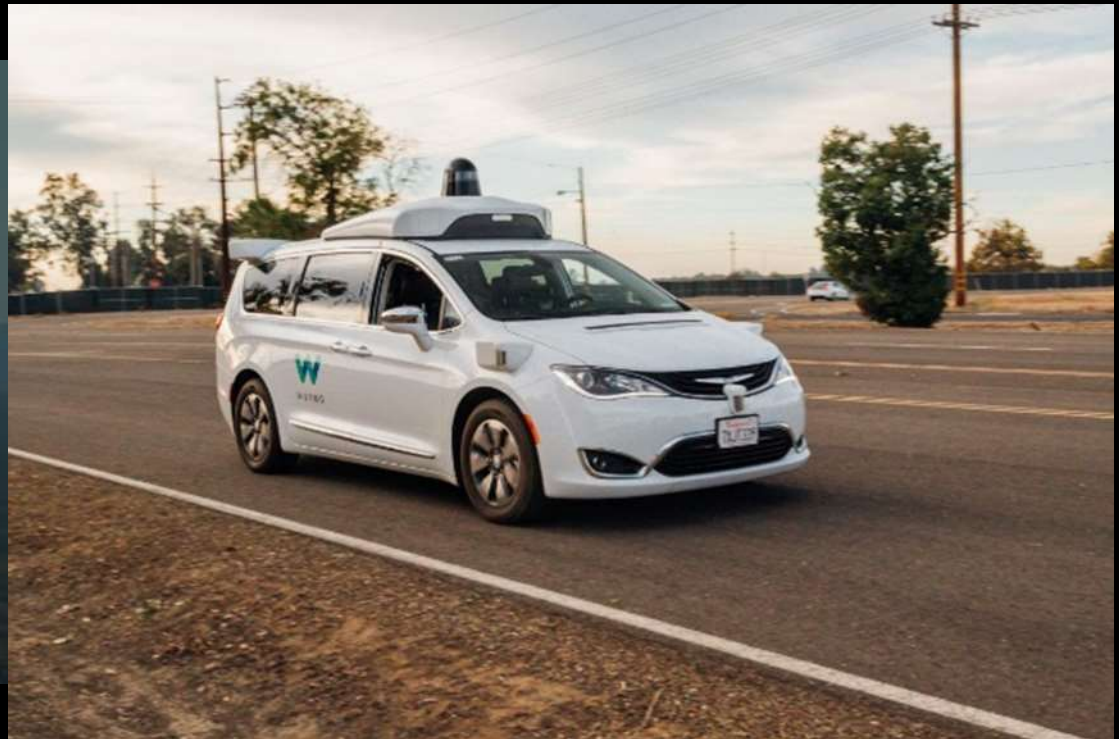


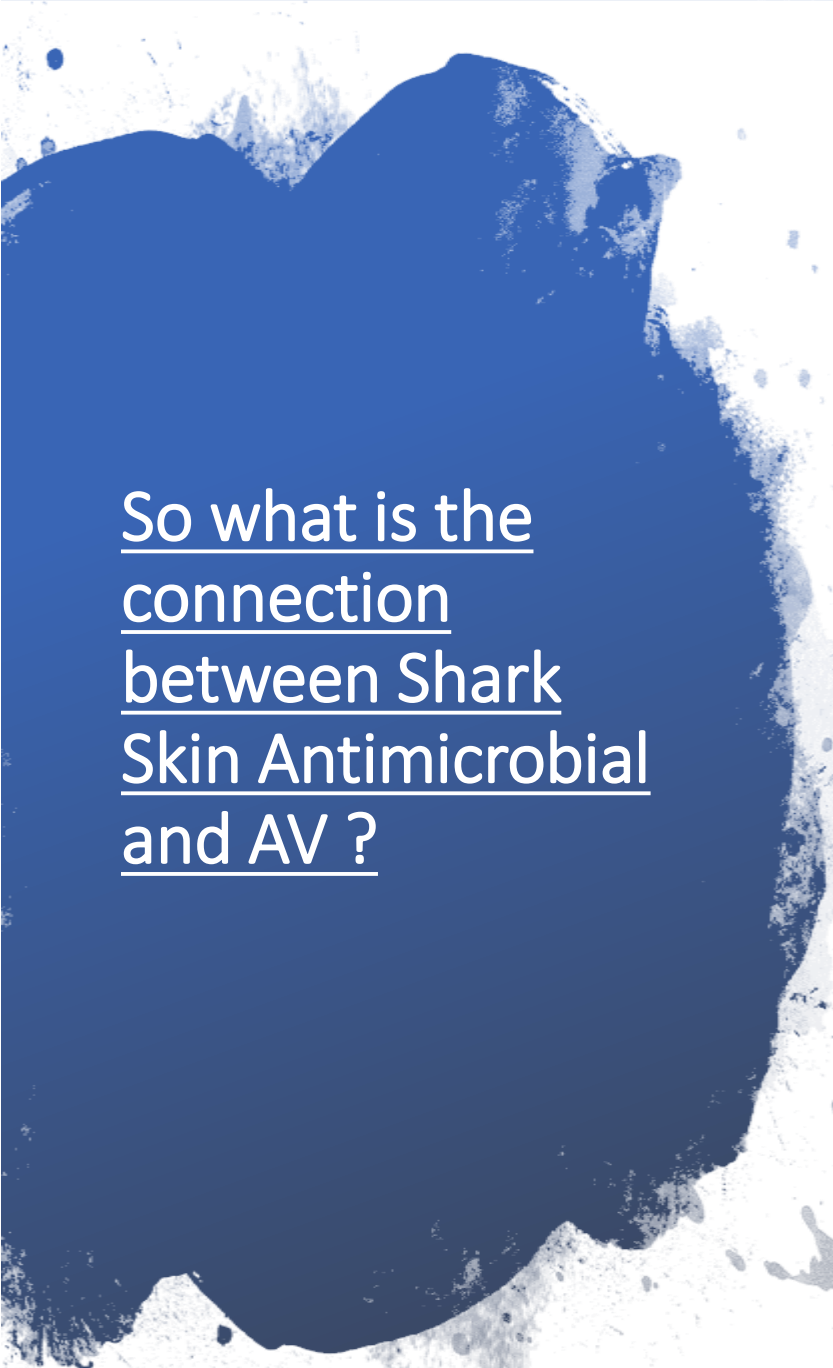
# Benefits of this style of Riblet (Shark Skin) Production

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- ❑ **Contactless, continuous and fast application**
  - ❑ *Reduce cost and time of application*
  - ❑ *Greater surface coverage and thus drag reduction*
- ❑ **Fabricated from military aircraft coating**
  - ❑ *Improve durability*
- ❑ **Live manipulation of riblet heights/geometry**
  - ❑ *Optimize riblets for fuel savings over PDM*
  - ❑ *Possible self-cleaning properties for maintenance*

# So what is the connection between 'Shark Skin' Antimicrobial and Autonomous Vehicles?





So what is the connection between Shark Skin Antimicrobial and AV ?

- AV will have the capability to pick up and deliver passengers at an extremely high rates
- The 'touch surfaces' within the AV have the potential to hold Microorganisms that can be easily transferred to the next passenger
- Auto manufacturers expect to have the first mass produced level 5 AV in operation by 2021
- When that AV Taxi shows up will you have the 'Hotel Room Experience?'

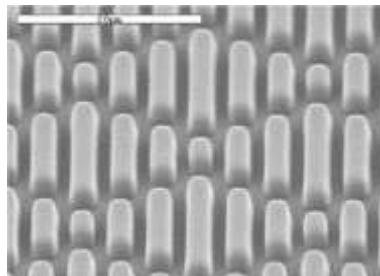
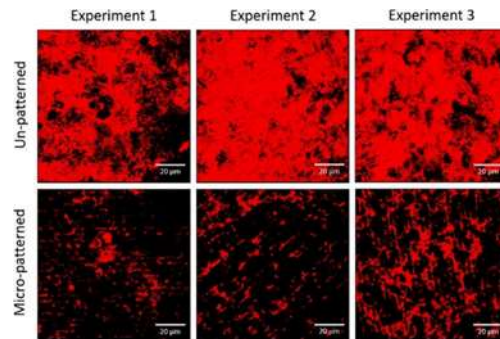
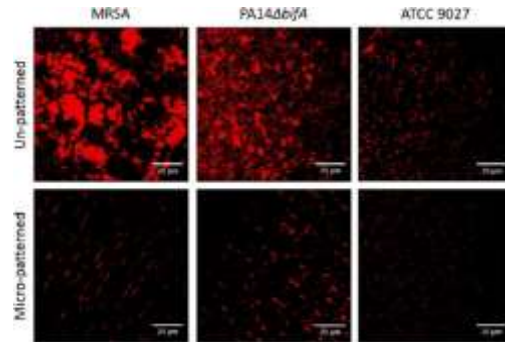
# Current Riblet (Shark Skin) Antimicrobial Surfaces in the Market



- ❑ Sharklett Technologies, Inc. is currently marketing Shark Skin technology
- ❑ Hospital high-touch environment surfaces with the Shark Skin technology can create a bacterial inhibition area
- ❑ Hospital-acquired infections account for more than \$30 billion in excess healthcare costs



# Current Riblet (Shark Skin) Antimicrobial Surfaces in the Market



- ❑ Clinical testing has shown that Shark Skin technology reduces such pathogens as MRSA and *P. aeruginosa*
- ❑ Additional testing showed that in a mucin rich environment that *P. aeruginosa* was reduced by 58% over three separate experiments

Micro-patterned surfaces reduce bacterial colonization and biofilm formation in vitro: Potential for enhancing endotracheal tube designs, May RM, Hoffman MG, Sogo MJ, Parker AE, O'Toole GA, Brennan AB and Reddy ST, Clinical and Translational Medicine 2014 3:8



## Shark Skin Riblets

- Shark Skin is self-cleaning, anti-biofouling, hydrophobic, drag reducing and aerodynamic.
- Anti-biofouling and self-cleaning properties is attributed to the micro-structured riblets found on its dermal denticles
- These micro-structures distinguish sharks from other aquatic species, such as whales, which are covered by barnacles.

Bio-mimicking nano and micro-structured surface fabrication for antibacterial properties in medical implants, Jaggessar, A., Shahali, H., Mathew, A., and Yarlagadda, P., Journal of Nanobiotechnology, (2017) 15:64



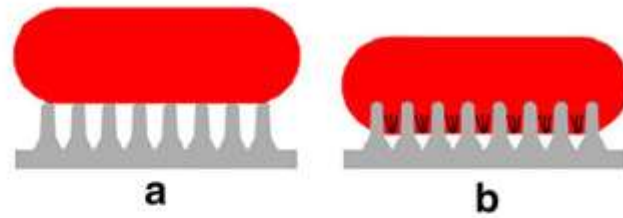
# Shark Skin Riblets Structures on Spiny Dogfish & Copper Sharks

- Spiny Dogfish (mud) shark structure
  - Triangular riblets
  - Width of 100 to 300 microns
  - Peak radius of 15 microns
  - Height 200 to 500 nm
  - Center to center spacing of 100 to 300 microns
- Copper Shark
  - Length 200 to 300 microns
  - Height 20 to 30 microns
  - Width of 50 to 80 microns
- Silicone patterned shark skin micro-structures
  - Reduced drag resistance on submarines and ships by 15%
  - Reduced algae cell attachment on submarines and ships by 67%

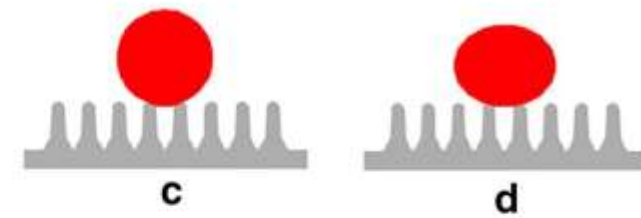
Bio-mimicking nano and micro-structured surface fabrication for antibacterial properties in medical implants, Jaggessar, A., Shahali, H., Mathew, A., and Yarlagadda, P., Journal of Nanobiotechnology, (2017) 15:64

Nano-structure  
of cicada wing

Height: 200nm  
Cap dia: 60nm  
Base dia: 100nm  
Spacing: 170nm

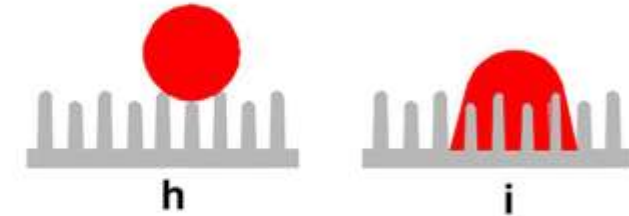
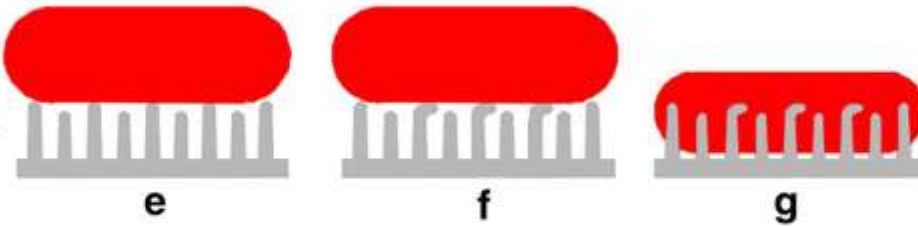


Gram positive bacteria



Nano-structure  
of dragonfly wing

Height: 189-311nm  
Dia: 37-57nm



Nano-structure  
of gecko skin

Height: 2-4μm  
Top dia: 10-20nm  
Spacing: 500nm

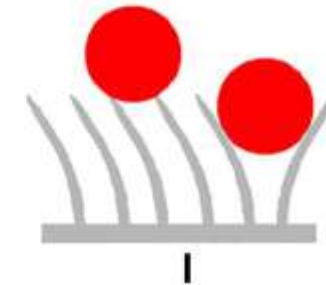
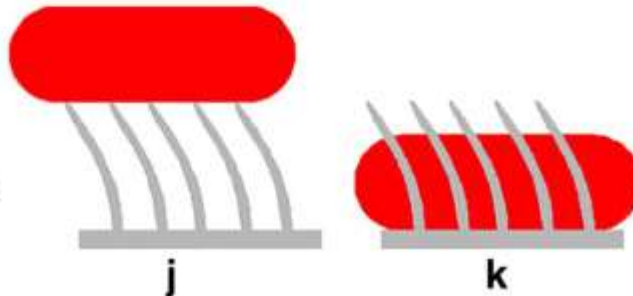


Fig. 4 Schematic showing bacteria-nano-structured surface interaction of: a, b cicada wing and gram-negative bacteria, c, d cicada wing and gram-positive bacteria, e–g dragonfly wing and gram-negative bacteria, h, i dragonfly wing and gram-positive bacteria, j, k gecko skin and gramnegative bacteria and i gecko skin and gram-positive bacteria. Nano-structure dimensions are indicated next to each species, dimensions not to scale

# Potential Riblet (Shark Skin) Antimicrobial surfaces in other markets



Dr. Joshua Jacobs, an orthopedic surgeon, displays a model of a cementless hip replacement in 2014.

- Medical implants are great sites for bacterial adhesion, reduction in patient immunity, bacterial infection and can result in revision surgery
- Medical implants need antibacterial coatings
- Performance of Bio-mimicking nano and micro-structured coated surfaces have shown antimicrobial performance
- The mechanism for this antimicrobial performance is that the bacteria cell walls stretch and disfigure when they interact with textured surfaces.
  - Stretching occurs in the regions between structures and if sufficient, cell rupture and death occurs for the bacteria

Bio-mimicking nano and micro-structured surface fabrication for antibacterial properties in medical implants, Jaggessar, A., Shahali, H., Mathew, A., and Yarlagadda, P., Journal of Nanobiotechnology, (2017) 15:64



# How Synthetic Shark-Skin is making Aircraft Carriers more Hydrodynamic



- Aircraft Carriers suffer from a build up of barnacles and algae on the hull of the ship
- Besides reducing drag the Shark Skin coating offers anti-biofouling properties
  - It would prevent the buildup of barnacles and algae on the hull of the ship
- Reduction in the amount of fuel and maintenance costs to remove the barnacles and algae
  - The US Navy spends \$50 million per year de-fouling aircraft carriers.

Biomimetic Materials: How synthetic Shark-Skin is making aircraft carriers more Hydrodynamic; Jacobs, A., Mallela S., and Wilson, S., University of Pittsburgh, Swanson School of Engineering, First Year Conference Paper, 08.03.2019

# So where do we go next?

- ❑ Current 'Shark Skin' products are embossed into the plastic film
  - ❑ These structures are limited to the shape and size of the embosser
- ❑ Micro Tau's unique UV Cure 'Shark Skin' coating has a vast number of digital structures that it can produce
  - ❑ This is due to the photolithography method borrowed from computer chip fabrication
  - ❑ These unique 'Shark Skin' structures could be optimized to maximize the reduction microbial activity in the AVs 'Touch surfaces'



## Conclusions

- The development of UV A cure automotive coatings is finding use in the aerospace coatings industry
- This technology was then adapted to manufacture Micro Tau's unique UV Cure 'Shark Skin' digital structures that resulted in 5% drag reduction in wind tunnel testing
- The possibility exists that the Micro Tau UV Cure 'Shark Skin' digital micro-structures could inhibit microbial growth for 'Touch Surfaces' in Autonomous Vehicles



# Update on the 'Shark Skin (riblet)' Technology

# PATENT ISSUED ON 3D RIBLETS

- ❑ **US 11,441,048 One Component UV Curable Compositions and Methods for Making Same**
  - ❑ Dvorchak Enterprises LLC, Monroeville, PA (US)
  - ❑ M.J. Dvorchak & M.E. Zupancic
  - ❑ Issue Date; September 13, 2022

# MicroTau receives grant from NSW for UAVs



**MicroTau**  
*Printing nature's surfaces to solve human problems*

Announcement February 2021

**MicroTau receiving \$980k from the NSW Government to bring shark skin efficiency to unmanned air vehicles**



 \$980 thousand from the Office of the NSW Chief Scientist & Engineer through the NSW Physical Sciences Fund

 Investment will allow MicroTau to standardise our Direct Contactless Microfabrication equipment and materials to deliver our shark skin drag reduction product and improve efficiency and range of Unmanned Air Vehicles.



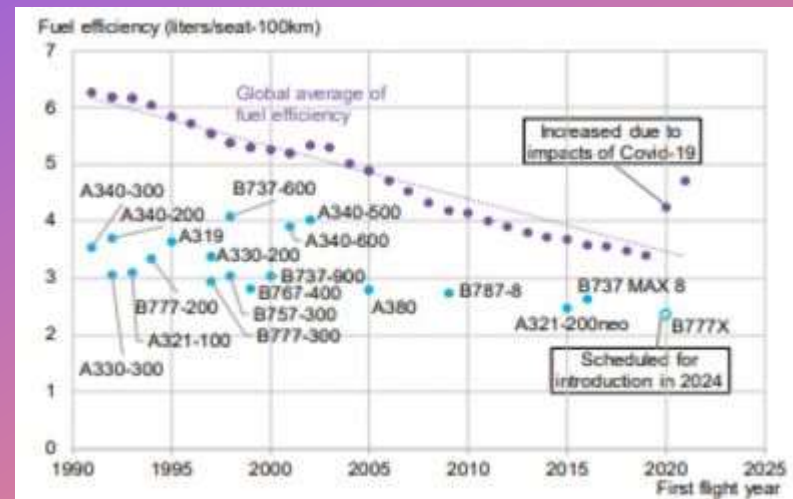
[www.microtau.com.au](http://www.microtau.com.au)



# RIBLET FILMS

- ❑ Lufthansa Cargo is covering 10 Boeing 777 freightliners
- ❑ with 'Shark Skin' film named AeroShark
- ❑ The AeroShark film will reduce the drag by 1%
- ❑ This 1% drag reduction will reduce fuel burn by 3,700 tons
- ❑ and reduce CO<sub>2</sub> by 11,700 tons annually

- ❑ Nikon Corporation has developed a shark-skin film for the Japanese Airline ANA
- ❑ Two jet airliners are being equipped with this shark skin film with the expected energy efficiency of 2%



<https://www.freightwaves.com/news/lufthansa-replicates-sharkskin-to-boost-fuel-efficiency-of-cargo-jets>

<https://insights.globalspec.com/article/19537/japanese-airline-testing-shark-skin-inspired-film>

# From 2022, Lufthansa Cargo will equip all Boeing 777 F freighters with AeroSHARK



For the entire fleet of ten aircraft, this translates to annual savings of around 3,700 tons of kerosene and just under 11,700 tons of CO<sub>2</sub> emissions, which is the equivalent of 48 individual freight flights from Frankfurt to Shanghai.

# Acknowledgements

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**This work is supported by the Operational Energy Capability Improvement Fund (OECIF) from the Office of the Assistant Secretary of Defense for Operational Energy Plans and Programs, ASD(OEPP) and by the Air Force Research Laboratory. We would also like to acknowledge the Ohio Aerospace Institute, through which this work was funded.**

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