MTECH

RESEARCH SEMINAR

Presentation

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CHIRAL METAMATERIALS

"Exploring the Unique Properties of Non-Symmetrical Structures for Advanced Materials"

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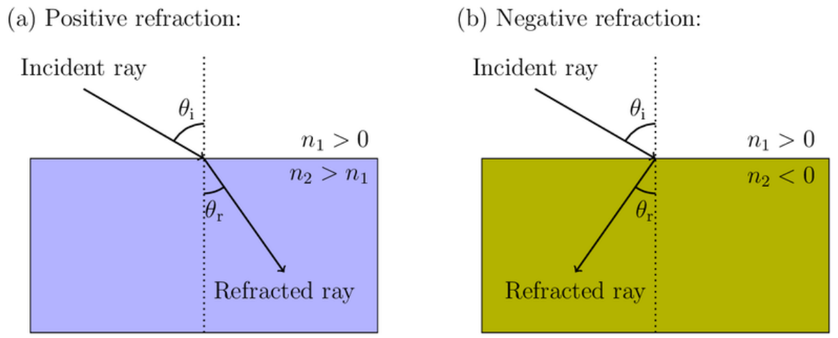
MEMS Department

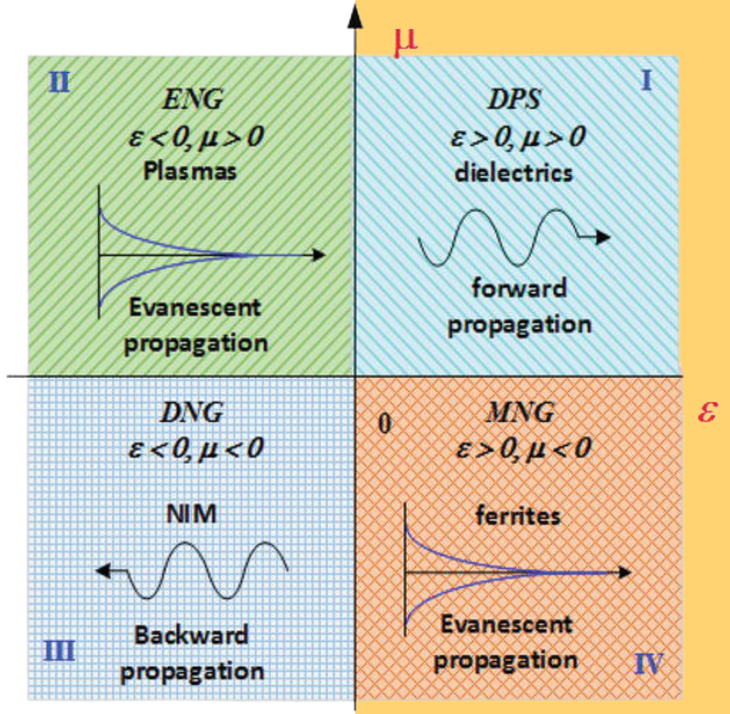
LIST OF CONTENTS

INTRODUCTION

"META" = BEYOND

- Artificially structured materials
- Properties not seen in natural materials.
- Negative refractive index :





1968 — **Veselgo:** Propose the concept of Left Hand Material

1999 — **Pendry et al.** realized manmade electric plasma utilizing wire medium of -ve permittivity.

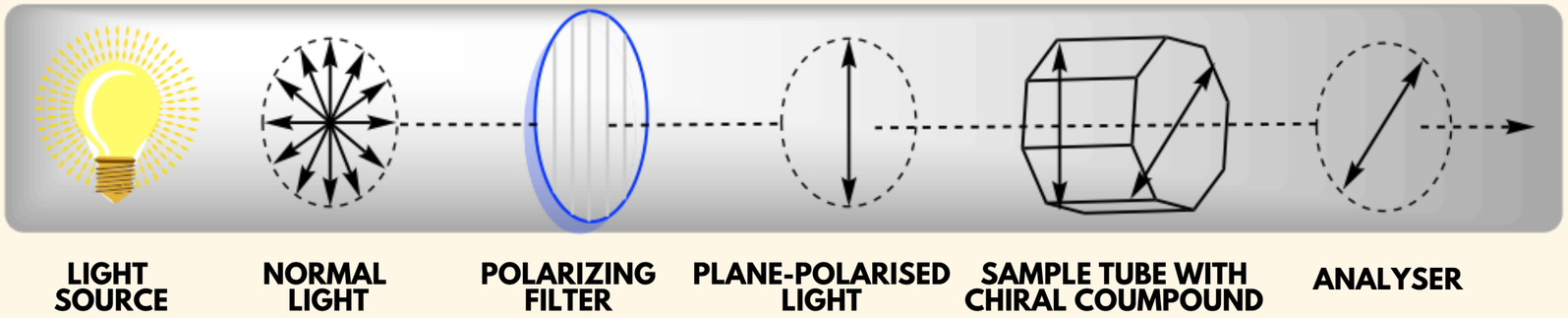
2001 — **Smith et al.** Made 1st manmade LHM by utilizing SRRS and wires.

2006 — **Leonhardt:** The optical transformation was proposed to ontrol the propagation of wave using metamaterial

Prof. John Pendry

CHIRALITY ?

- **Lord Kelvin** first used word "**Chirality**" to describe **handedness** in 1873.
- So chiral medium is composed of particles that **can not be superimpose on their mirror image**.
- In 1910, **Lindeman** introduced the "**Optical Activity**" phenomenon with collection of helical coils as artificial chiral molecules.



- Tretyakov et al realised the possibility of negative refraction by **chiral nihility** in 2003.
- The idea of chiral nihility is that when μ and ε of a chiral medium are small and very close to zero.
- **In 2004, Pendry** discussed possibility to achieve negative refraction.

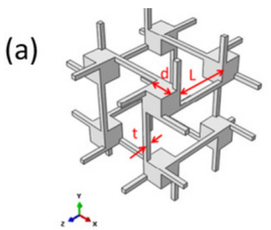
Image ref., Wu *et al.* (2019). Mechanical design and multifunctional applications of chiral mechanical metamaterials: A review. Materials & Design, 107950.

WHAT MATERIALS ARE USED?

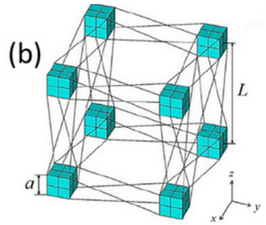
It can be made from a wide range of materials, including metals, plastics, ceramics, and semiconductors.

- Gold
- Silicon
- Polymers
- Graphene
- Magnesium oxide
- Carbon nanotubes

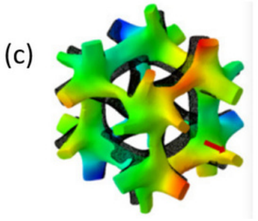
The specific material used depends on the desired properties and the manufacturing process.



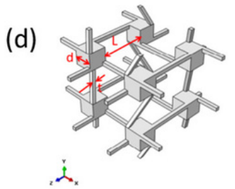
Anti-tetrachiral



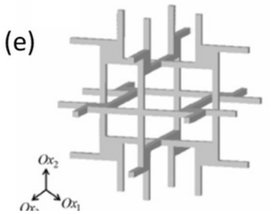
Chiral metastructures



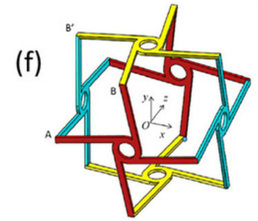
auxetic lattice with anti-tetrachiral



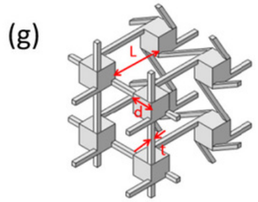
Chiral-antichiral-antichiral



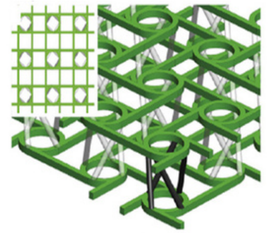
Anti-tetrachiral lattices



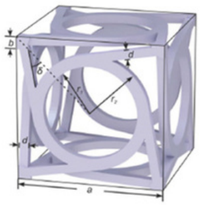
chiral lattice with negative Poisson ratio



Chiral-antichiral-antichiral



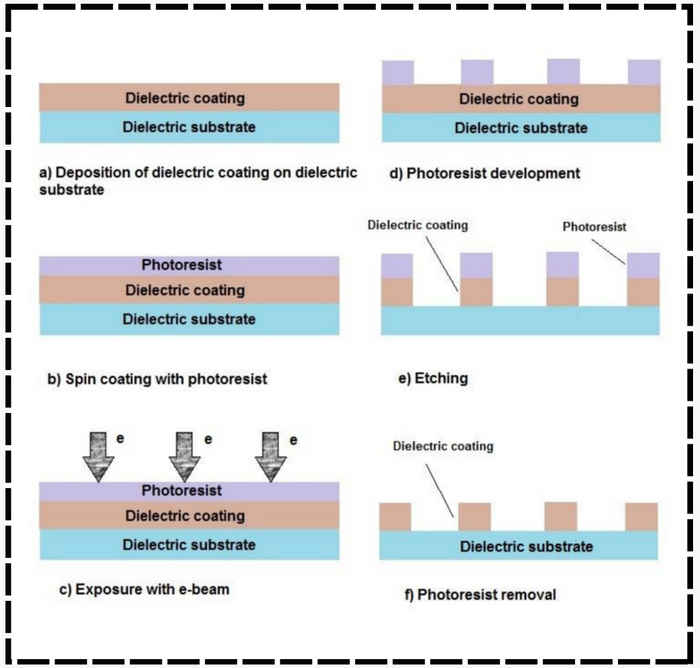
Cellular with planar anti-tetrachiral topology



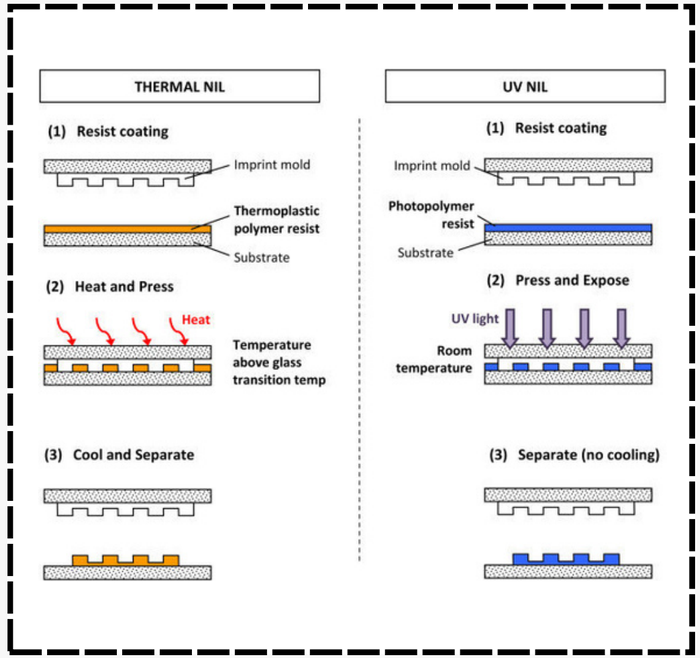
Compression-twist chiral

Image ref., Wu *et al.* (2019). Mechanical design and multifunctional applications of chiral mechanical metamaterials: A review. Materials & Design, 107950.

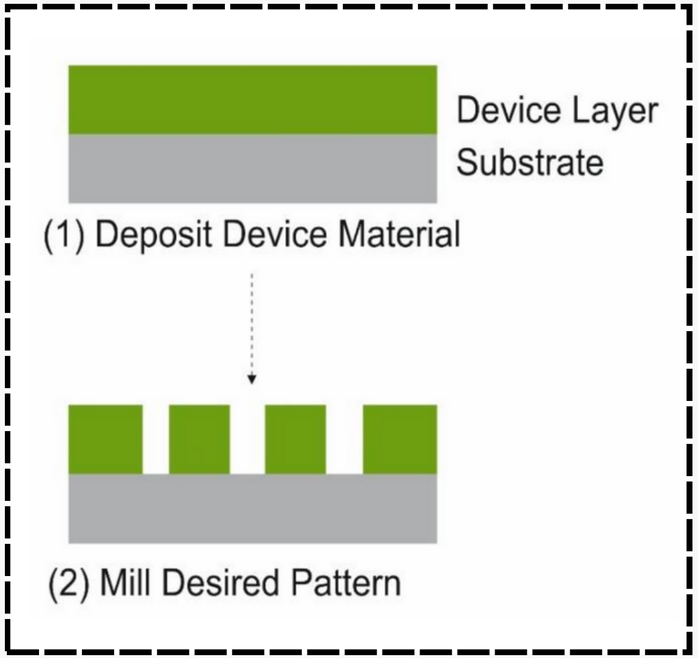
FABRICATION PROCESS



Electron Beam Lithography



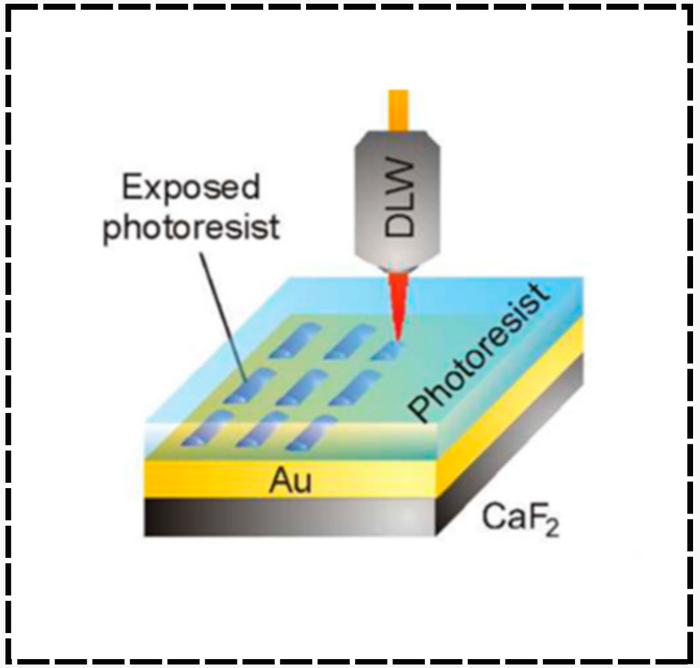
Nanoimprint Lithography



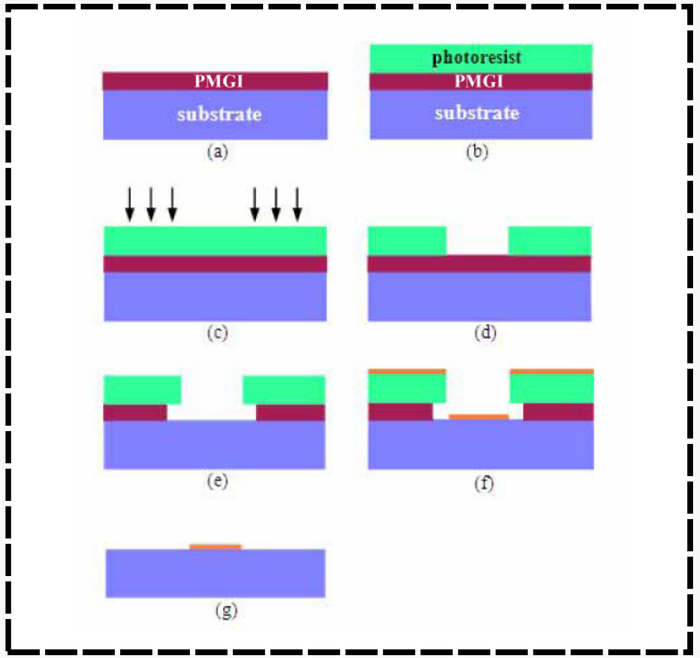
Focused Ion Beam Lithography

Image ref. : sisan *et al.* (2019). Metamaterials in the World of Materionics Overview of Fabrication Processes.

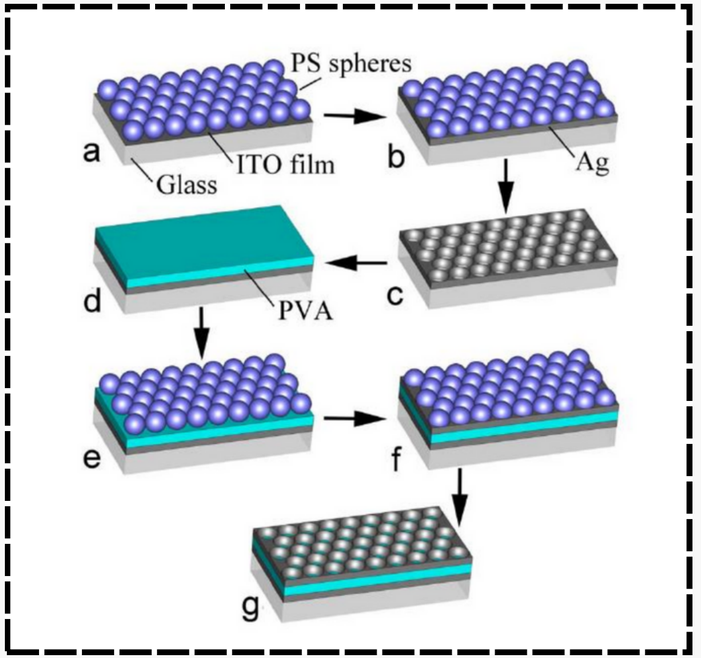
FABRICATION PROCESS



Laser-direct-write (LDW) lithography



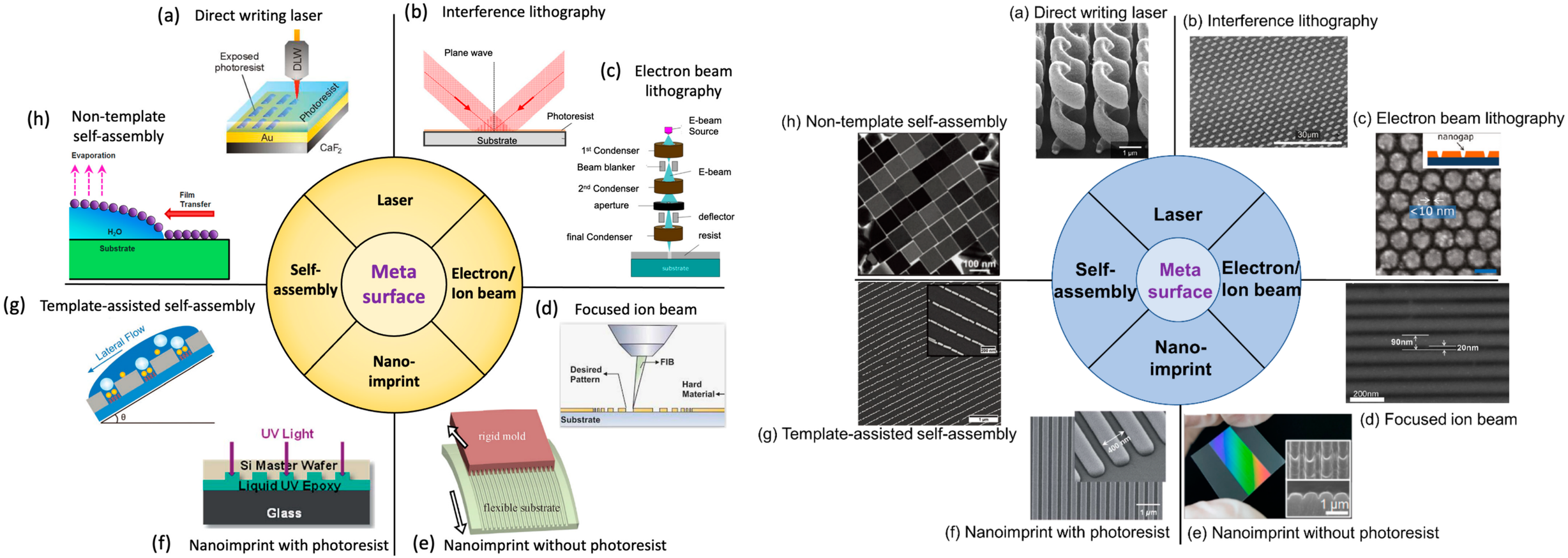
Laser-interference lithography (LIL)



Self Assembly

Image ref. : sisan *et al.* (2019). Metamaterials in the World of Materionics Overview of Fabrication Processes.

METHODS WITH SEM IMAGES



Comparison of fabrication processes with gold

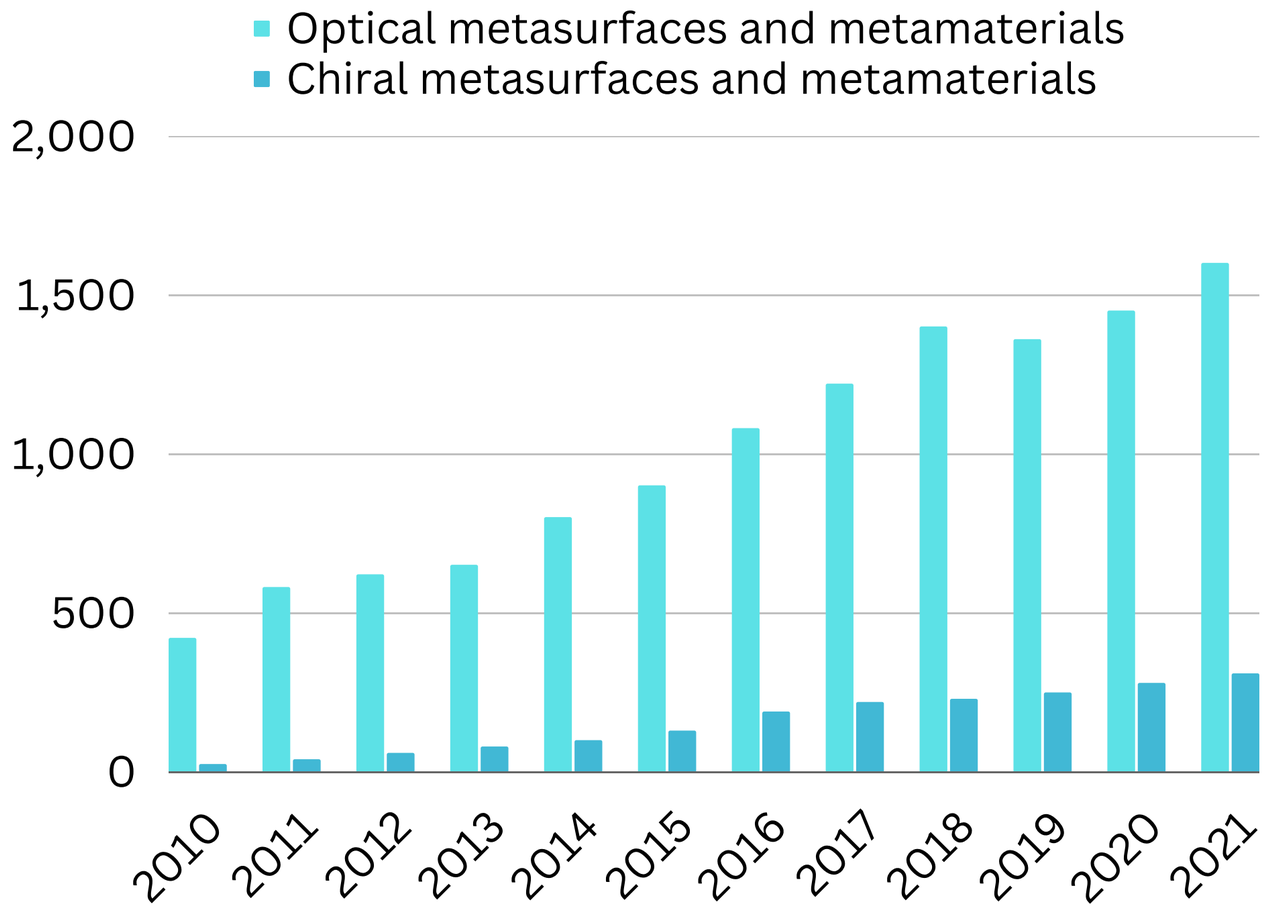
Image adapted from Xiong *et al.*, (2022). Microscopies Enabled by Photonic Metamaterials. Sensors. 22. 1086. 10.3390/s22031086.

Wide Range of Applications

Medical Sector	Automotive	Aerospace	Sensors
Antennas/Sensors	Motor Magnetic Materials	Communication System	Materials Identification
Medical Imaging	Night Vision System	LIghtweight Aircraft	Parameter Sensing
Strain Sensing	LED Headlight	Invisibility cloaks	Tunable sensors
Cancer Detection	Laser Radar	Superlenses	Biosensing

Several other applications invisible slab, light & sound filtering, Spectroscopy, metamaterial absorber, MEMS, Remote sensing, smart material application, Spectroscopy etc.

HISTORICAL DEVELOPMENT



Yearwise publications

2018 - 2019

Optical Metasurfaces

Publication was reduced afterwards increased.

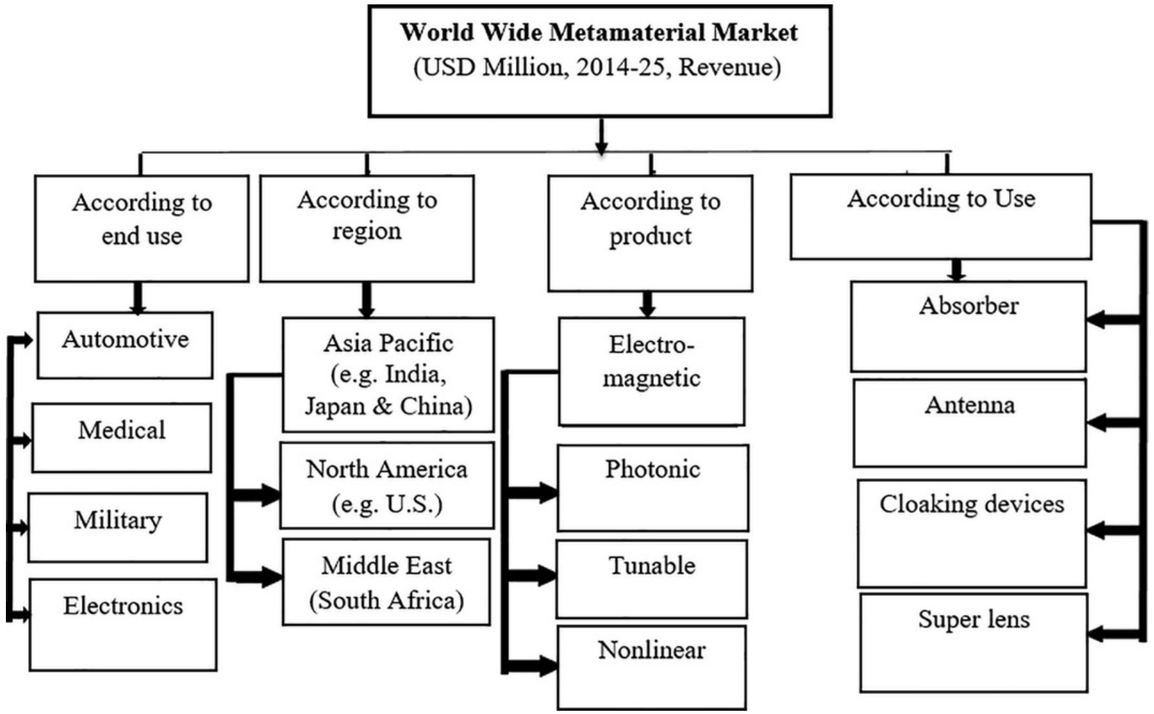
2022 - 2030

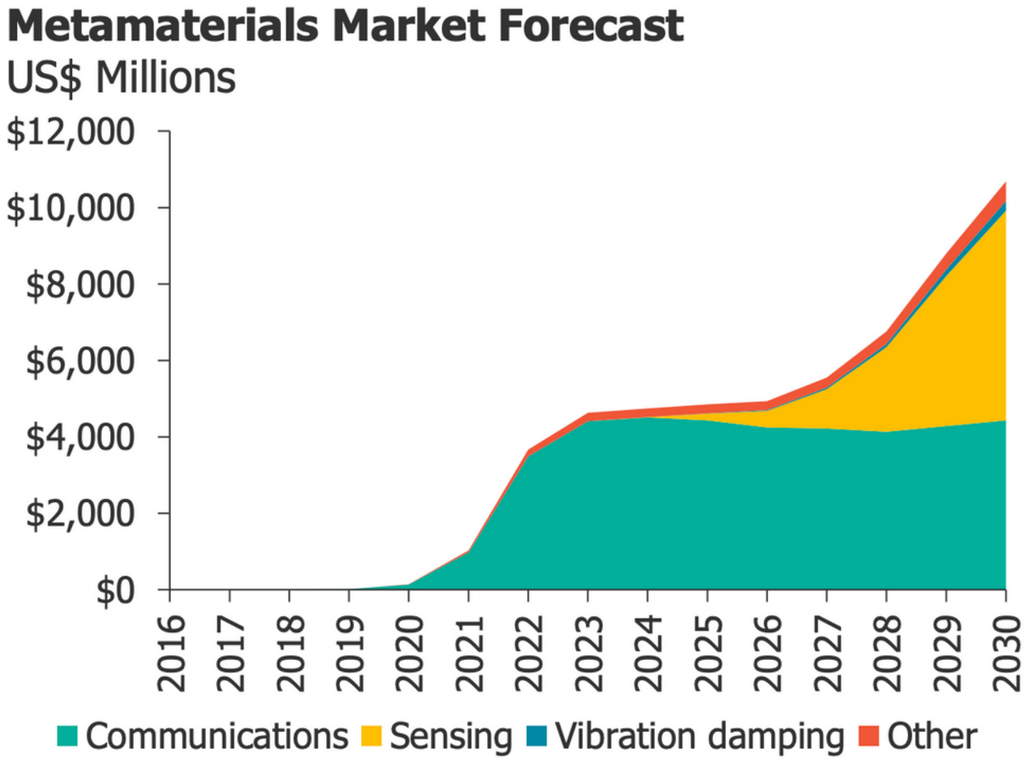
Chiral Metasurfaces

Percentage of articles will increase more.

Data ref., Cen *et al.*, (2022). Ultrathin Suspended Chiral Metasurfaces for Enantiodiscrimination (Adv. Mater. 37/2022). Advanced Materials. 34. 2270263.

GLOBAL MARKET ▪ ▪ ▪





In 2016

It is estimated that the worldwide metamaterial market size was <u>USD 316 million</u>.

By 2030

The medium market metamaterial size according to report study it estimate to reach <u>$10.7 billion</u>.

Vicari, A.; Holman, M.; Schiavo, A. Metamaterials Market Forecast, 2019. Available online:

FUTURE ADVANCEMENTS

In the future, there are several potential advancements that could further enhance the capabilities of chiral metamaterials. These include:

New fabrication techniques

new fabrication techniques may be developed that make it easier and more cost-effective to produce chiral metamaterials.

Multifunctional chiral metamaterials

It may be possible to engineer chiral metamaterials that exhibit multiple optical properties simultaneously.

Integration with other technologies

It can be integrated with other technologies, such as microfluidics, to create new types of sensors and devices.

Enhanced tunability

Developing chiral metamaterials that are more tunable, allowing their optical properties to be adjusted in real-time in response to changing conditions.

KEY SEMINAR LEARNING

1. Historical Development
2. Concept and theory analysis
3. Fabrication methods
4. Worldwide market analysis
5. Future advancements and technology

THANK YOU