EXECUTIVE SUMMARY

Metamaterials Market Forecast

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Executive Summary

Metamaterial devices will grow to a $10.7 billion market in 2030.

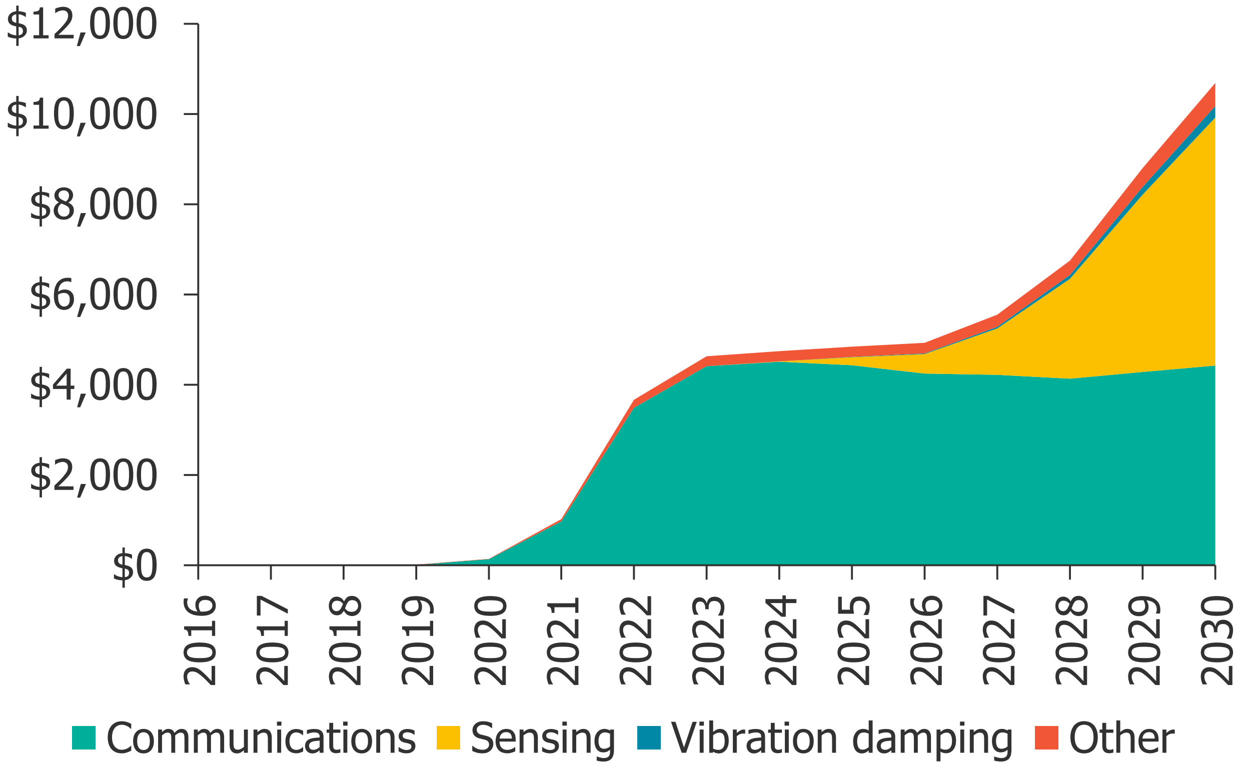
The rollout of 5G infrastructure will drive the initial wave of growth in metamaterials, which enable higher-performance antennas.

As 5G matures and levels off, metamaterials for improved radar and lidar will take off, helping shrink the size and cost of these critical sensors in self-driving cars.

Metamaterials provide significant near-term opportunity for differentiation among device makers. They also create strong medium-term risk of disruption for both device makers and materials companies that fail to understand their potential impact.

Metamaterials Market Forecast

US$ Millions



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What are metamaterials?

Metamaterials use fine structural patterning to enable unusual electromagnetic, acoustic, or mechanical properties. They're made by combining and patterning standard materials and do not typically require novel chemistries. Metamaterials can offer properties that do not exist in any bulk material or are unachievable in other ways, including:

- Zero or negative refractive index
- Extremely high reflectivity or absorption of specific frequencies
- Highly directional absorption and emission spectra

To manipulate light and sound, the structural patterns require features about an order of magnitude smaller than the relevant wavelength.

See our 2014 report "Breaking the Rules: Emerging Metamaterials Drive Performance in New Directions," and our Metamaterials Tech Page for more details about the composition and capabilities of metamaterials.

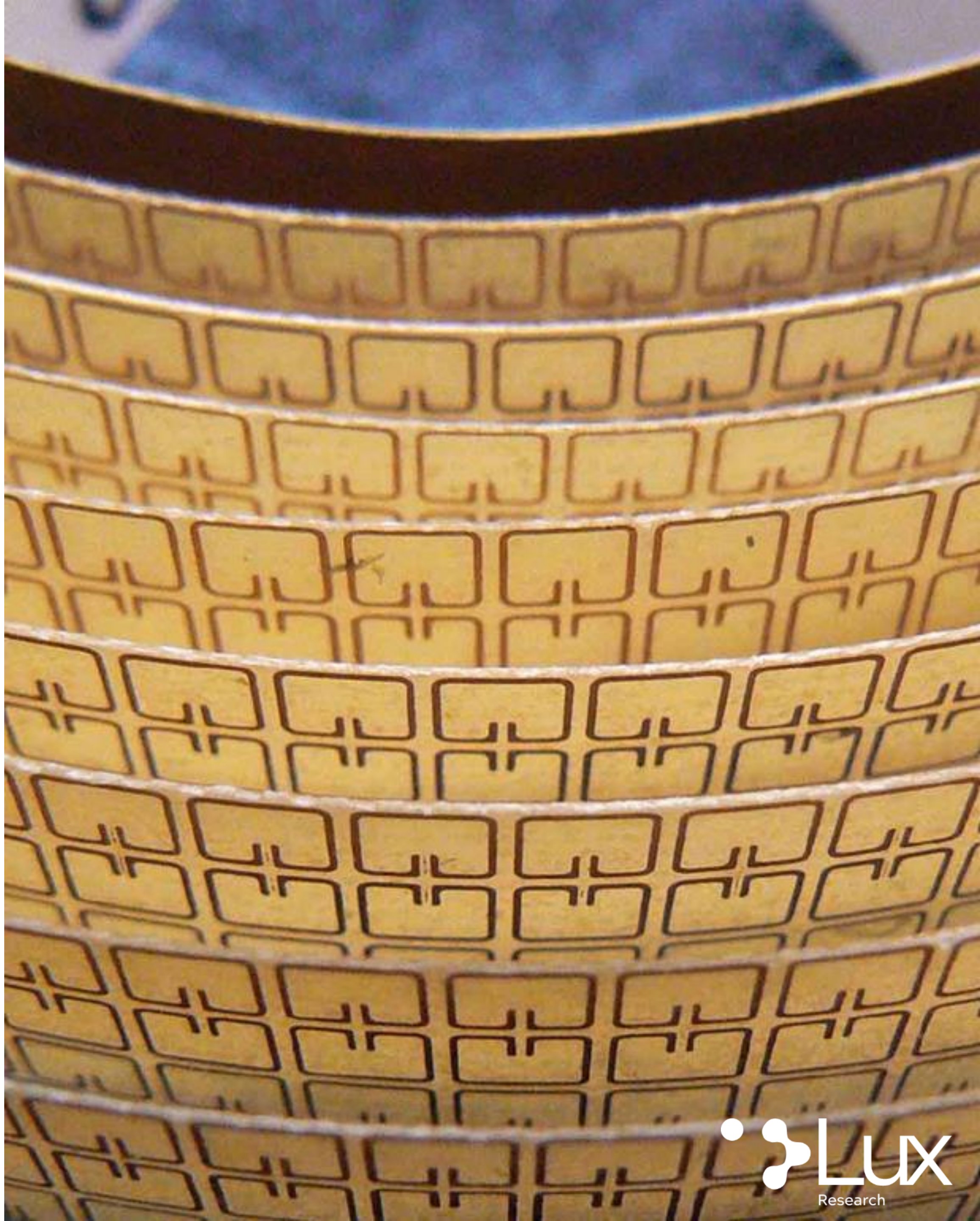

Image source: Duke University

Metamaterials are approaching commercialization; this report explores the timing and scale of the opportunity

While the first metamaterial products, wireless communication antennas, hit the market in 2009, the difficulty of designing metamaterial structures and the cost of manufacturing them made their use prohibitive in most applications.

In the past few years, design and manufacturing methods have matured due to advances in modeling and simulation software, additive manufacturing, and lithography, making near-term at-scale metamaterial adoption feasible in several large applications.

In the full report, we model the growth of the metamaterial market in key applications through 2030. We specifically focus on electromagnetic and acoustic metamaterials, as these have the greatest potential near- and medium-term impact.

Temperature Map of Metamaterial Thermal "Invisibility Cloak"

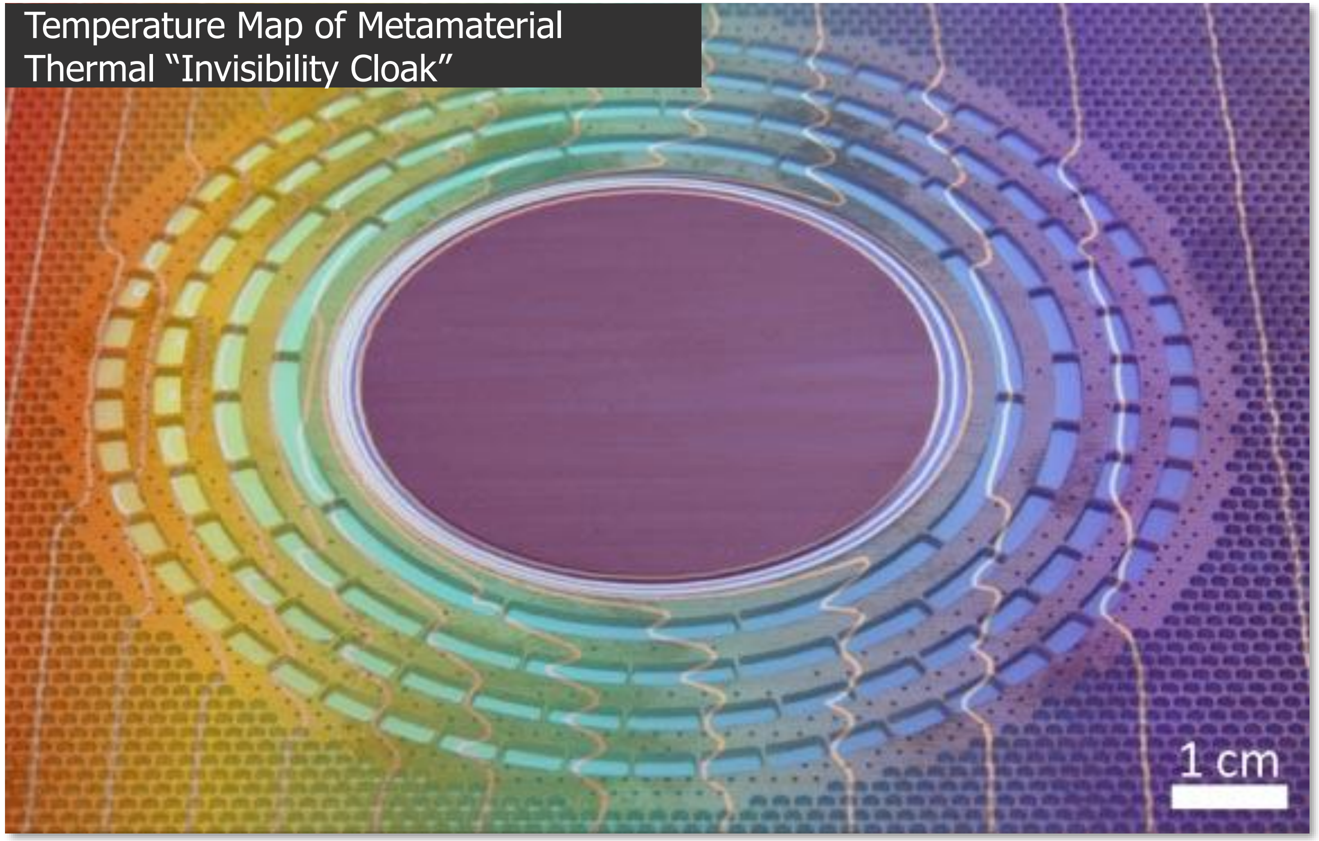

Image source: Karlsruhe Institute of Technology

What types of metamaterial technologies are ready for commercial adoption?

We classify metamaterials based on the types of waves they can manipulate, whether electromagnetic (radio and microwave, or optical) or acoustic. The scale of the wavelength determines the dimension of the patterning needed and thus the type of production methods used. The full report focuses on three categories:

Radio and microwave

Because these electromagnetic waves have long wavelengths, metamaterials that affect them only need patterning on a scale of hundreds of microns or longer. As a result, they can often be made using standard printed circuit board (PCB) processes and materials or other relatively inexpensive processes.

Optical

Optical metamaterials, controlling shorter wavelengths of electromagnetic radiation, require fine patterning through lithography and are much more expensive to produce than radio and microwave metamaterials – but still much less expensive than even a few years ago.

Acoustic

Acoustic metamaterials only require patterning at the scale of centimeters to tens of centimeters and may be produced using 3D printing or even assembled manually.

Metamaterials span a wide range of potential applications

Since the first demonstrations of metamaterial capabilities in the late 1990s, researchers have promoted numerous potential applications in a wide range of industries, including:

Radio and microwave	Optical	Acoustic
Communications Sensing Energy harvesting Wireless charging Stealth and cloaking	Sensing Stealth Solar power LED lighting Laser protection Stealth and cloaking	Vibration damping Acoustic insulation Stealth and cloaking

In the full section of this report, we take a deeper dive into each application space to separate out reality from hype and near-term from long-term potential. The executive summary highlights details for the communications application.

EXAMPLE FROM FULL REPORT:

Communications see a variety of benefits from metamaterials

Introduction:

The unique capabilities of electromagnetic metamaterials include the ability to have a zero or negative permeability, permittivity, or refractive index. When metamaterial elements are incorporated into an antenna, they enable:

- Smaller physical size by up to an order of magnitude
- Several-fold reduced power consumption
- Tighter beam-forming and beam-shaping

These antennas can be used for end uses including:

- 5G devices
- 5G infrastructure
- Mobile broadband for aircraft, automotive, marine, and rail
- Satellite communications

Key Players:

KYMETA

PIVOTAL COMMWARE

TeraView

FRACTAL ANTENNA SYSTEMS INC

Sample Product:
Wireless mobile broadband antenna from Kymeta

Image source: Kymeta

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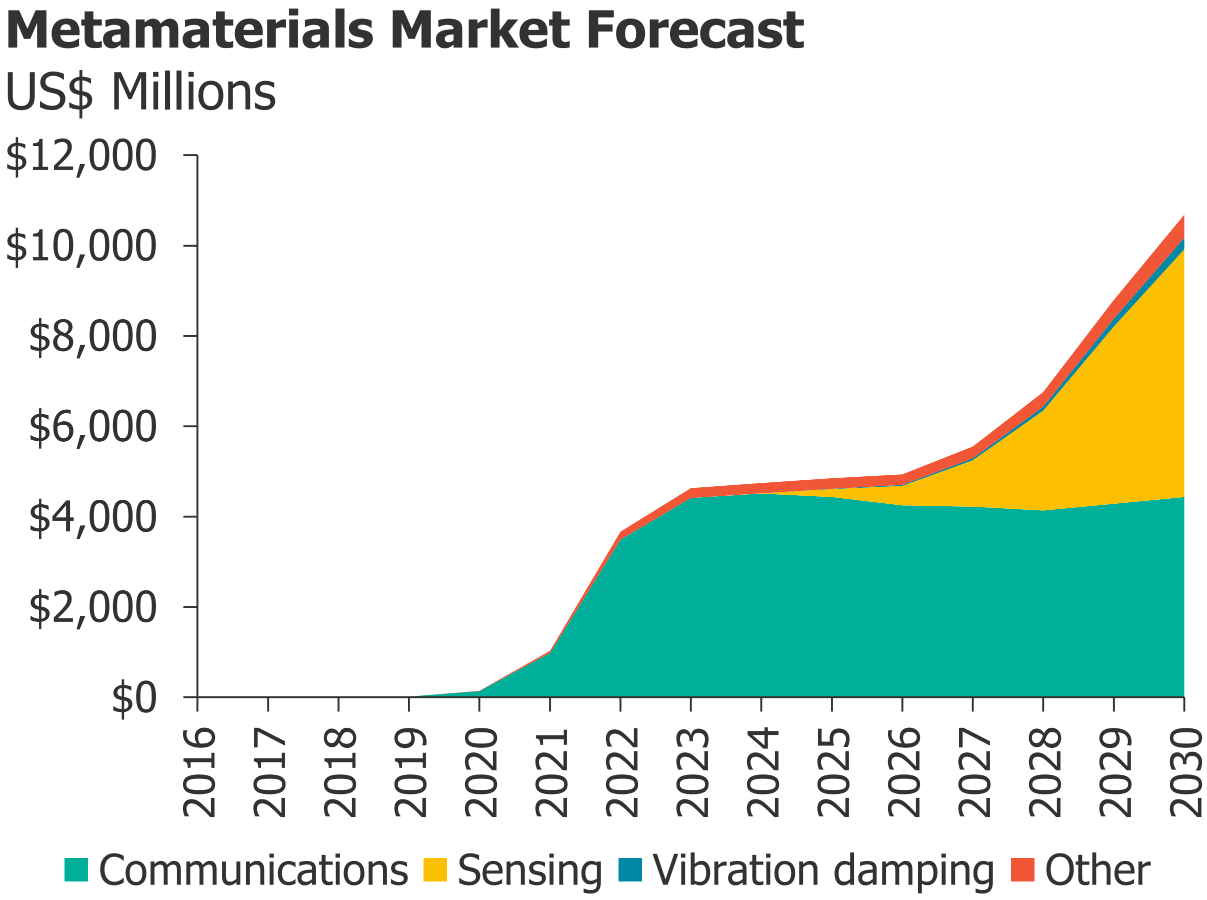
Metamaterial device markets will total $10.7 billion in 2030

We modeled the growth of metamaterial-containing devices across eight different applications through 2030. The model looks at potential addressable markets and gauges likely metamaterial adoption from likely cost, maturity, and performance based on input from a wide range of primary and secondary research.

We explicitly size the markets for metamaterial components in communications, sensing, and acoustic applications. Numerous other individually small applications are likely to appear; these we grouped together into an "Other" category.

All told, metamaterials reach $10.7 billion in 2030. Through 2025, communications uses are by far the leading growth driver, but **by 2030, sensing uses grow to be the largest segment**, reaching $5.5 billion compared to $4.4 billion in communications.



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EXAMPLE FROM FULL REPORT:

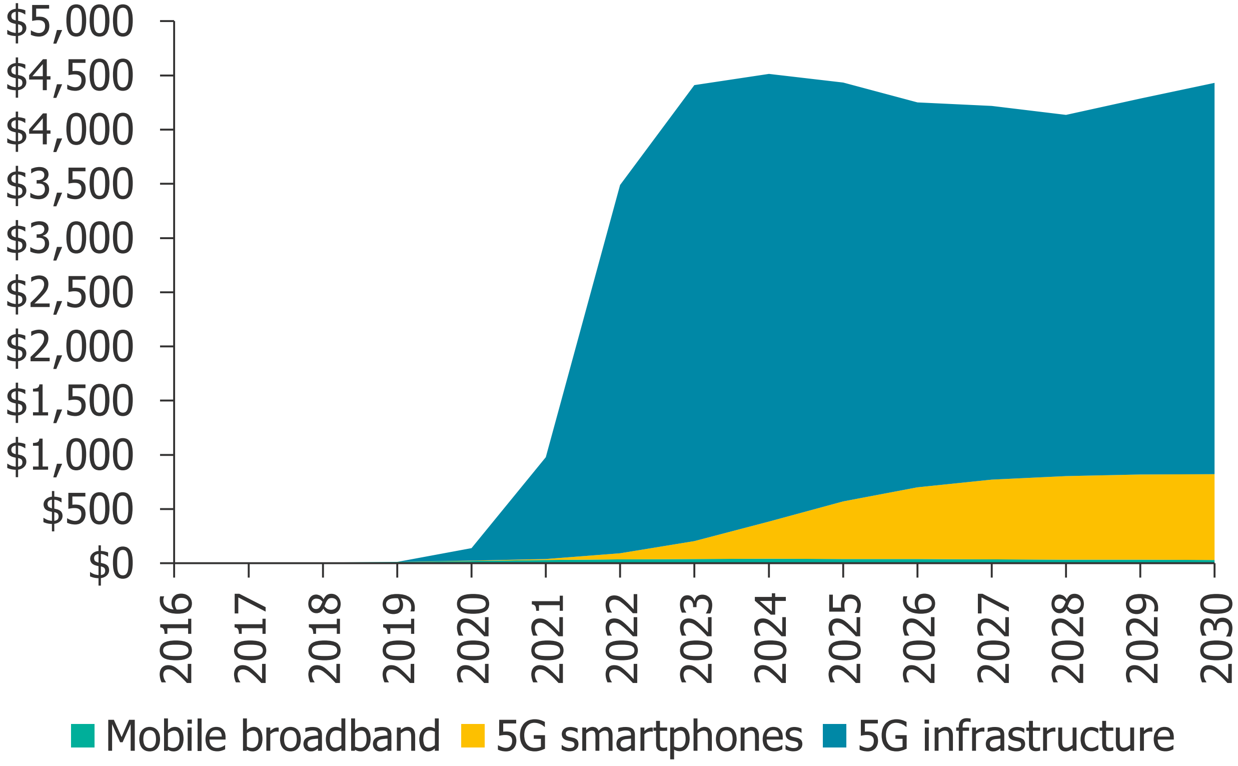
Communications applications peak in 2024 at $5.4 billion, then decline to $4.4 billion in 2030 as 5G rollout finishes

Communications applications for metamaterials include mobile broadband, 5G-enabled smartphones, and 5G base station infrastructure.

Mobile broadband devices, such as those from Kymeta, provide internet service aboard aircraft, on ships, or in remote locations. Metamaterials will become common here due to better price, size, and power consumption compared to other methods, but the total number of devices will be relatively small.

5G infrastructure will roll out over the next 10 years in highly populated areas, and nearly all smartphones will be 5G-capable by 2025. Metamaterials are not the most mature option for either device or base station antennas, but superior performance will help capture market share beginning in the early 2020s. By 2030, metamaterials will capture 10% share for base stations and 40% for mobile phones.

Communications Market Forecast
US$ Millions



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Electronic device makers and automotive OEMs face major disruption risk from metamaterials in the next decade

Metamaterials carry significant disruption risk in communications and sensing applications, particularly for radio-wave, microwave, and millimeter-wave frequencies, by combining smaller size, lower power, higher directionality and control, and comparable cost. **Once metamaterial options reach the market, conventional offerings in these areas are likely to become uncompetitive**.

Metamaterial adoption does not require high capex, as devices can continue to use conventional materials and processes with metamaterial designs. However, **it will take time for developers to become fluent in metamaterials as a design language, and companies that do not begin this process now risk falling behind**.

Well-protected design IP is likely to be critical for metamaterials, as they rely on standard materials and processes. The very first metamaterial startup, Rayspan, went out of business due to IP litigation in 2009 after selling tens of millions of wireless routers, and even today, a small number of players own and share key core IP that new entrants need to innovate around.

Key early metamaterial antenna patents are set to expire in the 2024 to 2028 timeframe. At that point, we expect to see a rapid increase in the number of companies developing metamaterials, similar to the increase in 3D printing experienced after early FFF patents expired between 2005 and 2008.

Materials and chemicals companies must move downstream to capture the opportunity that metamaterials offer

Materials companies that understand metamaterial structures can devise ways of incorporating novel functionalities into existing material offerings, so that they can be used in new applications. Possible examples include metallic sound absorbers that perform as well as polymer foam, molded surfaces that create structural color without any pigment, and metal films that are alternately thermally insulating and conducting in different regions. This means that **metamaterials can be a competitive threat to incumbent specialty materials (or semifinished goods) producers while presenting an opportunity for some more commodity material producers** to create higher-value products.

Metamaterial structures rely on combinations of materials, not individual materials – for example, combinations of a conductor (copper) and insulator (polymer) in a printed circuit board. **A company that controls the combination of needed materials has the power to optimize those combinations for metamaterials use**; materials developers should move downstream to integrate materials that pair with their current offerings in metamaterial structures.

At the end of the day, however, as a design-driven trend, similar to additive manufacturing, **metamaterials tend to create more value for device makers than pure materials developers**. To capture the value, materials companies may choose to move further downstream into device or component design for metamaterials to capture greater margins or to develop best practices for using their materials in metamaterial structures.

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