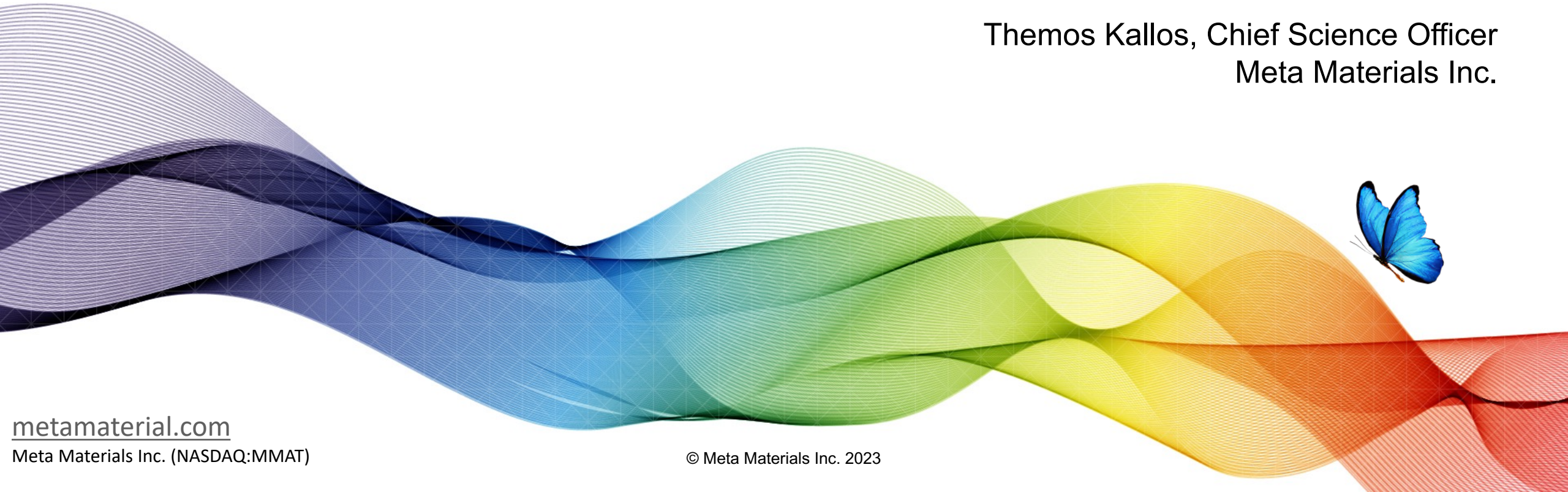
META®
Go Beyond.

Design and Manufacturing of Transparent Antennas for Satellite Communications

Themos Kallos, Chief Science Officer
Meta Materials Inc.



Outline

- About Meta Materials Inc.
- NANOWEB® Platform Technology
- Transparent Antennas
- Manufacturing Techniques

About META

The META Timeline

- **2021** — **1st Metamaterial Company on NASDAQ**
- **2011** — **META Founded (London, UK)**
- **2000** — **Negative Refraction Demonstrated**
- **1968** — **Veselago's Paper**
- **1865** — **Maxwell's Equations**
- **1492 AD** — **America Discovered**
- **55 BCE** — **Romans invade Britain**
- **776 BCE** — **First Olympiad**
- **3000 BCE** — **Great Pyramid Built**
- **10,000 BCE** — **Farming**
- **200,000 BCE** — **Early Humans**

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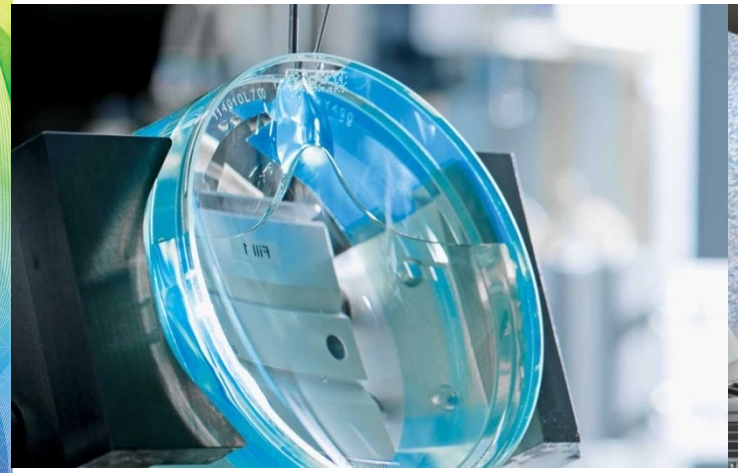
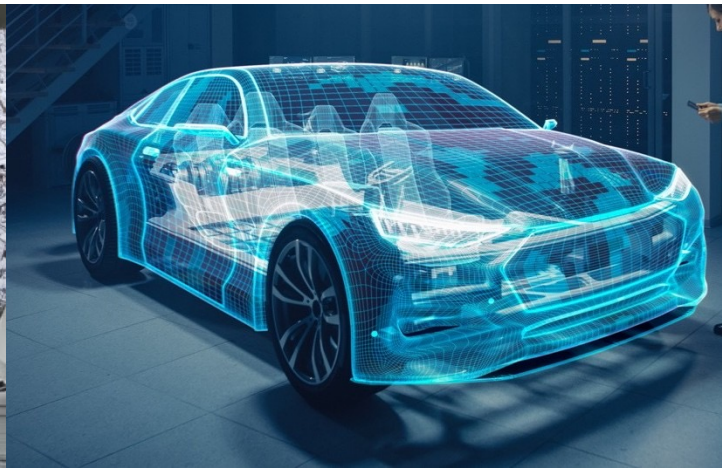
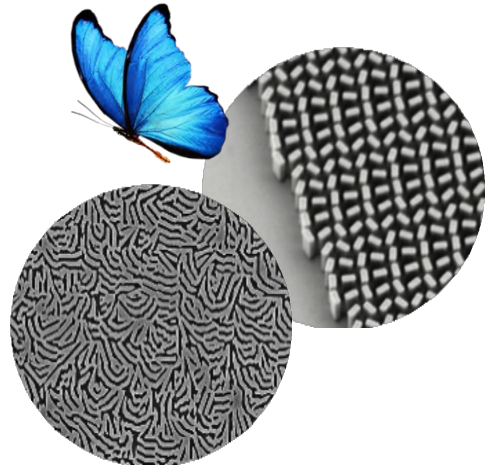


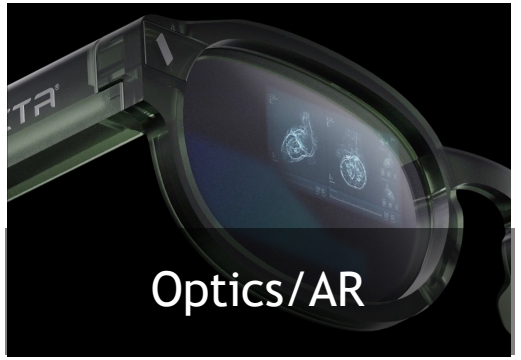


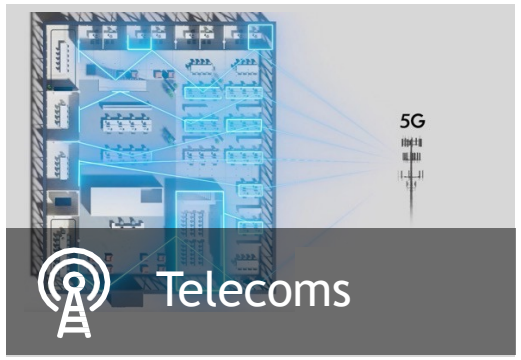
We deliver breakthrough performance, previously thought unattainable, by utilizing nanotechnology and metamaterials to design, integrate, and manufacture sustainable, highly-functional films & intelligent surfaces.

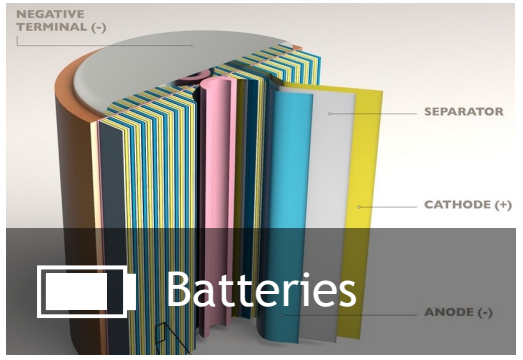
The META® Core Capabilities

We are a world class designer, integrator and producer of functional films and intelligent surfaces, utilizing proprietary metamaterials that allow us to offer breakthrough technology and solutions across the following industries:









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The META Design & Integration Advantage

SPEED

- META uses AI software to design a library of patterns for different applications and which can typically develop new custom solutions within hours vs months

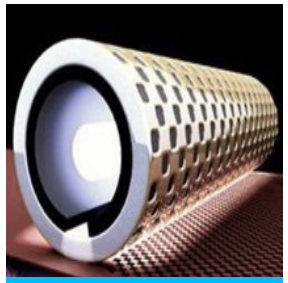
SCALE

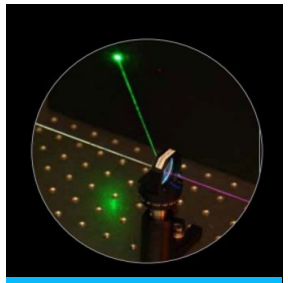
- META is one of the first companies to develop proprietary roll-to-roll production equipment to produce large area, high volume nanocomposites

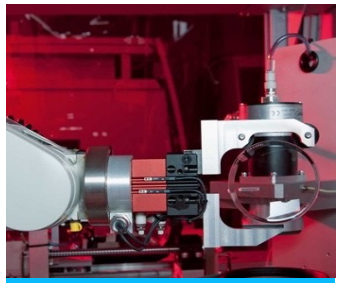
COST

- Increasing the roll-to-roll web width and line speed should drive costs down to a few $/m^2

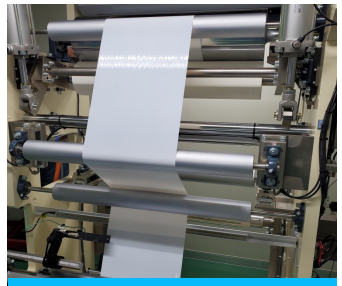
TECHNOLOGY PILLARS

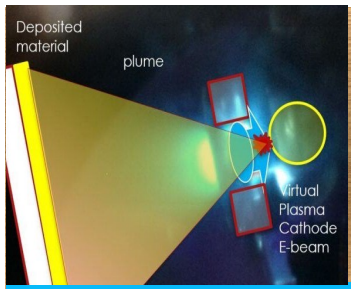

Lithography


Holography


AR Fusion®
Optical Combiner


Vlepsis™
Electro Optics


NPORE® Ceramic
Nanocomposites



PLASMAfusion™
High Speed Coating


Wireless Sensing

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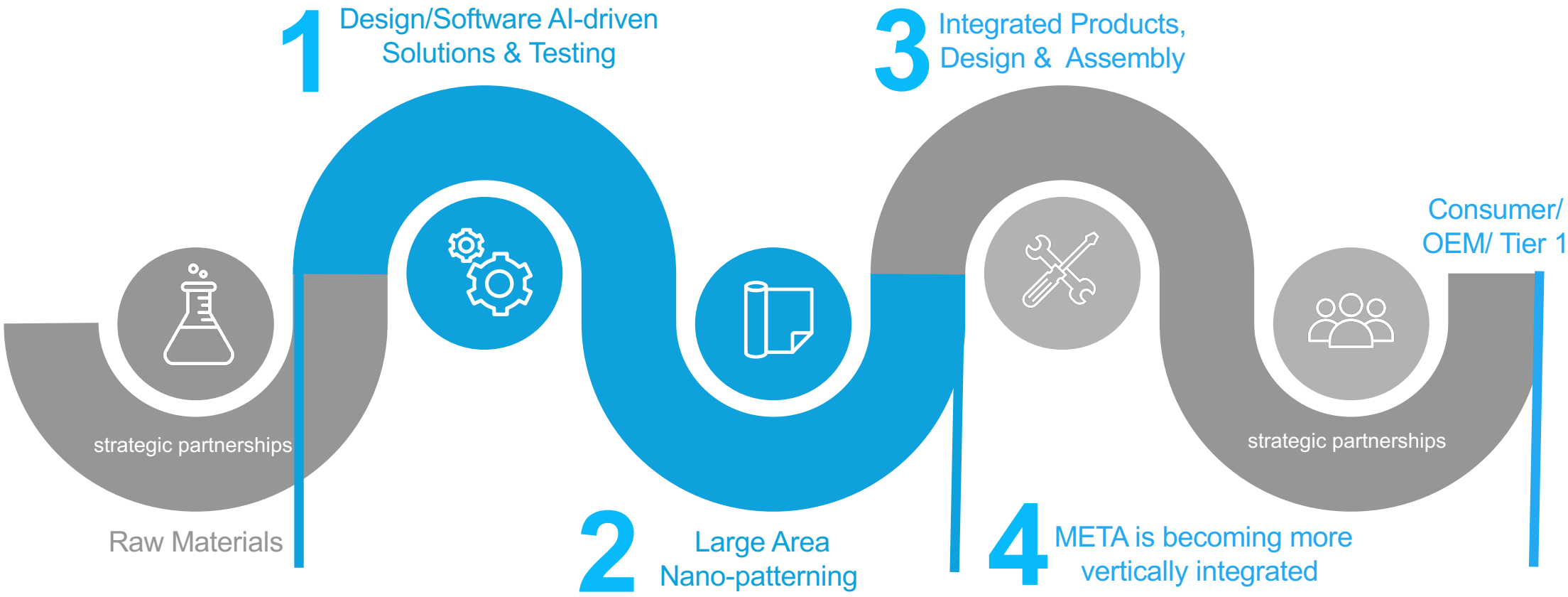
META Solution Provider in the Value Chain



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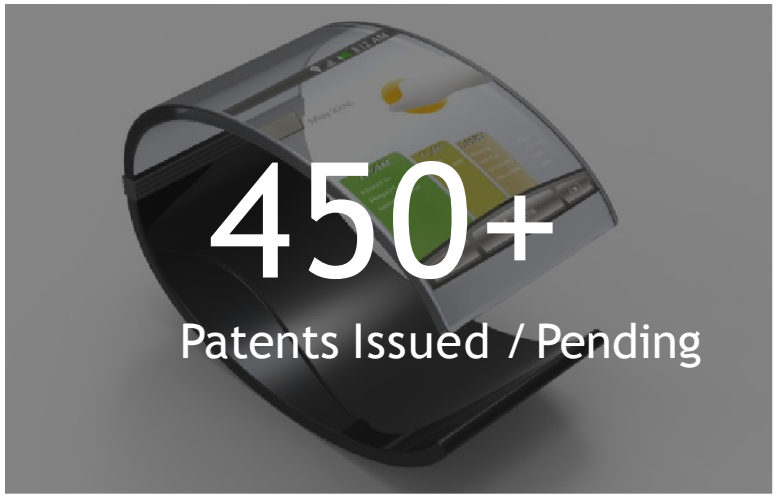
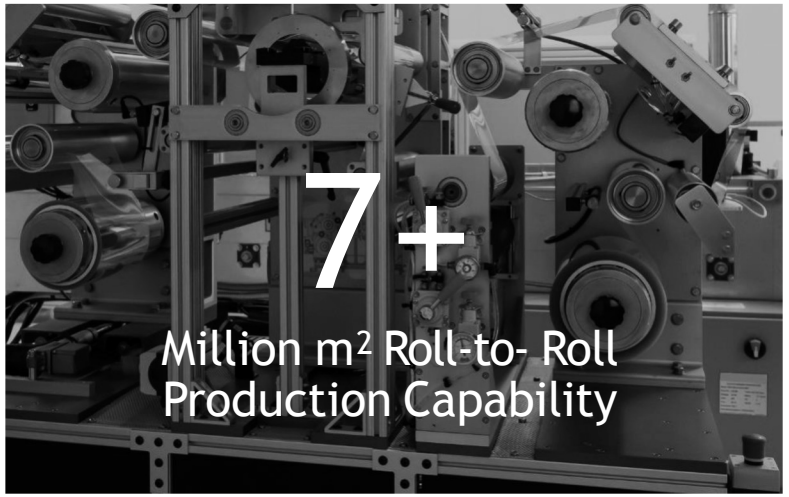
Our Background





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Company Timeline

Algorithm Developed
1st Patent App Filed

New Head Office
Halifax, NS Canada

NRC & NSERC Grants

AIRBUS
1st Major OEM Deal Prototype, Proof of Platform

MRI & GlucoWise®
begin Human Testing

Series A and OEM
Key supply and licensing partnerships with Boeing, Artemis optical & Covestro

Product Launch METAAIR®

BD Partnership

Listed to Trade on CSE

Partnership with

Nasdaq
June 28, Begins

Partnership in 5G with

Acquired assets & IP of Swiss lens manufacturer **Interglass for ARfusion®**

Partnership with

2011-2017	2018	2019	2020	2021	2022

University Collaborations
UNB, UdeM

Acquisition
Rolith Inc.
(Pleasanton, CA)
20 Patents families

Partnership with Lockheed Martin

Acquisition
Mediwise
(London, UK)
28 Patent Families

SATAIR
Global Distribution Agreement

Acquisition
Nanotech Security Corp. leading developer of Nano-Optic security features

Acquisition
Plasma App LTD.
Strengthening our IP portfolio in Battery Materials

Acquisition
Optodot Corporation
Over 100 issued or pending Patents

AWARDS

NANOWEB®
IDTechEx
Best Manufacturing Technology Award

GlucoWise®
MIT Sponsored Business Award

Meta Materials
2019 GLOBAL CLEANTECH 100 Company

metaAIR®
Silver A' DESIGN Award + Best Aviation Product / Laureates Aviation Week

Meta Materials
LUX Research Innovator of Year 2021 Award

Future 50
Fastest growing sustainable companies Award

Go Beyond.

META's Global Presence

Halifax, Nova Scotia, Canada
Head Office
Research and Development
Manufacturing facility

Thurso, PQ, Canada
Secure Manufacturing Facility

London & Oxford, United Kingdom
CoE High Speed Coating- PLASMAfusion™

Boston, MA, United States
CoE Battery Separators – NPORE®

Pleasanton, CA, United States
CoE - Nanoweb® applications
USA Sales Office

Burnaby, BC, Canada
CoE - Security producs

Baltimore, MD, United States
CoE - Electro-Optics Vlepsis™

Athens, Greece
CoE Medical & AI Development
EU HQ & Sales

Minato-Ku, Japan
Sales Development

META®
Go Beyond.

OEM Partners & Customers: Solving Global Challenges Together

Select Past and Current Co-Development Partners and Customers in Automotive, Medical, Aerospace & Defense, Consumer Electronics and Energy

META® Go Beyond.

Who we are

META®
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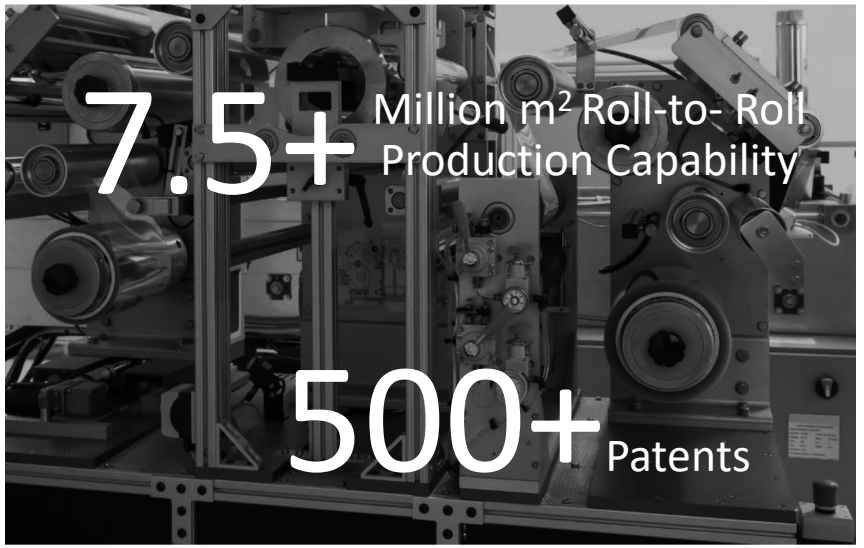
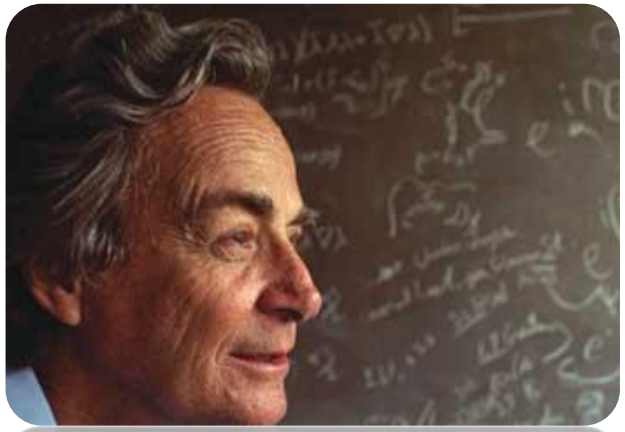
META® specializes in designing, originating, recombining, and mass-producing nanotechnology-based films with applications catering to a diverse range of products and markets.



Solutions



“I can’t see what exactly would happen,

but when we have some control of the arrangement of things in the small scale,

we will get an enormously greater range of possible properties that substances can have.”

1959

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Lithography

KolourOptik®

NANO-OPTIC GOVERNMENT AND BANKNOTE SECURITY

KolourOptik®: Sub-wavelength nanostructures that are near impossible to replicate and protect banknotes and government documents from counterfeits.

Key Differentiators:

- Ultra thin (< 10 micron),
- combination of movement, depth and multiple colors,
- advanced nanoscale manufacturing processes

Applications: Banknotes, passports, ID cards, drivers licenses, birth certificates.

KolourOptik® Stripe

- Movement
- Multi-colour images
- 3D stereo depth
- "Always on"

KolourDepth™

- Multiple 3D elements
- Multi-colour images
- Omni-directional movement
- "Always on"

LumaChrome Foil

- Used in 30+ banknote denominations
- Easy to use
- Striking colour transitions
- Durable

META® Go Beyond.

PARTNERS

AIRBUS

SATAIR

INDUSTRIES

metaAIR®

LASER GLARE PROTECTION

metaAIR® : Holographic laser protective films that offer professional pilots & law enforcement professionals the best combination of transparency, laser glare protection, and color fidelity.

Key Differentiators:

- Tuned nanostructures allow the lens to control how light is deflected and blocked, so dangerous green lasers are neutralized while the rest of the visible light spectrum is unaffected
- Exceptional color recognition, and superior visible light transmission and optical filtering combined

Applications: Aviation Eyewear & Law Enforcement self-adhesive film for police riot visors & handheld ballistic riot shields.

AVIATION WEEK Laureates

2018 Winner Best New Commercial Product

A'DESIGN AWARD & COMPETITION — AWARD WINNING DESIGN SILVER A' DESIGN AWARD 2019

META® Go Beyond.

PARTNERS

INDUSTRIES

holoOPTIX®

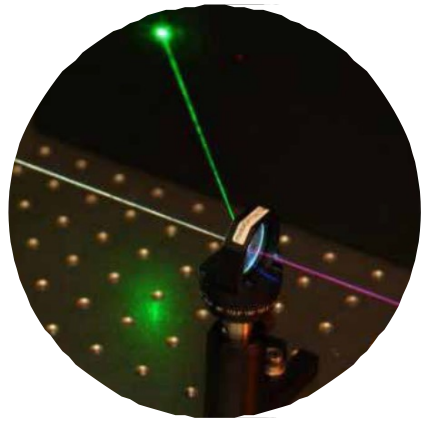
HOLOGRAPHIC OPTICAL COMPONENTS

META's Holography platform makes it possible to design and fabricate optical components that improve on traditional lenses and mirrors by adding extraordinary optical functions.

Key Differentiators:

- holoOPTIX® holographic notch filters enhance surfaces like film and glass with wavelength selectivity — the ability to reject a portion of the light spectrum while transmitting all other wavelengths.
- Achieved through laser created interference pattern - Volume Holographic Gratings (VHG) — that selectively transmit or reflect.

Applications: confocal microscopy, multi-photon microscopy, laser-based fluorescence instrumentation, life science applications.



Available Products:

- holoOPTIX® FLEX
- holoOPTIX® STRATA 1" diameter form factor for life science applications
- holoOPTIX® SLANT 1" form factor plus unique diffraction characteristics

META® Go Beyond.

PARTNERS

INDUSTRIES

CONFIDENTIAL
OEM's

ARfusion®

LENS CASTING - PRESCRIPTION AR EYEWEAR

ARfusion® integrates optical elements for AR (augmented reality) combined with lens casting technology developed by Interglass Technology AG

Key Differentiators:

- High volume fully automated lens casting, workstations, tools, test equipment, and technical data
- Proprietary specialty materials/foils supply in cooperation with Covestro AG
- "One stop shop" for prescription lenses and embedded elements such as optical combiners, waveguides, and eye tracking sensors

Applications: Complete integrated AR solutions, Cast prescription lenses, Embedded Holograms

Less energy
(10 sec vs 50 hrs curing time)

Zero water usage

Less material usage

META® Go Beyond.

PARTNERS

Confidential OEM's +

PPG SEKISUI

INDUSTRIES

NANOWEB®

TRANSPARENT CONDUCTIVE FILM

Achieving performance never thought possible

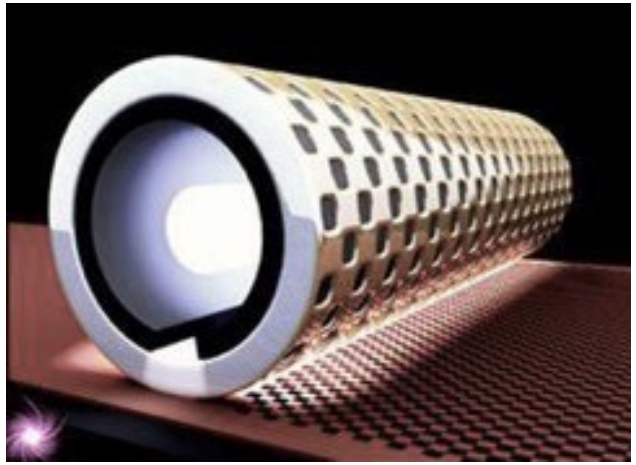
Key Differentiators:

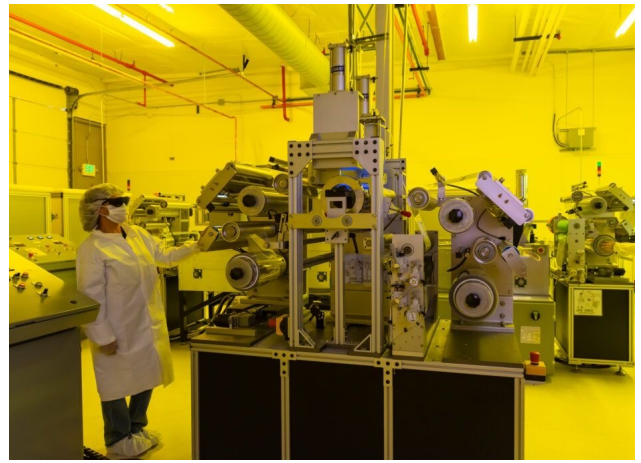
Proprietary RML® technology that can print sub-micron nano-structures directly into any hard or soft substrates.

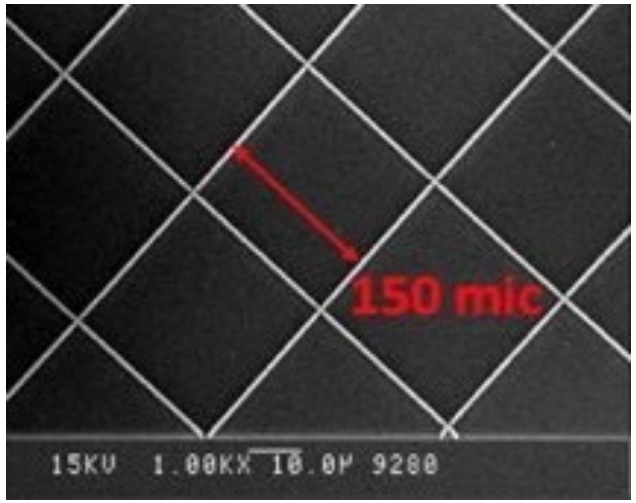
NANOWEB® offers multiplexed patterning, where additional functions beyond de-icing / de-fogging can be incorporated into the vehicle e.g. 5G, 4G, AM, FM antennas

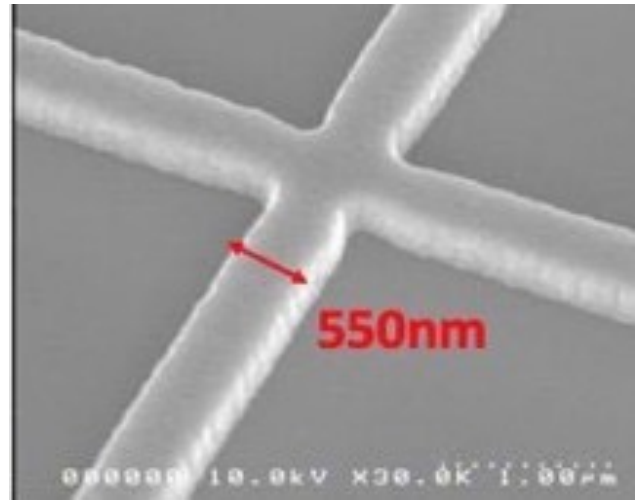
- 99% Transmission (excl. Substrate)
- 10-15 Ω/sq

Custom design per application for maximum performance:
- Pattern (spacing & line width)
- Metal choice (Ag, Au, Al, etc.)









META® Go Beyond.

PARTNERS

Confidential OEM's +

PPG SEKISUI

INDUSTRIES

NANOWEB®

Applications

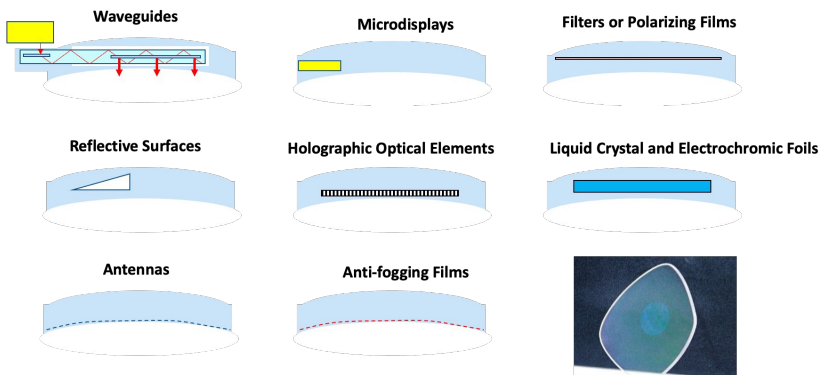
EMI Shielding
- Transparent Microwave Doors
- Automotive LiDAR protection

5G Reflectors / Transmitters

Transparent Antenna
- Glasses
- Automotive
- Mobile Devices

Prescription Lens Optical Combiners
- Augmented Reality Glasses
- Electrochromic lenses

De-Ice / De-fog Automotive & Consumer Product Applications



NANOWEB®
Best Manufacturing Technology Award

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Nanoweb

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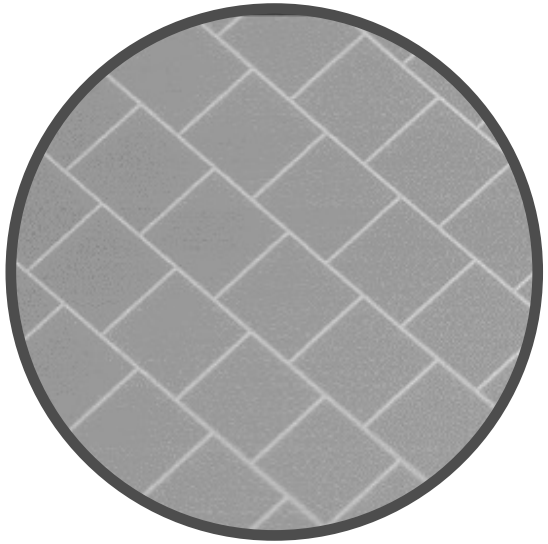
2023-05-28

NANOWEB®

Transparent conductive film



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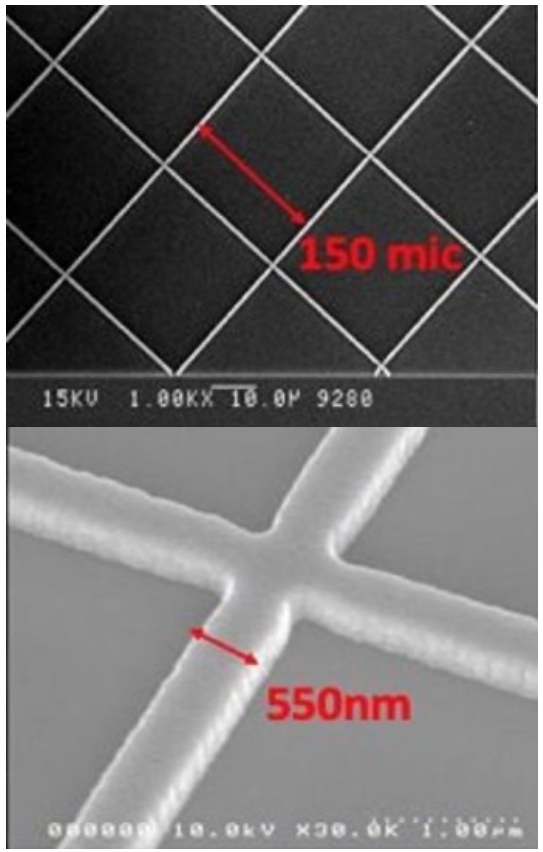
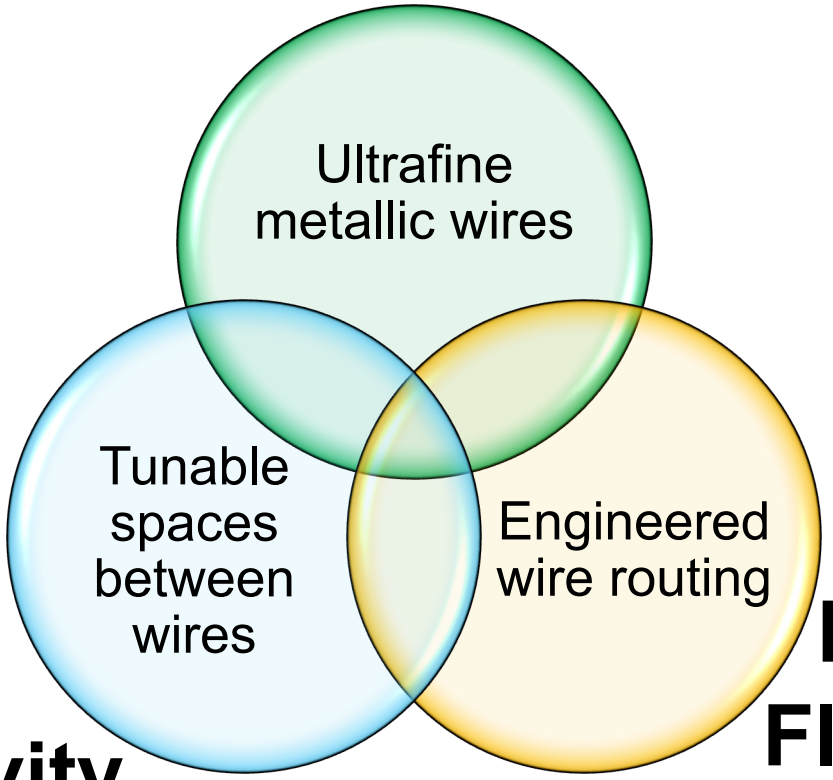
NANOWEB – The Engineered Transparent Conductor



High Transparency



High Conductivity

Design Flexibility

META® Go Beyond.

NANOWEB - Characteristics and Performance

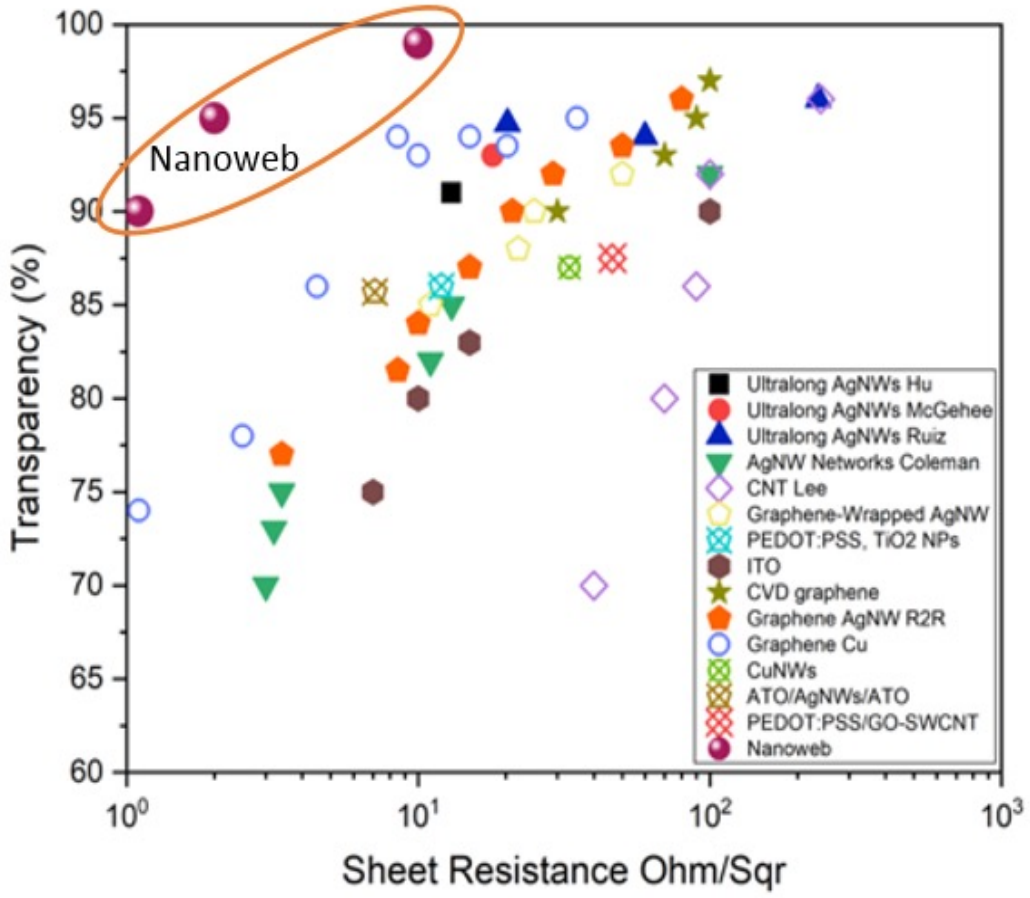
DESIGN

- **Wire width:** 0.20 to 1 micron
- **Wire spacing:** 10 microns and above
- **Wire thickness:** 50 nm to 1 micron
- **Wire material:** Ag, Cu, Al, alloys,
- **Substrate material:** Glass, PET, sapphire, etc.

(PC coming soon)

PERFORMANCE

- **Sheet resistance:** <1 to 20 Ω/sq
- **Optical transparency:** 90-98% (Fresnel corrected)



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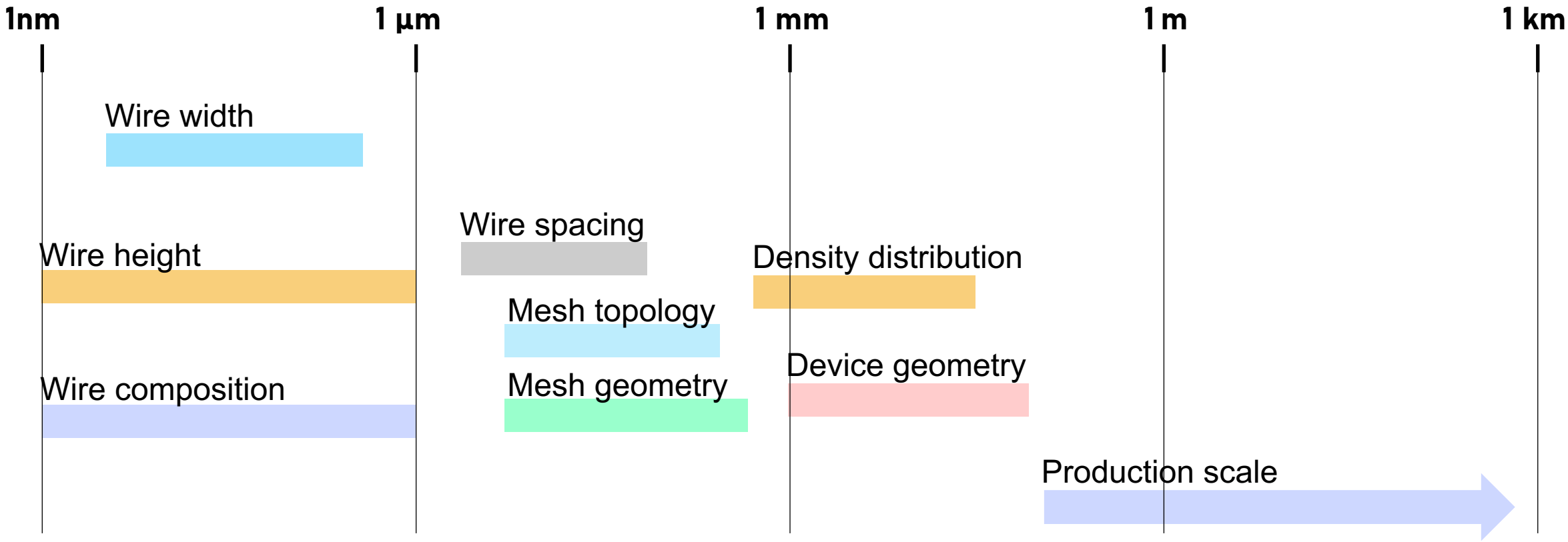
Engineered Across Multiple Length Scales



NANOWEB

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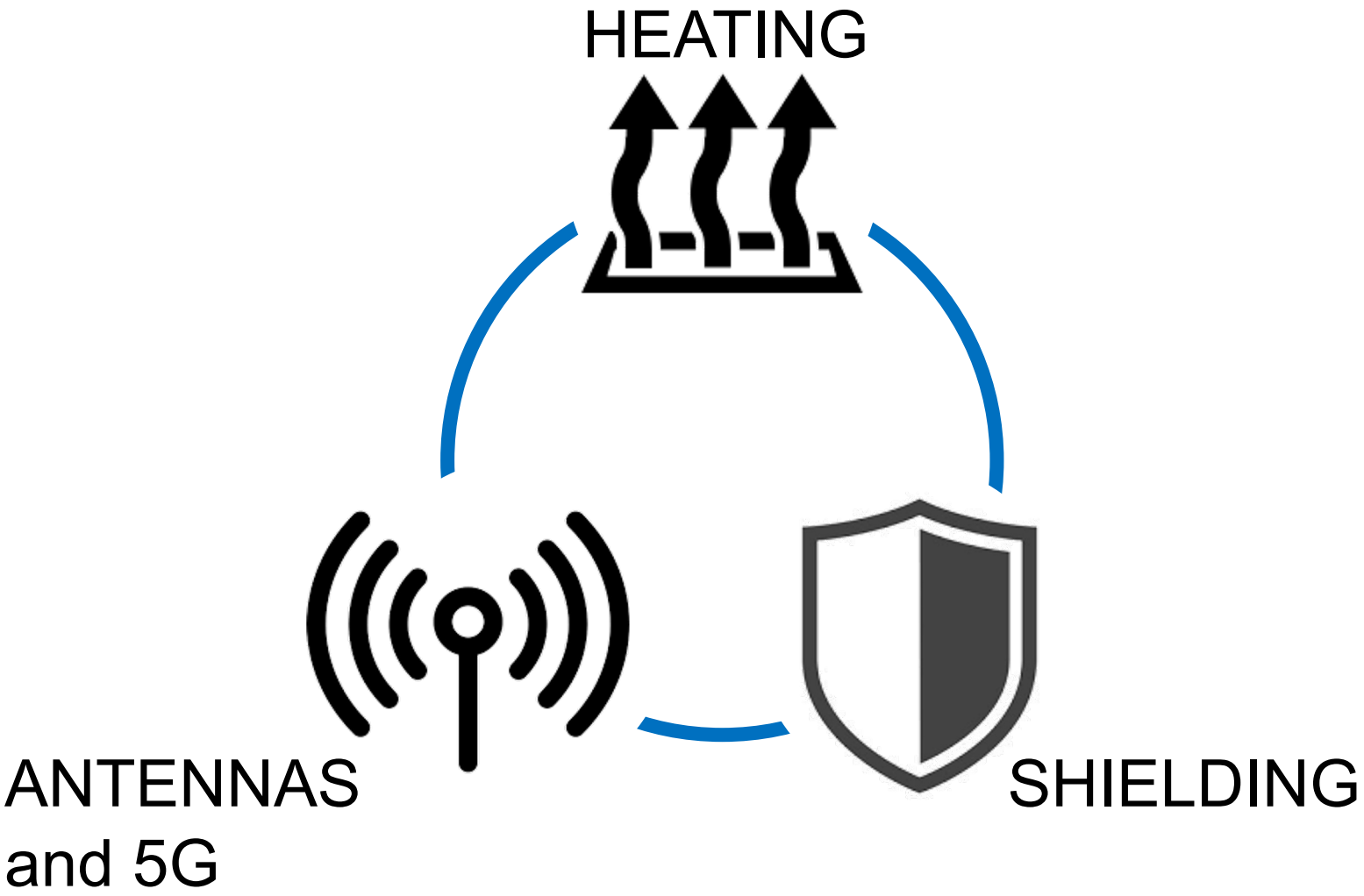
NANOWEB Application Areas



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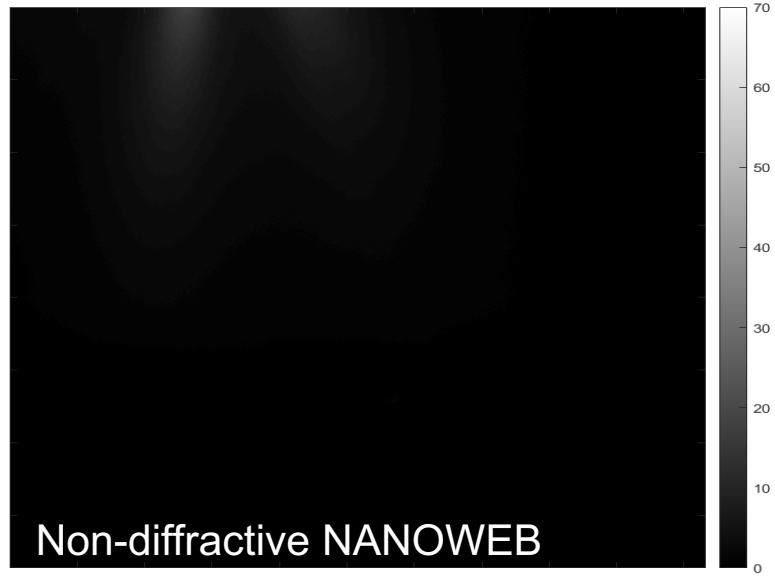
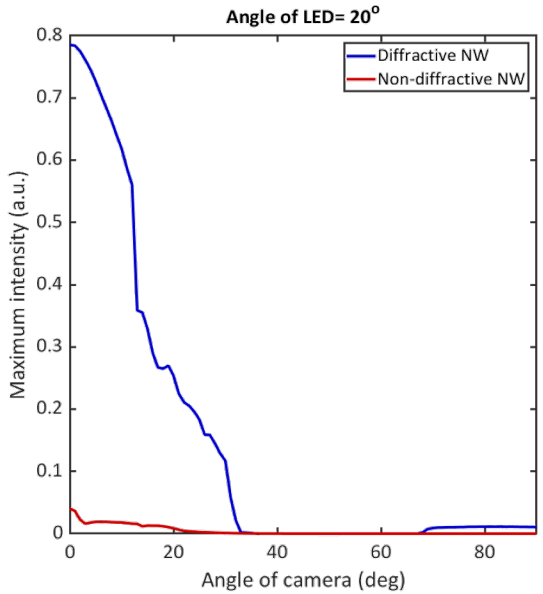
Engineered Diffraction Management

- Transmitted diffraction in visible regime tuned by mesh geometry
- Reduced artifacts for imaging sensors operating in the visible & NIR (LIDAR and cameras)



	Standard mesh	New mesh geometry – I	New mesh geometry – II
Optical transmittance	99%	99%	99%
Haze	1 %	1 %	< 0.7 %
Sheet Resistance	10 Ω/sq	6 Ω/sq	6 Ω/sq
Availability	Available	June 2023	August 2023



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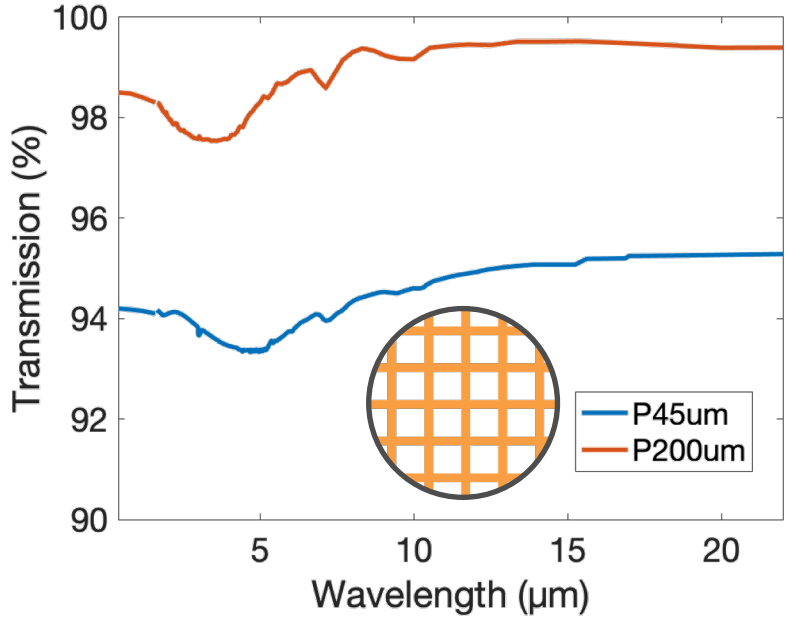
Long Wavelength Transparency

Multimodal sensor compatible

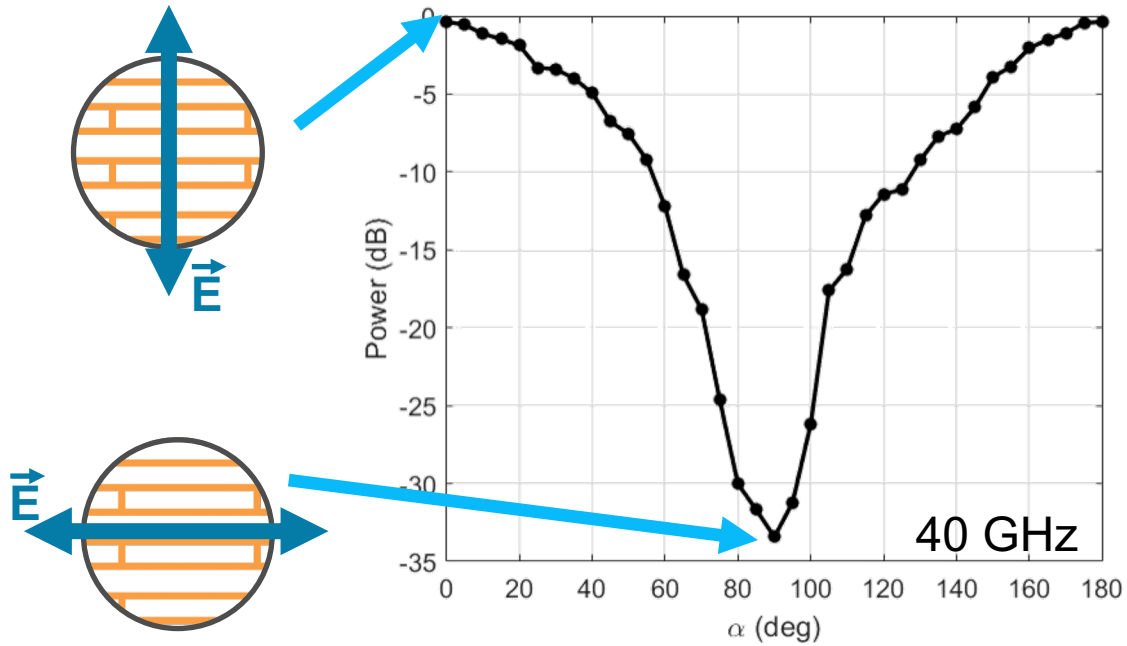
THERMAL

- Grid designs maintain high transparency from visible through LWIR region (unlike ITO)



RADAR

- Transparency into the RF achieved through adapted mesh design



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Transparent Antennas

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2023-05-28

Transparent Antenna Benefits

Integrate high-performing antenna functionality while maintaining visibility

Benefits:

- Invisible & aesthetic
- Compatible with lidar, camera systems
- Integrated de-ice, de-fog options
- Lightweight for easy installation
- Directional, Omni-directional antenna
- Highly customizable for multiple bands
- High conductivity
- Multi-band, ultra-wide band
- Excellent radiation performance

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Library Antenna Application Designs

Antenna for Augmented Reality WiFi/BT, 2.4/5.0 GHz

- Transparent antenna on the glass lens enables hi-band I/O reducing BULK and POWER – Eyeglass Formfactor

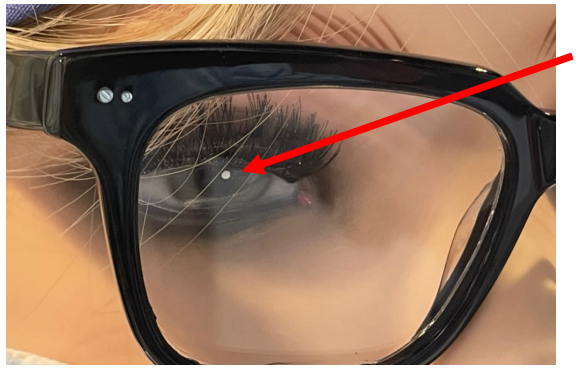
Automotive communication

- Transparent antenna (arrays) on the roof or windshield for LEO satellite communication (Ka/Ku bands)
- Vehicle to vehicle communications for autonomous driving

Automotive radar/lidar for collision avoidance (77 GHz)

TV reception: Transparent antennas on window for TV signal (400-800 MHz)

mm-wave 5G (26-28 GHz)



Transparent 5G Antenna invisible to naked eye

AR glasses with Transparent 5G antenna

Vehicle with ADAS and/or LEO satellite comms

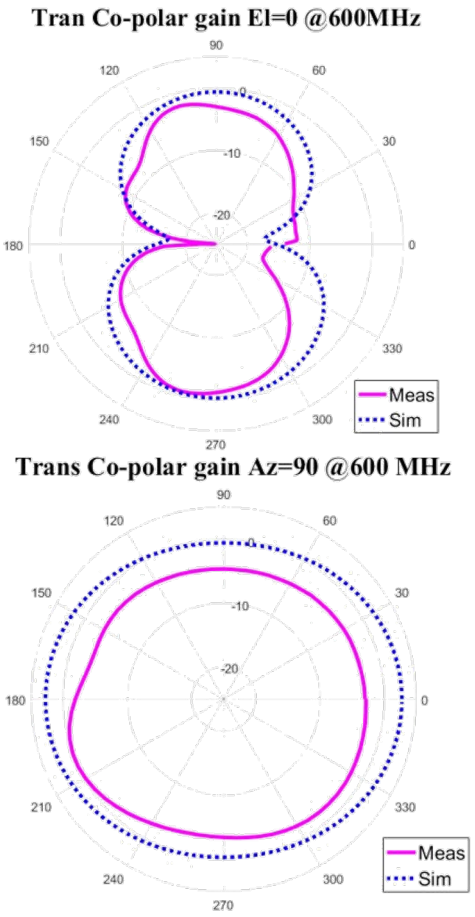
META® Go Beyond.

Antennas

Transparent antennas enable new design flexibility for antenna placement

- Radar TX/RX antennas embedded in windshield or headlamps
- 5G antennas in glazing
- Satellite antennas in rear windows or sunroof

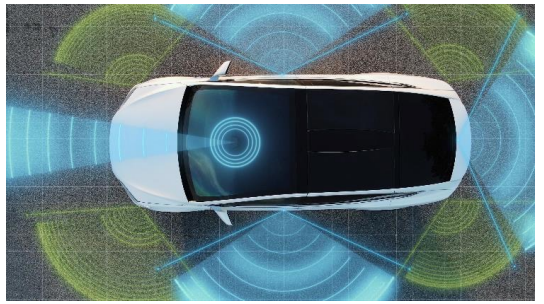
- Conventional antenna modelling approaches work (no need to model nano-properties)



META® Go Beyond.

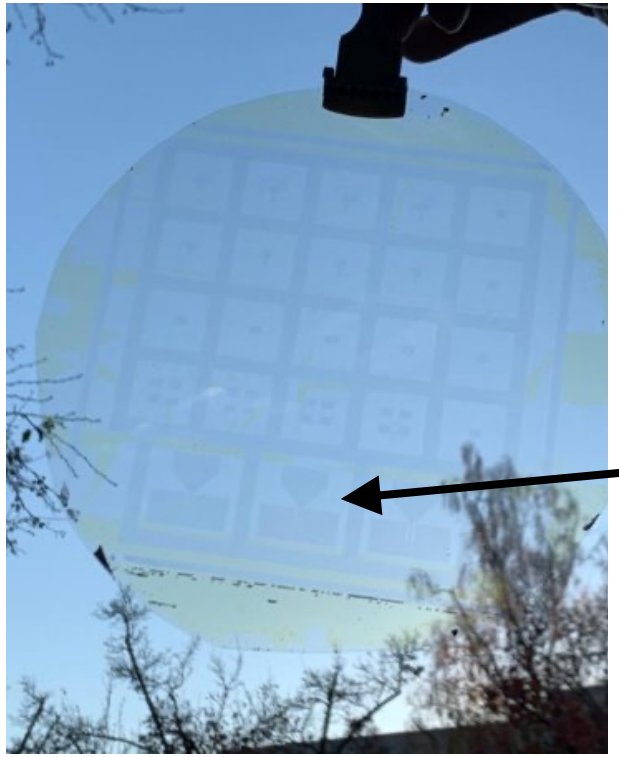
Antennas

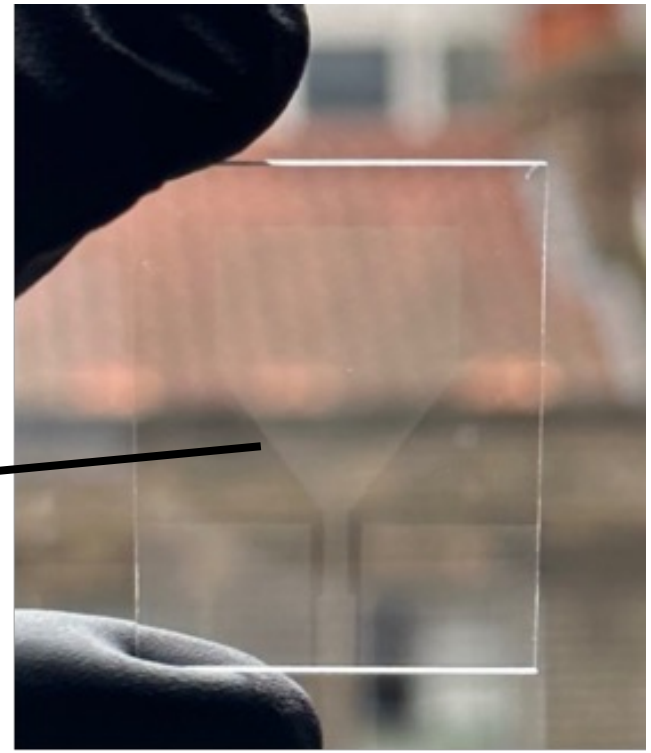
- Lithographically defined antenna structure(s)



Multiple antenna designs on one wafer:

Frequency	Application
2.4 GHz	WiFi / BT
5.0 GHz	WiFi
10 GHz	5G (proposed)
26-28 GHz	5G-FR2





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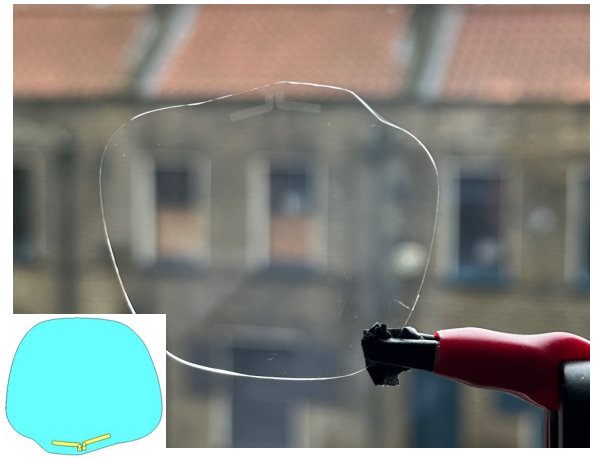
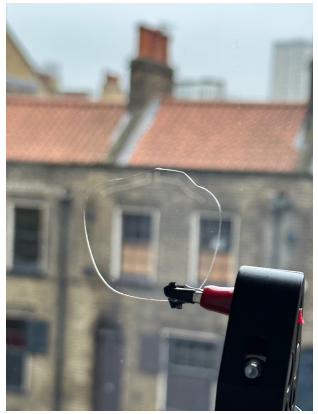
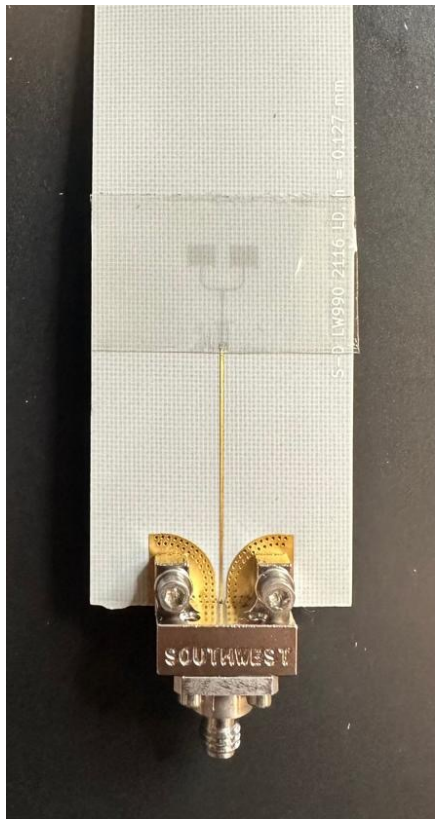
Selected Antenna Samples Produced in 2022

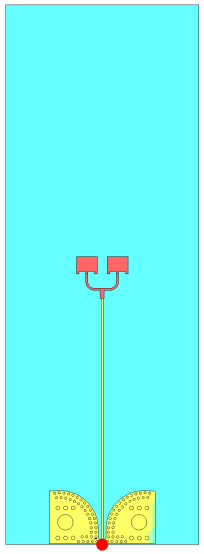


Dipole @5GHz on lens



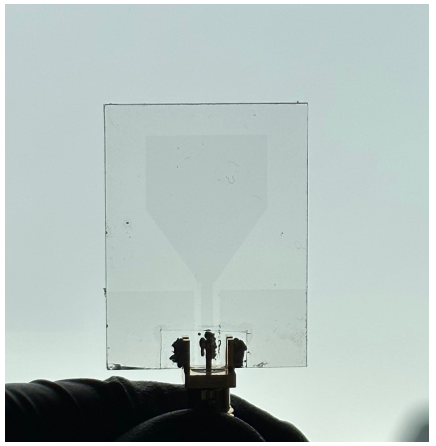
Dipole @2.4 GHz on lens

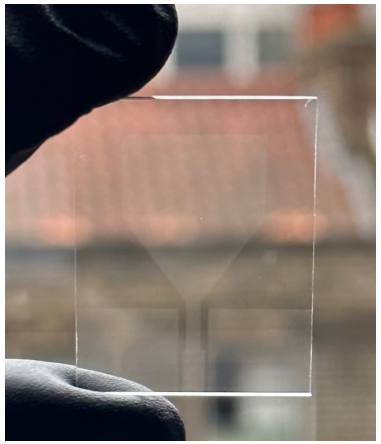




Automotive Radar 40 GHz

TV antenna patterned on Glass @400-800 MHz





Monopole @5.5 GHz on glass

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5.0 GHz WiFi Gen1 on glass lens on frame; AWE 2022 demo

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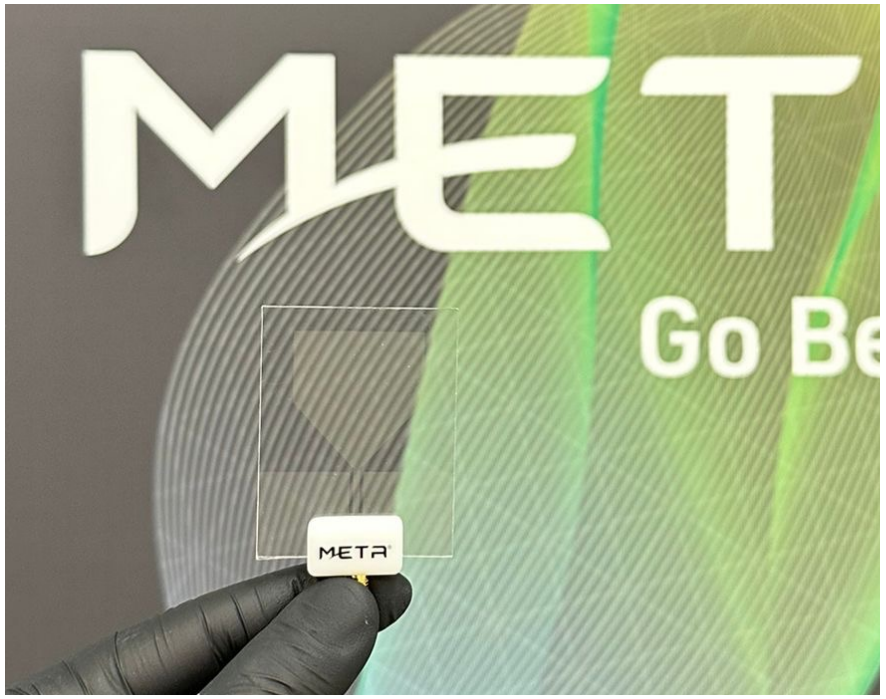
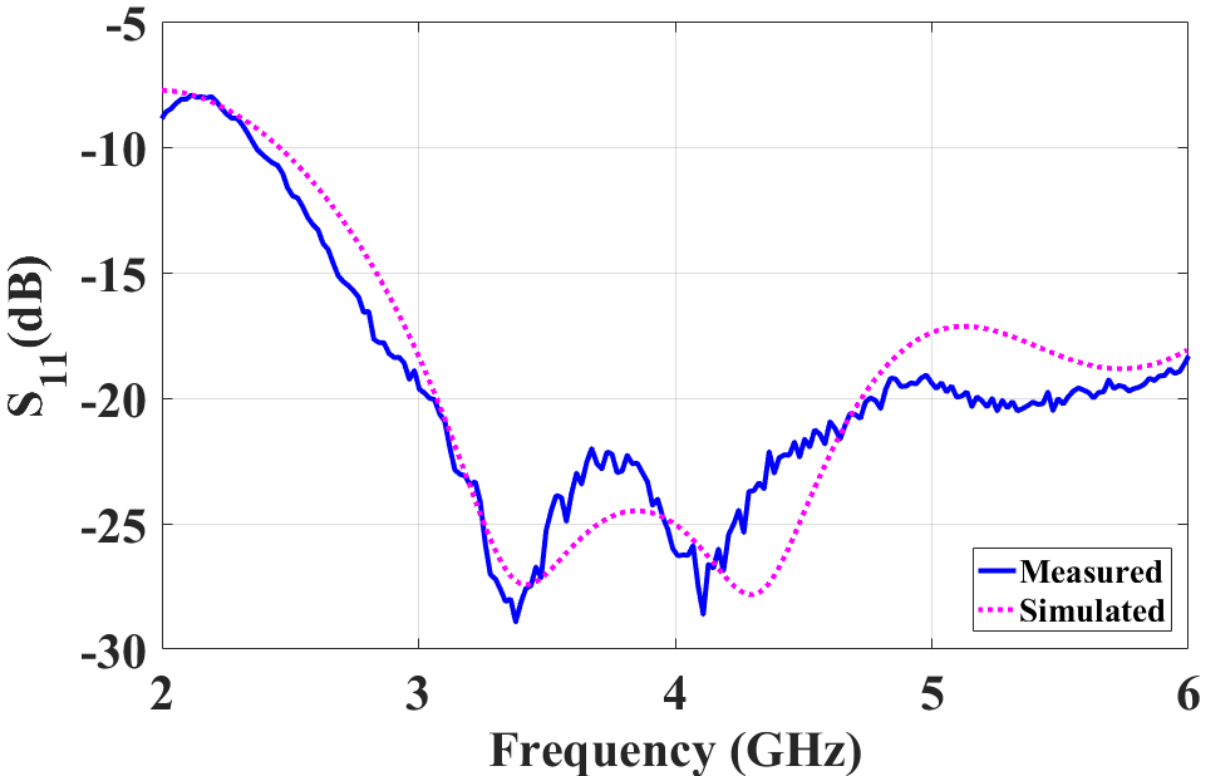
ANT-NGS-P25-GEN-004 Measured Data



Nanoweb P25 Monopole
ANT-NGS-P25-GEN-004



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Manufacturing

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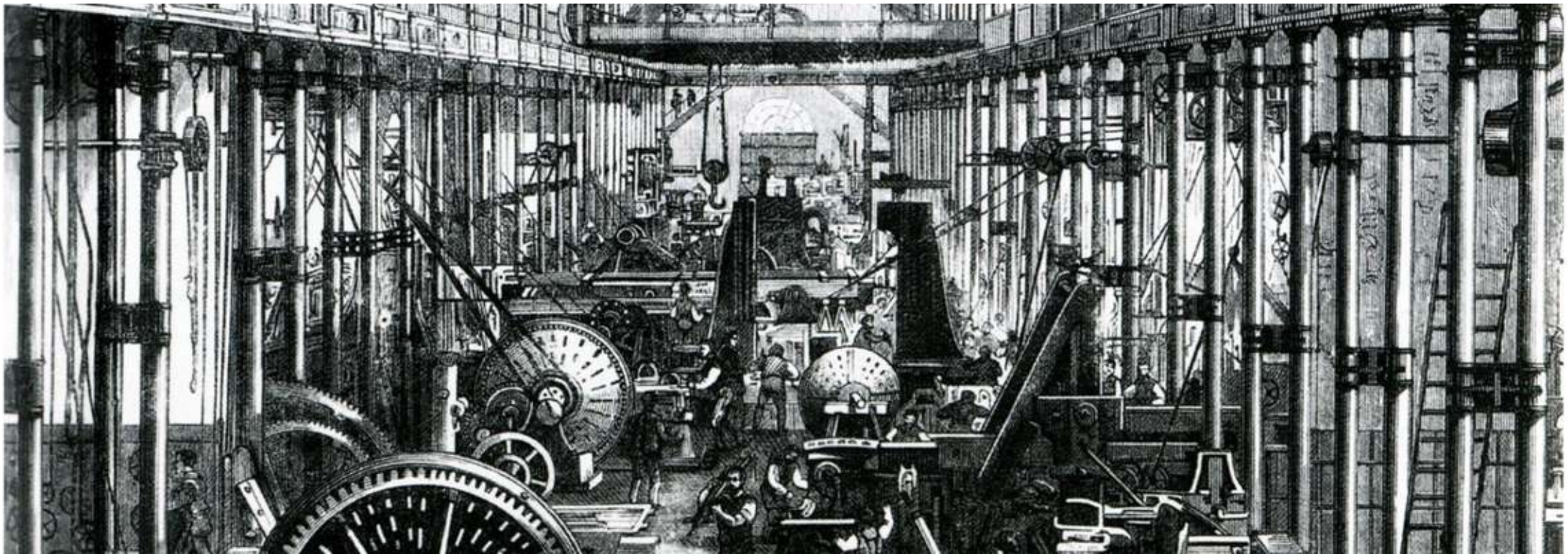

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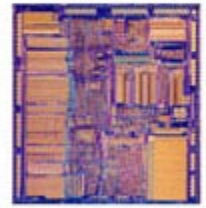
1950s	1960s	1970s	1980s	1990s	2000s	2010s
Silicon Transistor	TTL Quad Gate	8-bit Microprocessor	32-bit Microprocessor	32-bit Microprocessor	64-bit Microprocessor	3072-Core GPU
						
1 Transistor	**16 Transistors**	**4500 Transistors**	**275,000 Transistors**	**3,100,000 Transistors**	**592,000,000 Transistors**	**8,000,000,000 Transistors**

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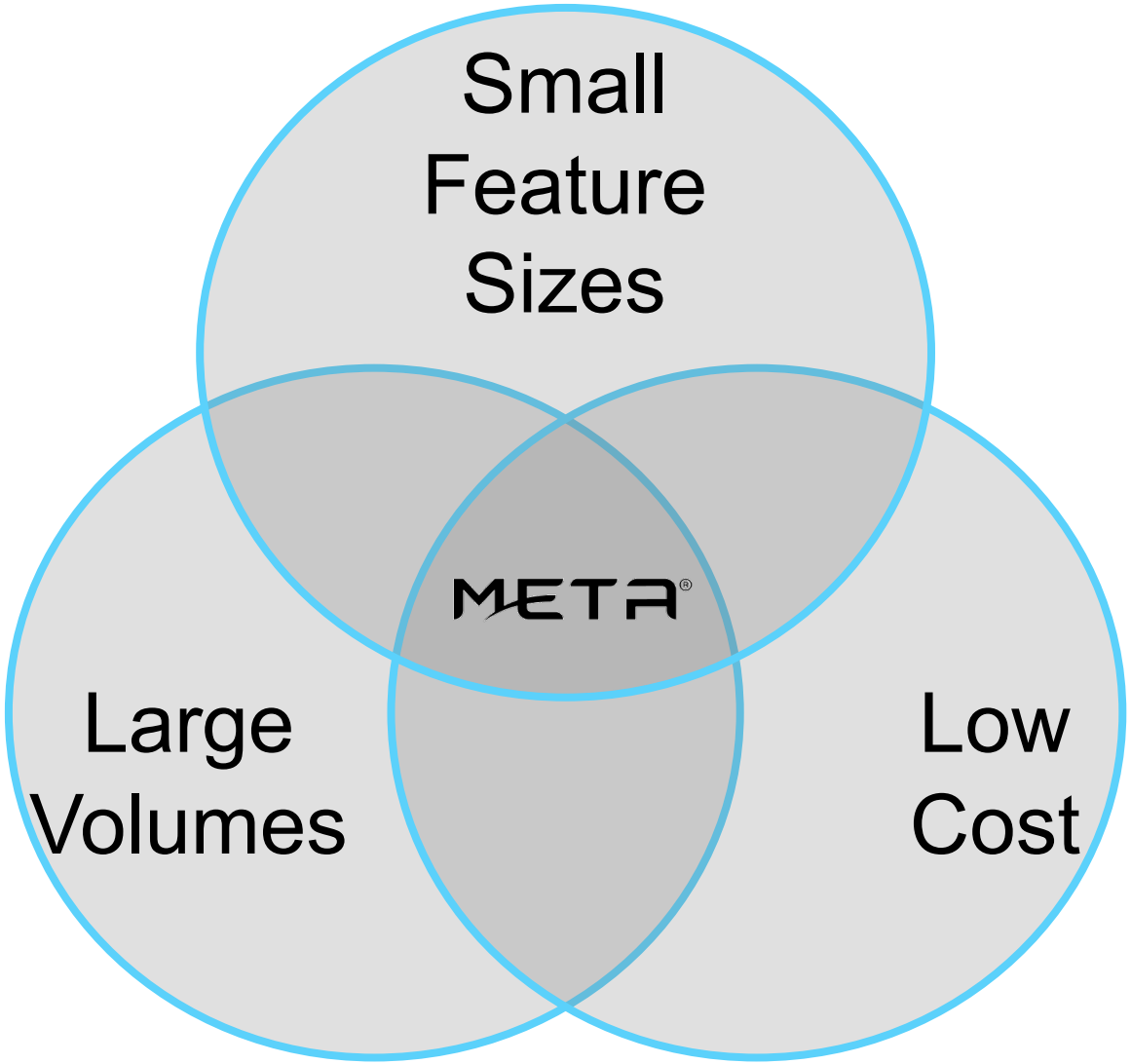

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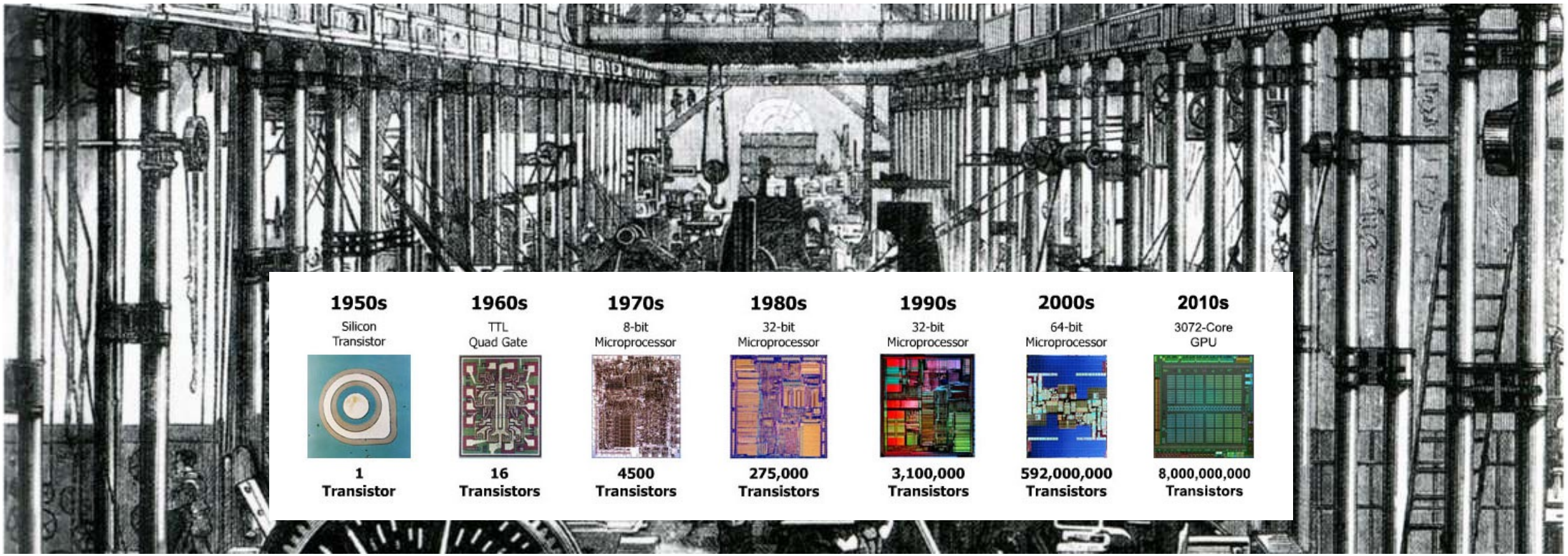

META®
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R2R Lithography Capabilities at META

R2R UV-NIL

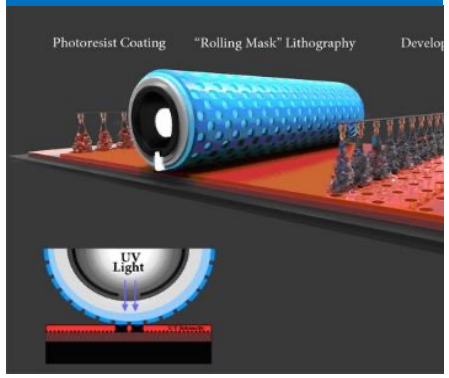
Merging of Micro and Nanostructures:
KolourOptik® secure brand protection

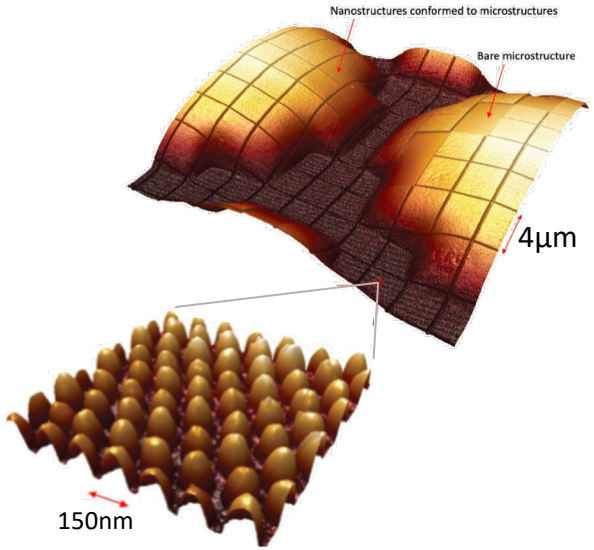
RML Lithography

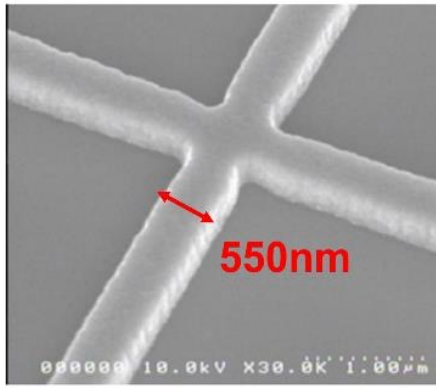
RML® produces sub-micron metal mesh:
NANOWEB® antennas, 5G communication, EMI shielding, de-ice/de-fog

NIL Lithography

Rolling Mask Lithography



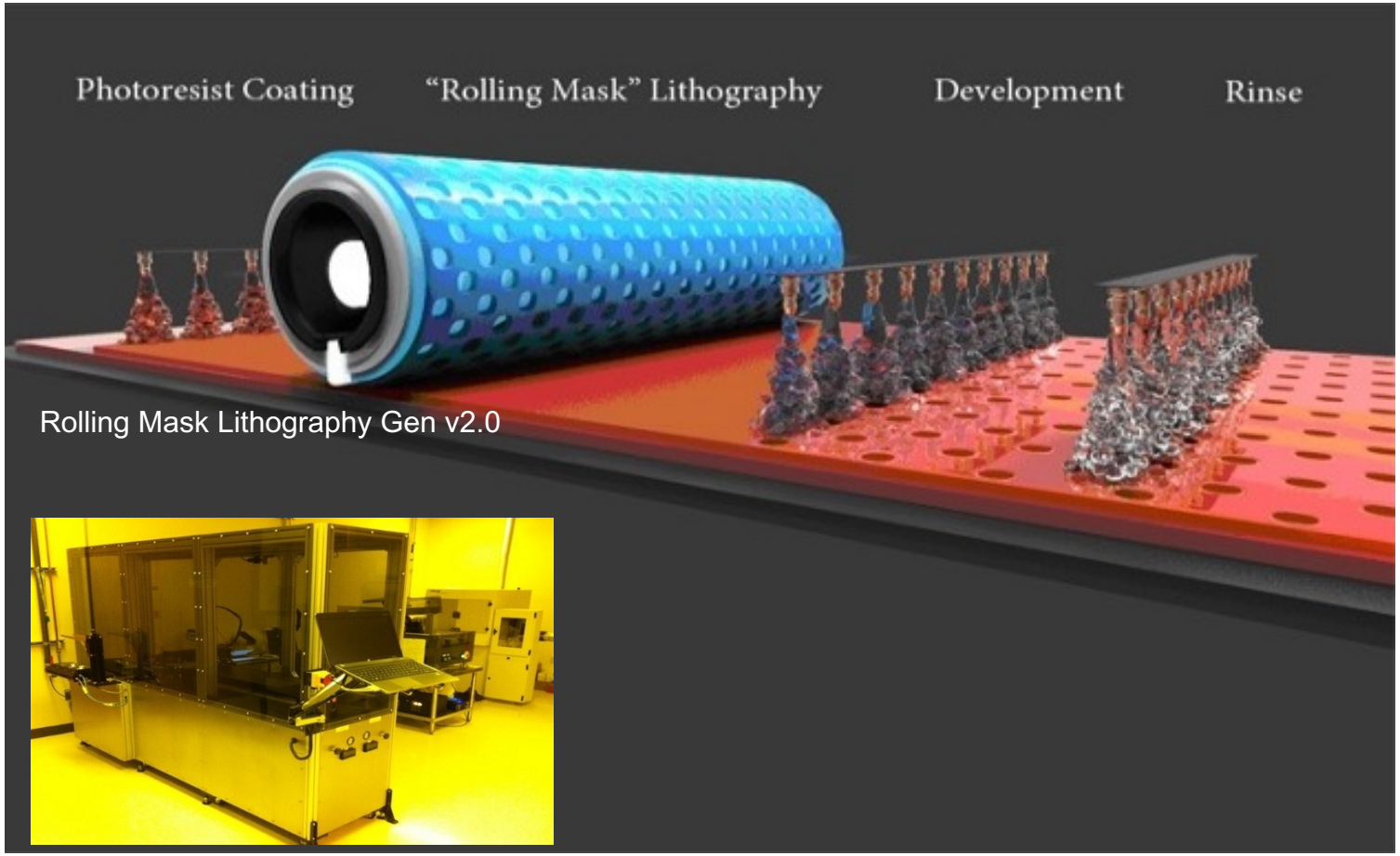


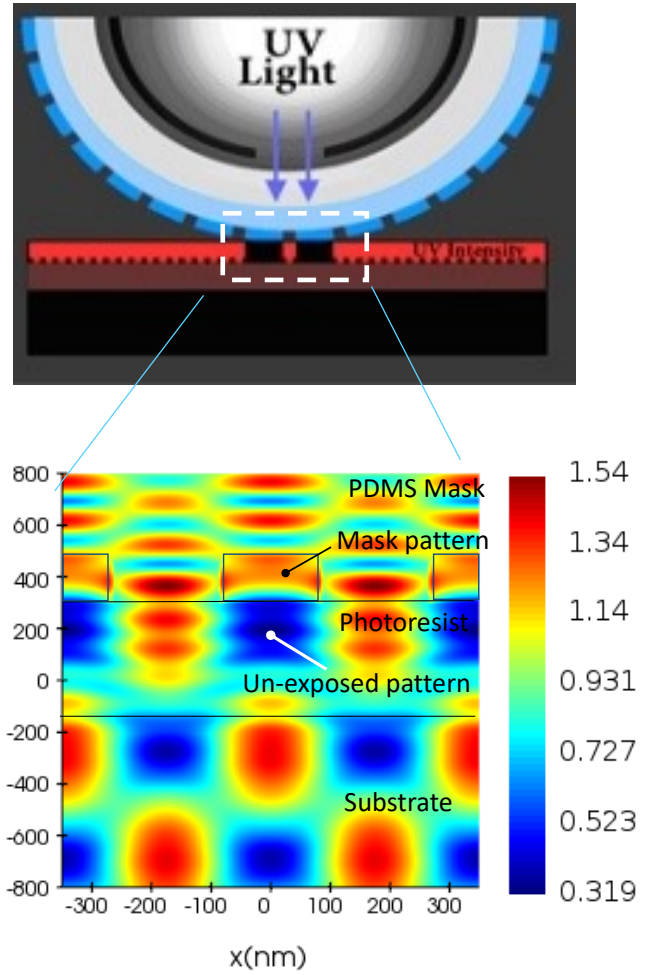


META® Go Beyond.

Rolling Mask Lithography

Proprietary **RML®** technology can fabricate nano-structures directly onto rigid or flexible surface





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Roll-to-roll Nanoimprint Lithography

Industrialized Nanofabrication

Design
- Optical Physics & Nanostructures
- Proprietary Software, 3D Image/Motion Graphics Development

Origination
- High-Resolution Electron Beam Lithography
- Proprietary Nanofabrication Processes and Intellectual Property

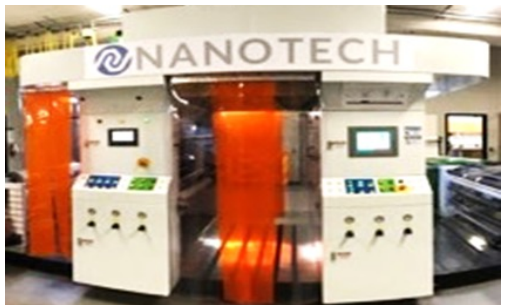
Recombination
- Expertise in recombination of nanostructures to preserve quality and fidelity over large areas

Production
- Decades of experience in high-volume, roll-to-roll web processing
- Secure facility with capacity >7 million m^2

EBL Origination

SR-NIL UV Recombination

R2R UV Casting NIL



R2R Vacuum Deposition

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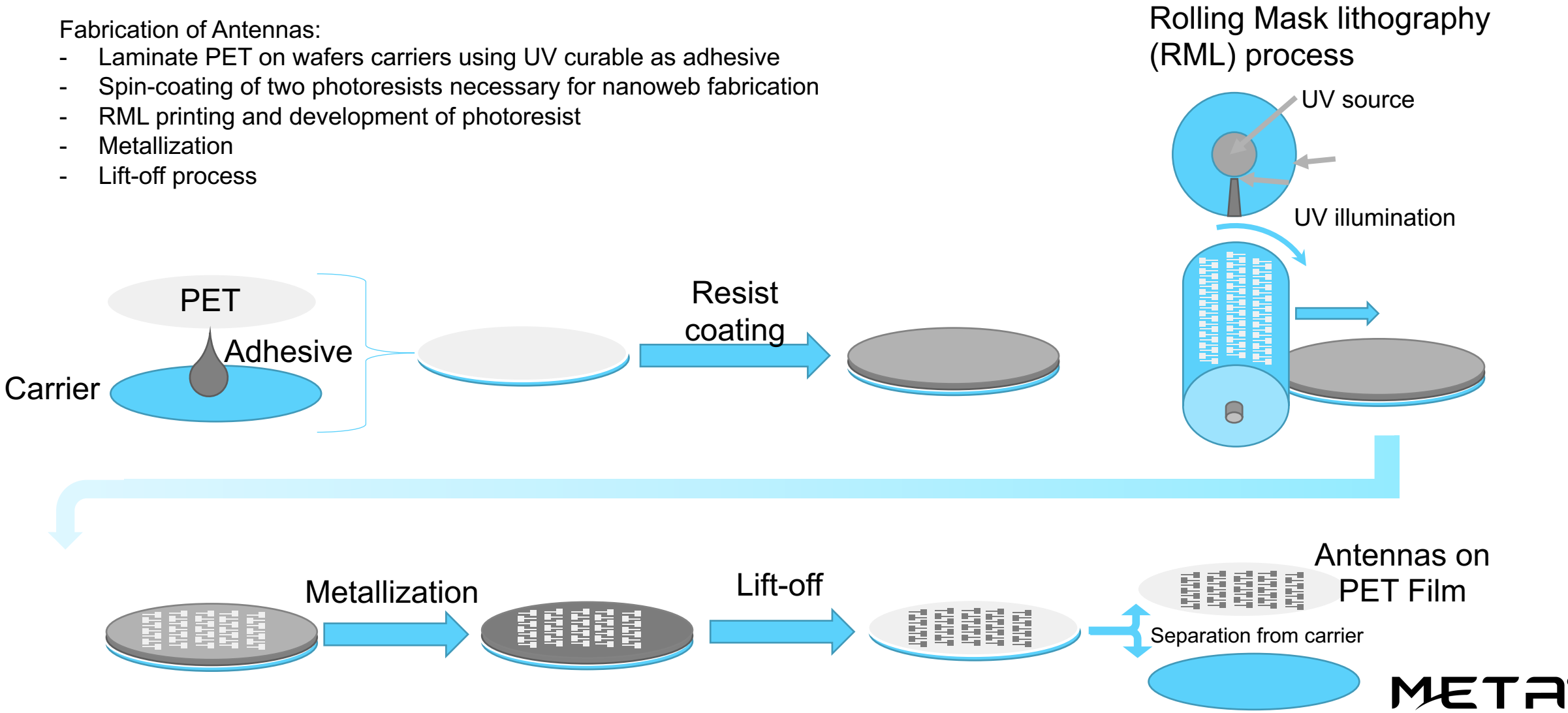
Fabrication – Nanoscale R2R Patterning “for Free”

Fabrication of Antennas:

- Laminate PET on wafers carriers using UV curable as adhesive
- Spin-coating of two photoresists necessary for nanoweb fabrication
- RML printing and development of photoresist
- Metallization
- Lift-off process



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In Closing

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“Themos,
I made marble look like
TRANSPARENT VEIL

You got this”

- Strazza

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