Fused Deposition Modeling 3D printed metasurfaces for microwave applications

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FOUNDATION FOR RESEARCH AND TECHNOLOGY – HELLAS

INSTITUTE OF ELECTRONIC STRUCTURE AND LASER

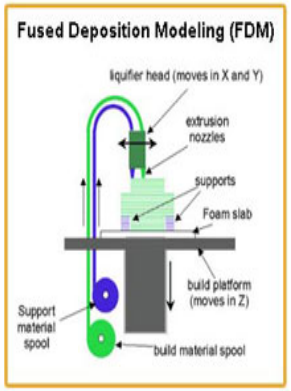
Outline

- Introduction to 3D printing / FDM
- Fabrication and characterization of the elementary SRR unit
- Sensing application
- Harvesting application

3D printing process

- ***Any process in which a material is joined or solidified under computer control to create a 3 dimensional object.***

4 Types of 3D Printing



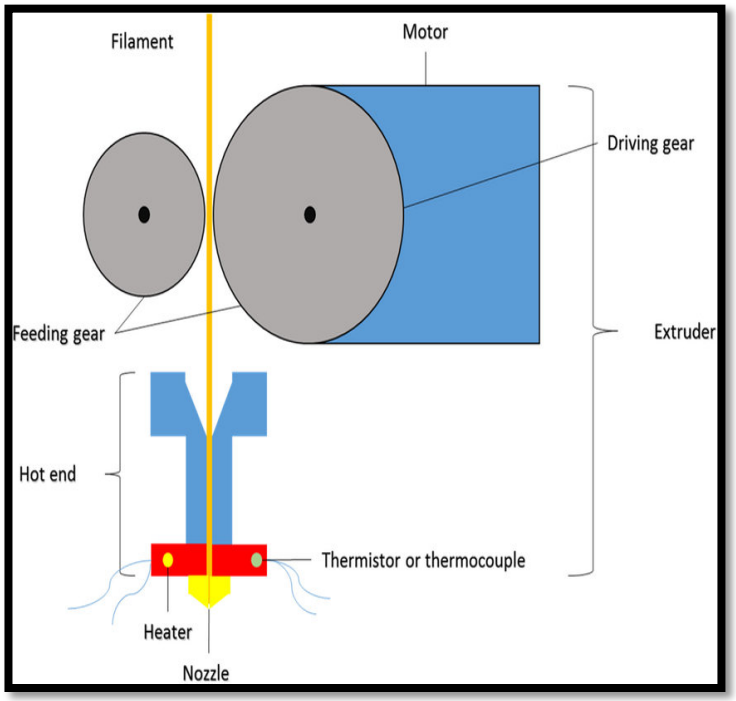
Novel technique of building 3 dimensional structures, made from polymer materials, polymer composites.

4 different types of 3D printing techniques

Construction of 3D polymer structures becomes rater easy by employing the 3D printing technology

Fused Deposition Modeling
3D printing process

Fused Deposition Modeling FDM process:



J. Zhang *et al.* International Journal of Pharmacheutics **519**, 186 (2017)

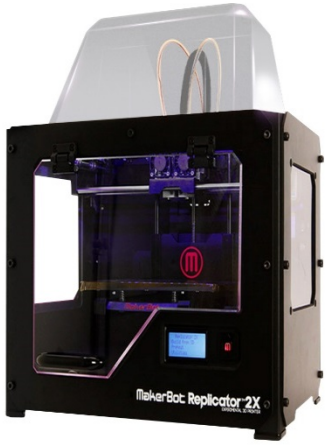
FDM advantages:

- ✓ Quick
- ✓ Low cost
- ✓ No chemicals are needed
- ✓ Ideal for 3D printing of polymers.
- ✓ Large samples

Disadvantages:

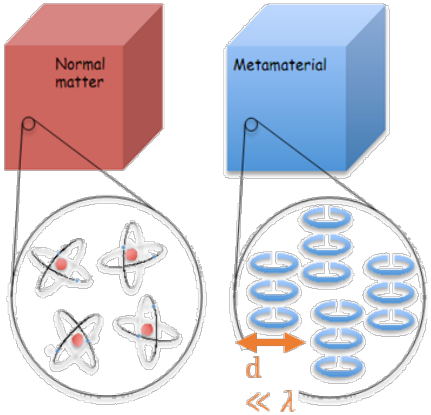
- Only polymers can be used
- Extruder Jams

From colorFabb BV website



Electromagnetic Metamaterials and Metasurfaces

Metamaterials/Metasurfaces Overview



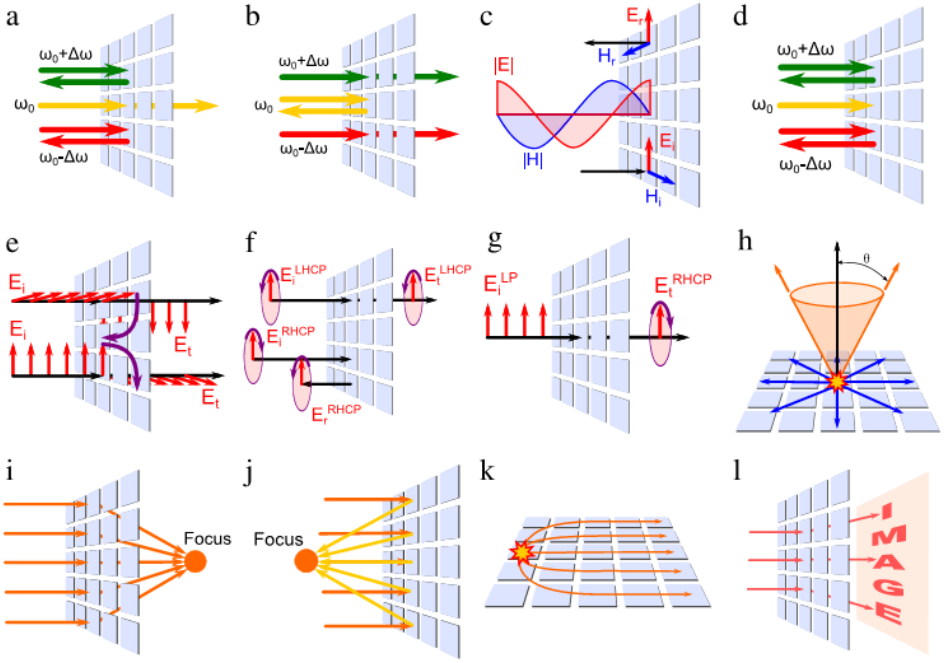
Metamaterials are artificial structures with **periodic subwavelength features**, which collectively behave as materials with **effective new properties**, e.g. ε_r and/or μ_r

- Meta-atom: Elementary "unit-cell
- Metasurface: 2D "sheet" metamaterial, typically thin planar layered composite

The modification of the metasurface local resonance provides the means of achieving exotic functions

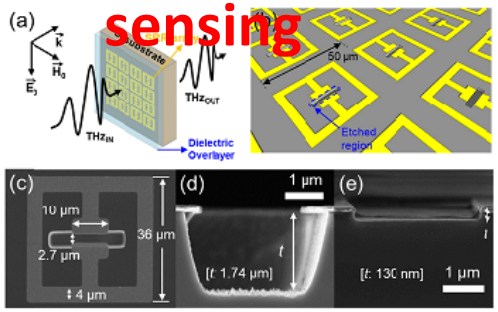
- band-pass/stop filters,
- perfect absorbers,
- polarizers,
- leaky-wave antennas,
- flat lenses

*S.B. Glybovski et al. / Physics Reports 634 (2016)

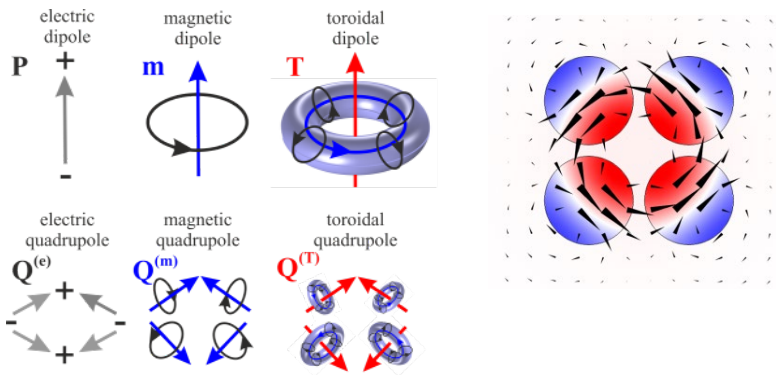


Metamaterials/Metasurfaces Overview

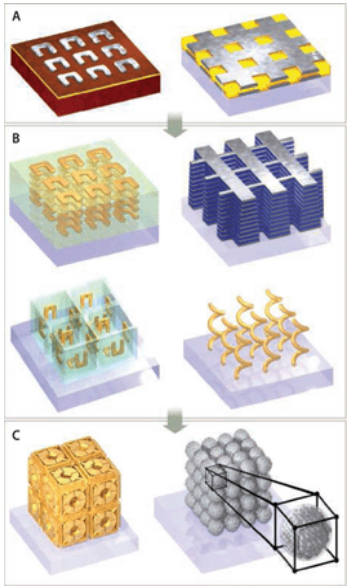
sensing



K. Meng, Optics Express 16 (27), 2019

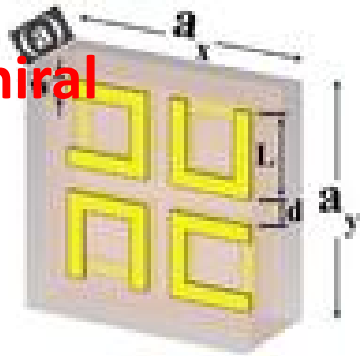


A.C. Tasolamprou, PRB 94 (20), 2016.



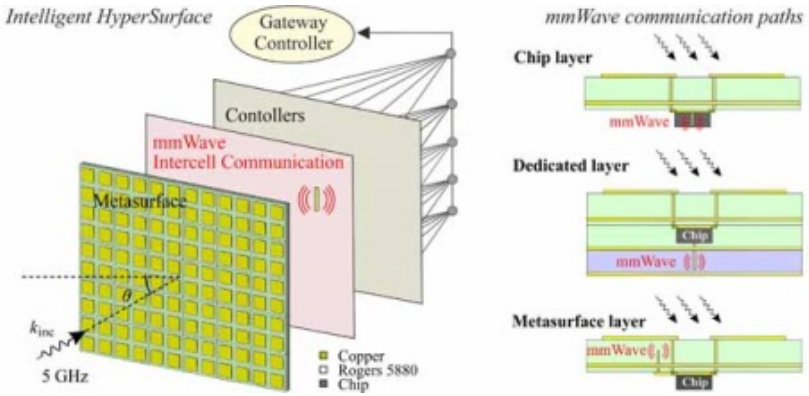
*C.M. Soukoulis, Science **330**, 1633, 2010*

chiral



G. Kenanakis, Optical Materials Express 2 (12), 1702-1712, 2012

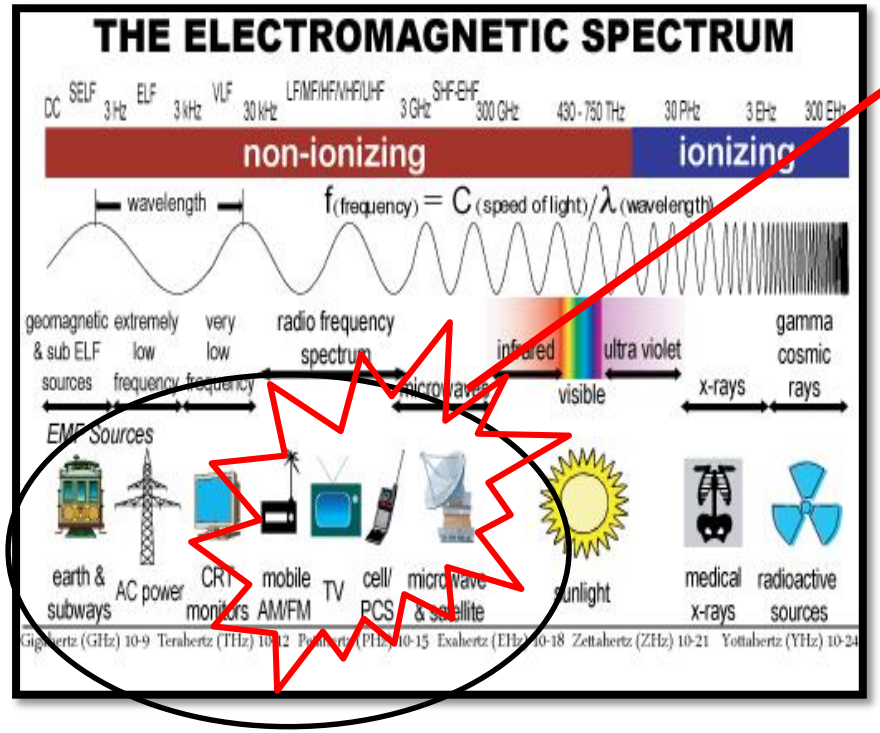
mm-scaled software defined



A.C. Tasolamprou, IEEE access 7, 122931-122948, 2019

Metamaterials/Metasurfaces for the microwave spectrum

Devices that could denefit from FDM printed components



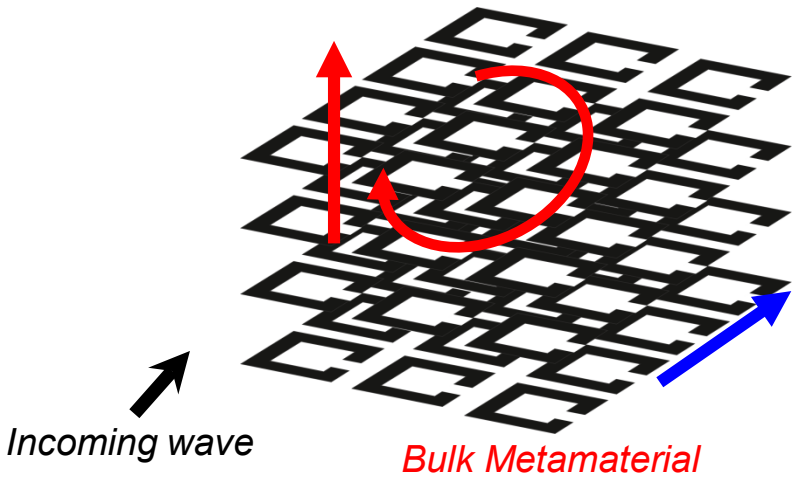
Every-day life use electronics

-Antennas
-Waveguides
-Filters
-Modulators
-Sensors
-Harvesters
and many more….

Split Ring Resonators

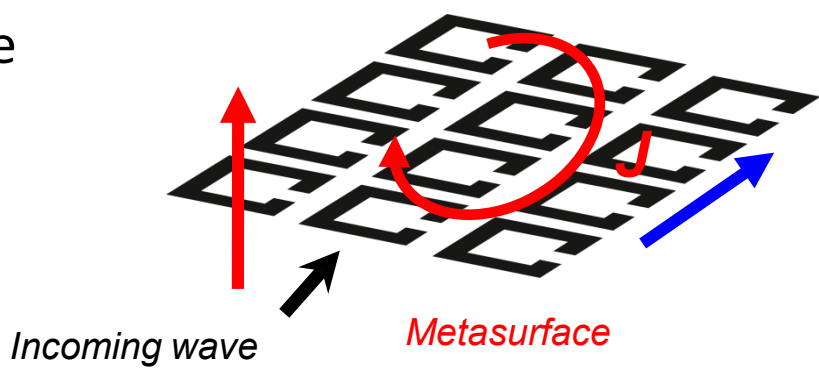
Principles of SRR e/m response

- The electric response in a SRR type of metamaterial is a results of the coupling of the electric field with the wire type modes.



- The magnetic response in a SRR type of metamaterial is a results of the coupling of the impinging waves and the infinite magnetic dipoles generated by the circulation of alternating currents.

Principle which applies also to the SRR metasurfaces



Main Idea

Conducting polymer composites (commercial) Polymer + **conductive** paint

+

FDM printing process

=

Effective mm units

Potential advantages:

1. Quick and easy production
2. Large scale production

Experimental Details: Materials

Commercially available polymer composites: ***No need to produce our own ones***

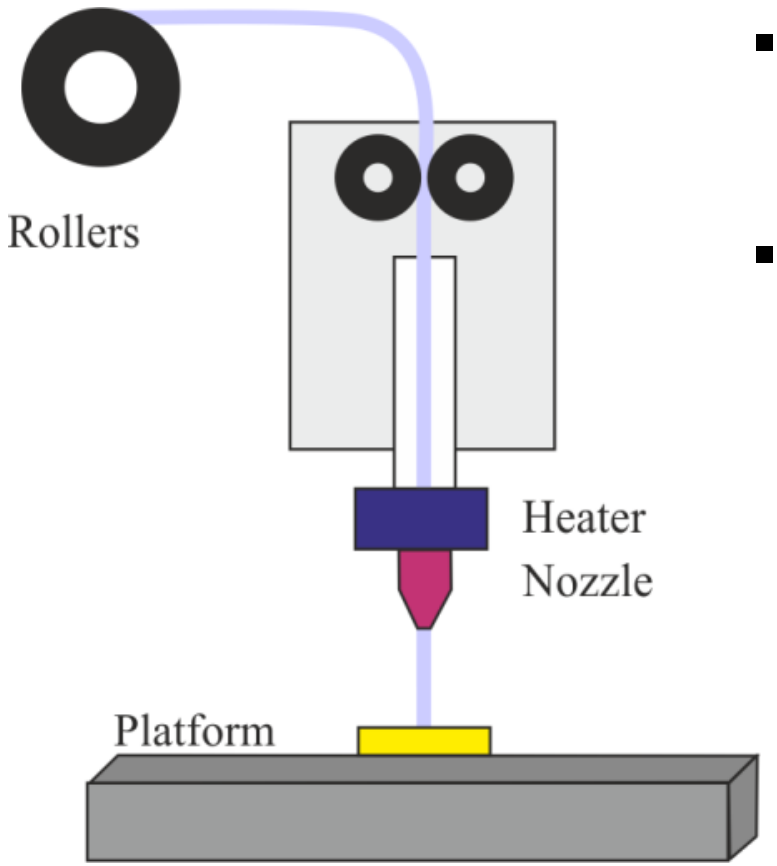
Acrylonitrile Butadiene Styrene
ABS
(Makerbot Industries)

ABS with carbon nanotubes 1% w/w
CNT-001
(3DXTECH)

Polylactic Acid (PLA) + graphite 2[illegible] w/w
CON-PLA
(Proto Pasta)

PLA + graphene 15% w/w
CON-GRA
(BlackMagic 3D)

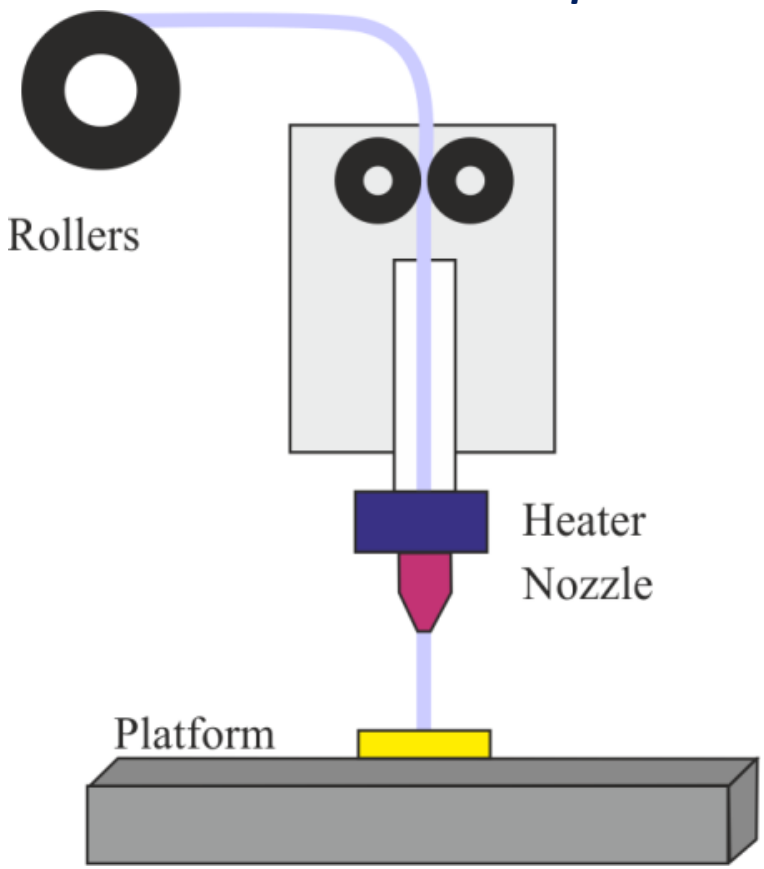
Experimental Details: Samples Produced



Filaments:

- Polylactic acid (PLA) filament painted over with conductive silver epoxy.
- Commercially available filament known as Electrify. A Polyvinylidene chloride (PVDC) matrix, in which copper (Cu) nanoparticles are included in a weight ratio 20% thus the electrical transport properties.

Experimental Details: Samples Produced



Samples in the mm

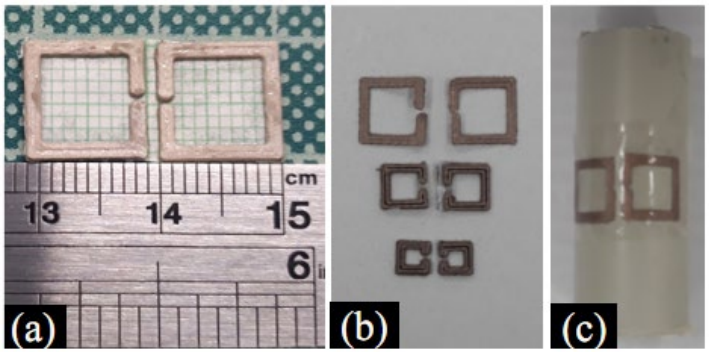
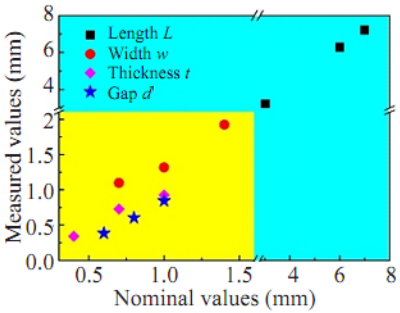


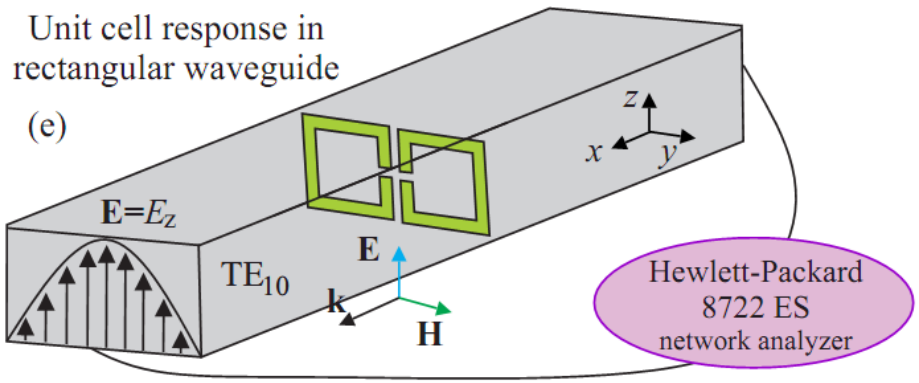
TABLE I
PRINTING CONDITIONS FOR PLA AND ELECTRICFY FILAMENTS

Printing Conditions	PLA	Electrify
Filament Diameter	1.75 mm	1.75 mm
Filament Conductivity	0	10^4 S/m
Nozzle Diameter	0.4 mm	0.4 mm
Nozzle Temperature	230°C	140°C
Printing bed temperature	110°C	Room temperature
Printing speed	25 mm/sec	15 mm/sec

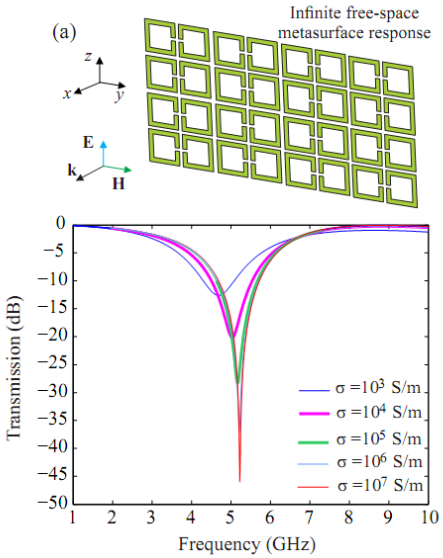
Deviation between design and fabrication



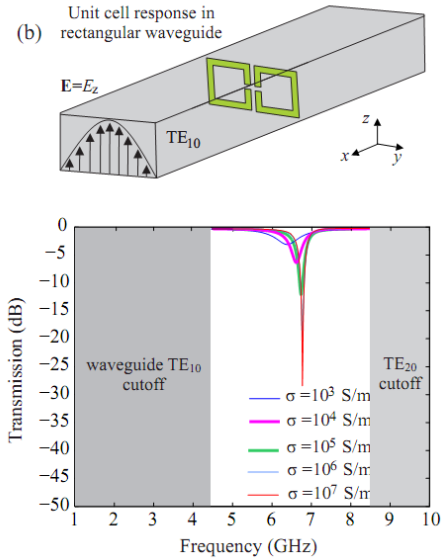
Experimental Details: Characterization



-Sharper resonances
-Lower frequencies



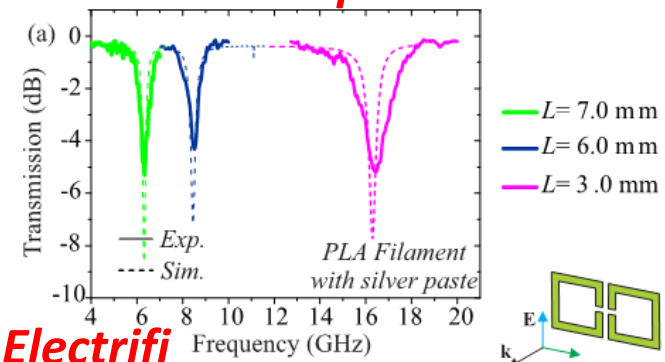
VS



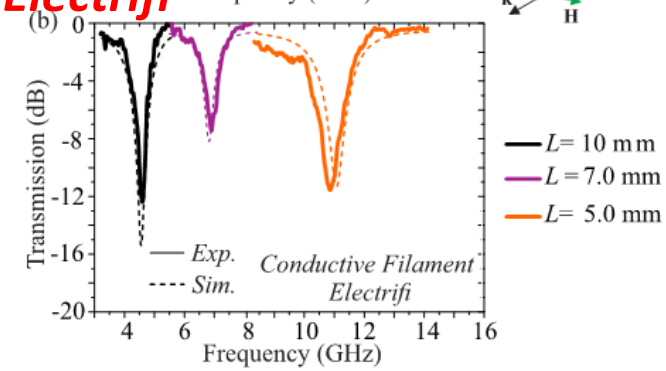
-Lower Q factor
-Higher frequencies

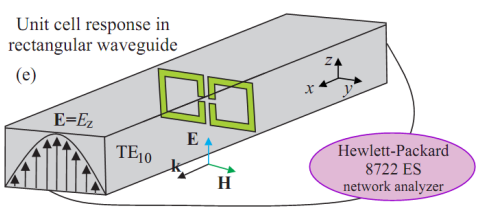
Experimental Details: Characterization

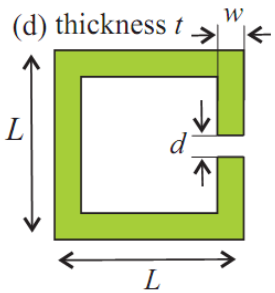
PLA with silver paste

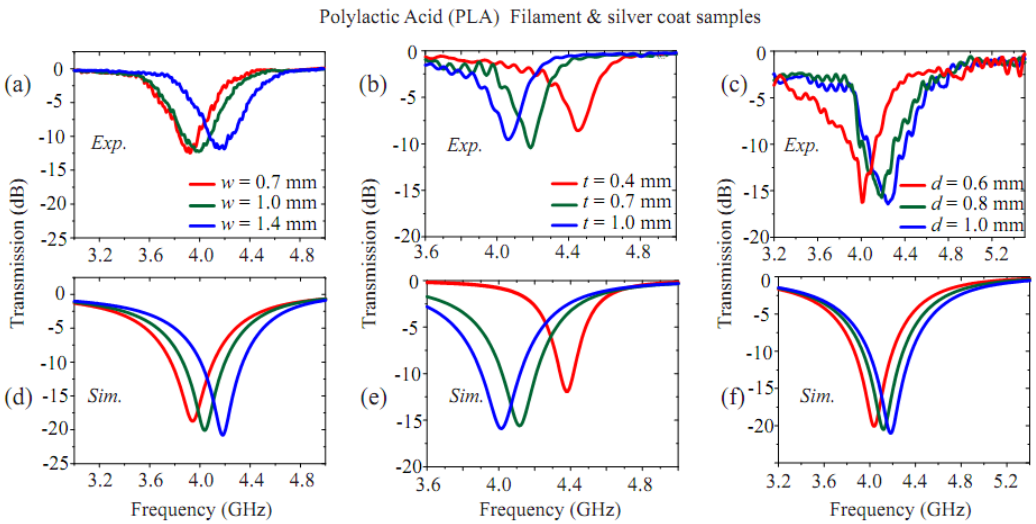


Electrifi



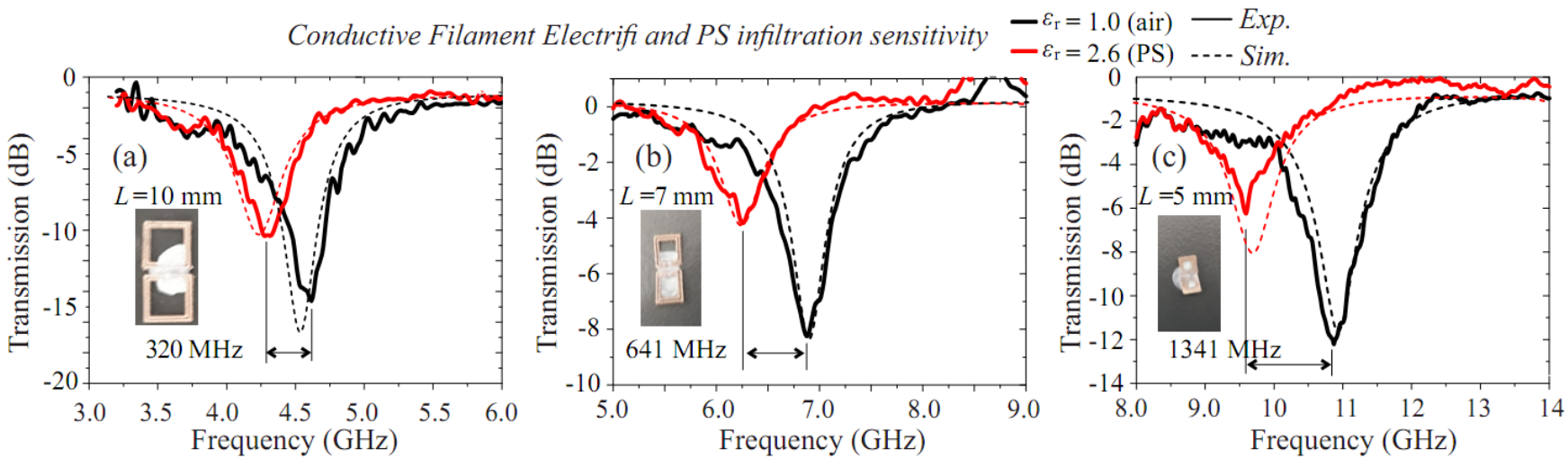






Characterization of the geometrical parameters effect on the metasurface response

Experimental Details: Sensing Function



- A droplet of polysterene (PS), diluted in toluene
- The toluene is evaporated, the PS is solidified into the SRR gap

✓ **The resonance shifts**

More information….

Open Access Article

Flexible 3D Printed Conductive Metamaterial Units for Electromagnetic Applications in Microwaves

by Anna C. Tasolamprou [1,*], Despoina Mentzaki [1,2], Zacharias Viskadourakis [1], Eleftherios N. Economou [1,3], Maria Kafesaki [1,2] and George Kenanakis [1]

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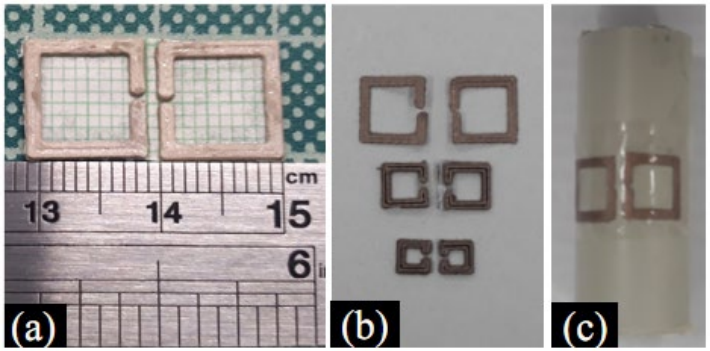
Conclusion

- ✓ Cost-effective, eco-friendly and accessible method
- ✓ Ultralight and flexible millimeter-scale metasurfaces using a household 3D printer
- ✓ Well defined resonances dependent on the geometrical parameters/infiltrating dielectric materials similar to those obtained for traditional PCB
- ✓ Electromagnetic components and fabrics for coating a plethora of devices and infrastructure units of different shapes and size.



Publications on 3D printing

Appl. Phys. A (2017) 123:736
DOI 10.1007/s00339-017-1353-z
Applied Physics A
Materials Science & Processing

Electromagnetic shielding effectiveness of 3D printed polymer composites

Z. Viskadourakis[1] · K. C. Vasilopoulos[1] · E. N. Economou[1] · C. M. Soukoulis[1,2] · G. Kenanakis[1]

Appl. Phys. A **123**, 736 (2017)

Appl. Phys. A (2016)122:802
DOI 10.1007/s00339-016-0338-7
Applied Physics A
Materials Science & Processing

Electromagnetic shielding effectiveness and mechanical properties of graphite-based polymeric films

G. Kenanakis[1] · K. C. Vasilopoulos[1] · Z. Viskadourakis[2] · N.-M. Barkoula[3] · S. H. Anastasiadis[1,4] · M. Kafesaki[1,5] · E. N. Economou[1] · C. M. Soukoulis[1,6]

Appl. Phys. A **122**, 802 (2016)

Applied Physics A (2019) 125:159
https://doi.org/10.1007/s00339-019-2469-0
Applied Physics A
Materials Science & Processing

Transport properties of 3D printed polymer nanocomposites for potential thermoelectric applications

Z. Viskadourakis[1] · G. Perrakis[1,2] · E. Symeou[3] · J. Giapintzakis[3] · G. Kenanakis[1]

Appl. Phys. A **124**, 159 (2019)

Applied Physics A (2018) 124:585
https://doi.org/10.1007/s00339-018-2014-6
Applied Physics A
Materials Science & Processing

3D structured nanocomposites by FDM process: a novel approach for large-scale photocatalytic applications

Z. Viskadourakis[1] · M. Sevastaki[1,2] · G. Kenanakis[1]

Appl. Phys. A **124**, 585 (2018)

Appl. Phys. A (2017) 123:623
DOI 10.1007/s00339-017-1238-1
Applied Physics A
Materials Science & Processing

3D printed graphene-based electrodes with high electrochemical performance

D. Vernardou[1] · K. C. Vasilopoulos[2] · G. Kenanakis[2]

Appl. Phys. A **123**, 623 (2017)

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European Union
European Structural and Investment Fund

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MINISTRY OF ECONOMY & DEVELOPMENT
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MANAGING AUTHORITY OF EPAnEK

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Partnership Agreement 2014 - 2020

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