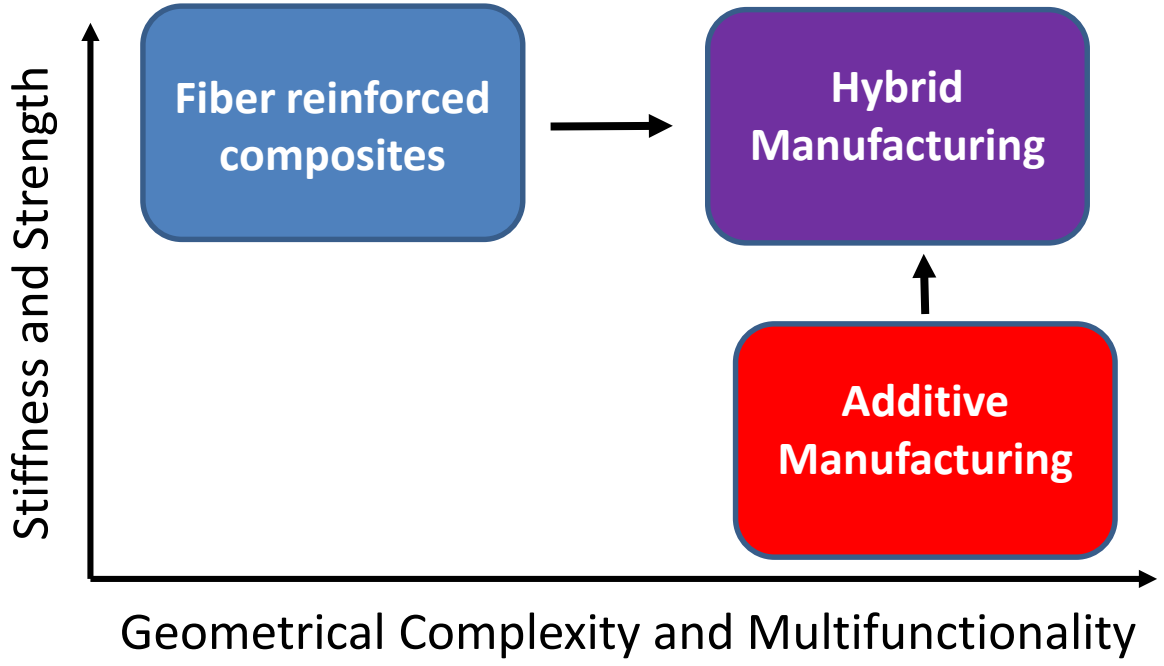
Hybrid Manufacturing of Multifunctional Composites

- The principal goal of this program are to explore hybrid manufacturing methods that combine traditional composites with emerging additive manufacturing (AM) technologies for the integration of electromagnetic functionality within a structural composite.

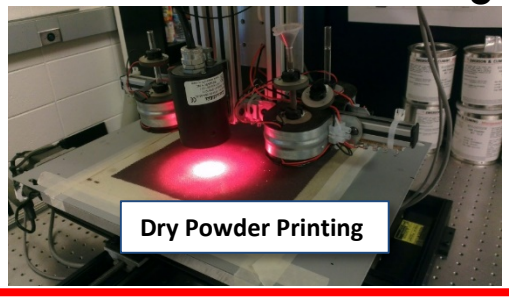


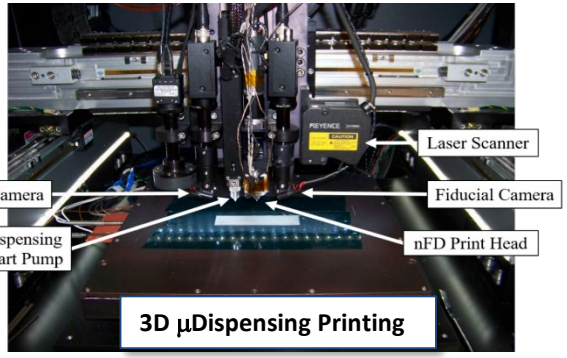
Hybrid Manufacturing of Multifunctional Composites

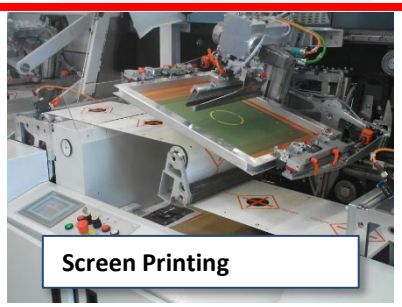
- The specific objectives of this effort include;
  - Development of new EM functionalized materials suitable for AM printing.
  - Development of new AM fabrication processes
  - Exploring new application spaces

Manufacturing Methods

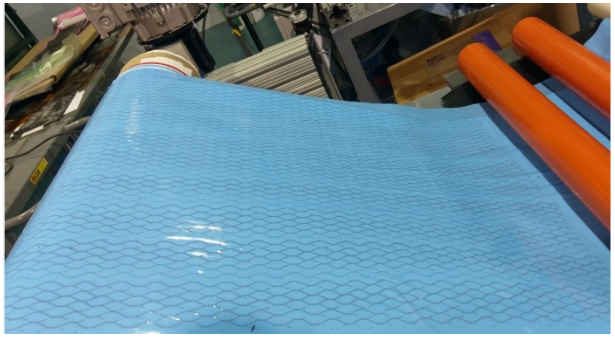
3D Additive Manufacturing







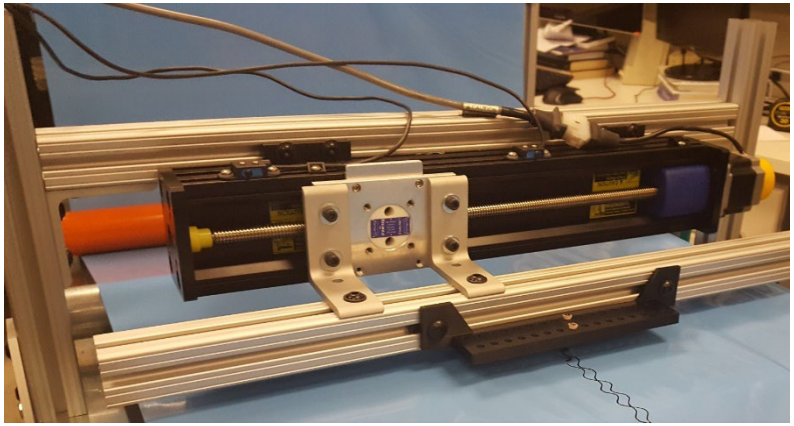
Full Scale Composite Manufacturing



Multifunctional Composites Additive Manufacturing

Scalable manufacturing process for printing of functional inks within a structural composite

Goal is to develop a scalable manufacturing process to fabricate structural composites with interesting electromagnetic properties

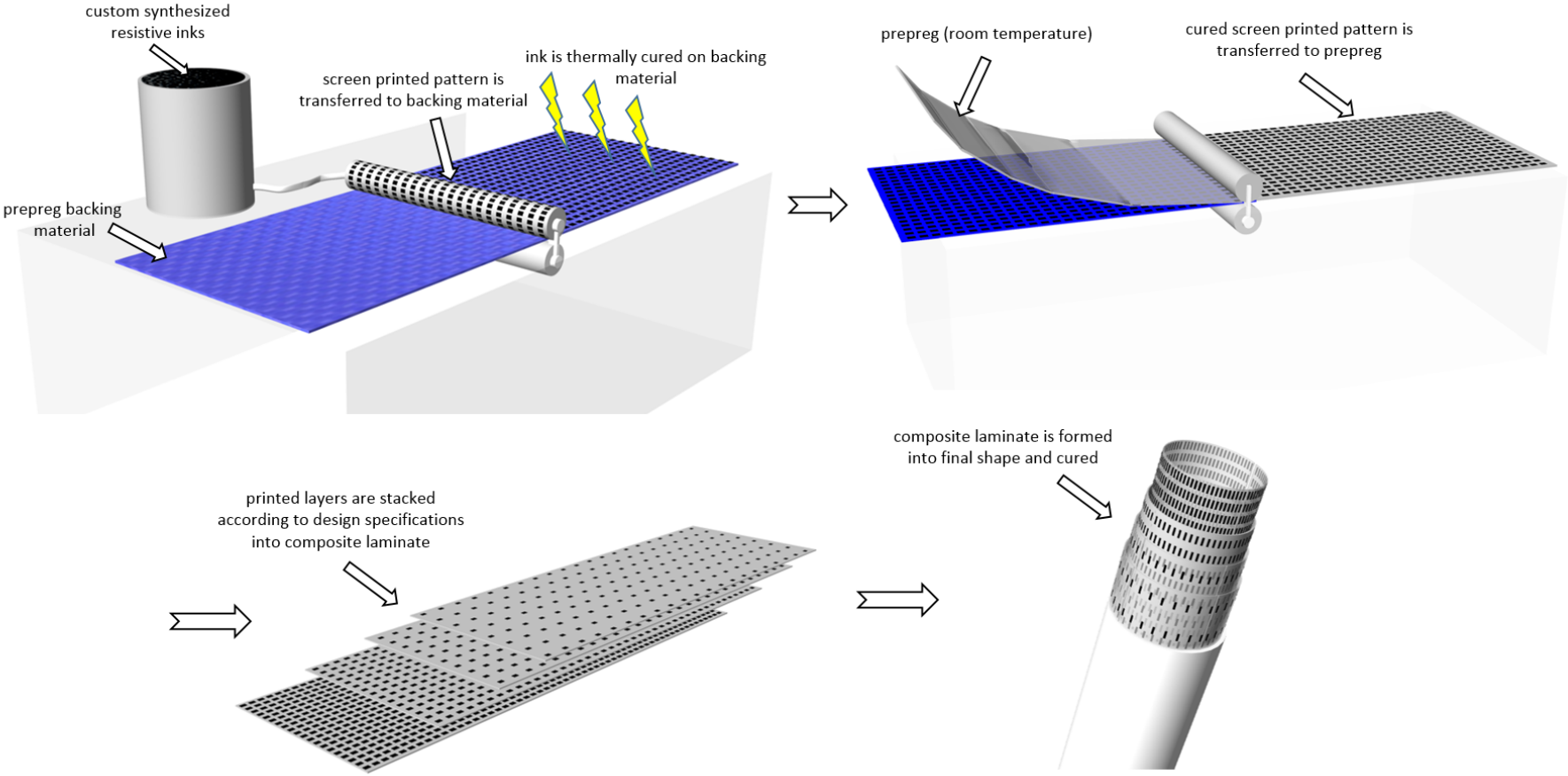


Desirable Process Properties

- ❑ Good repeatability from sample to sample
- ❑ Roll-to-roll printing for scalability
- ❑ Applicable to standard composite prepreg materials that have been Navy certified
- ❑ Should NOT require any significant change to the standard composite manufacturing processes
- ❑ Should NOT adversely affect the structural in any significant way.

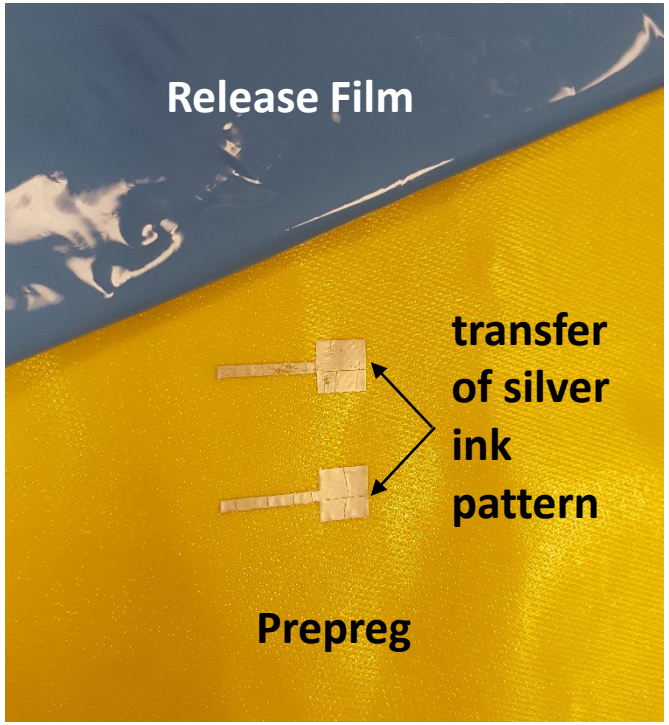
Scalable manufacturing process for printing of functional inks within a structural composite

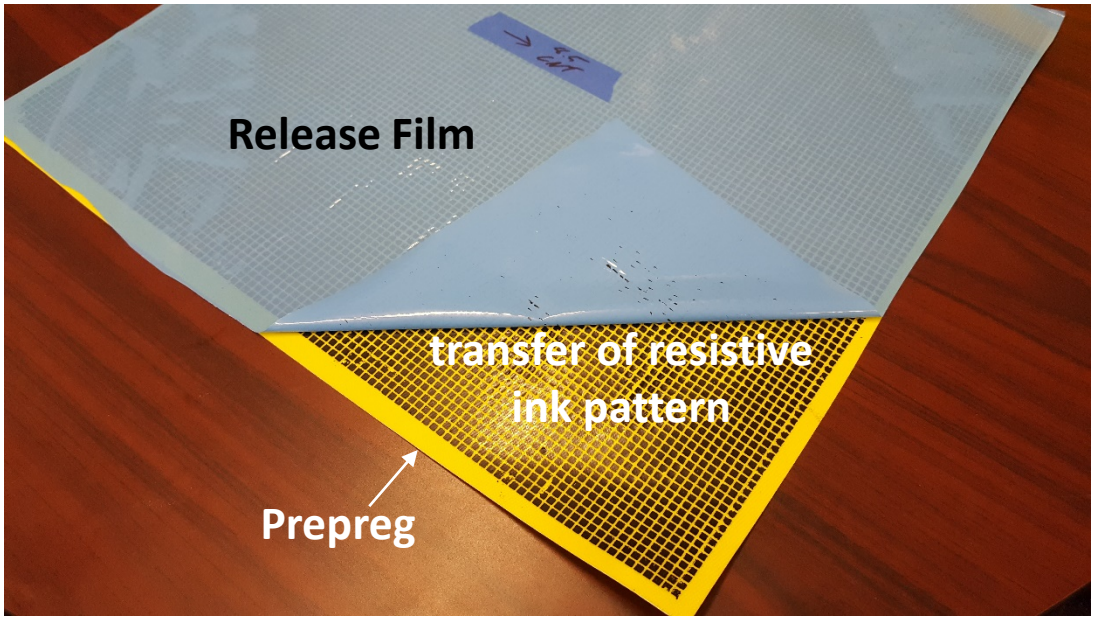
Release Film Transfer Patterning (RF-TraP)



Scalable manufacturing process for printing of functional inks within a structural composite

Release Film Transfer Patterning (RF-TraP)

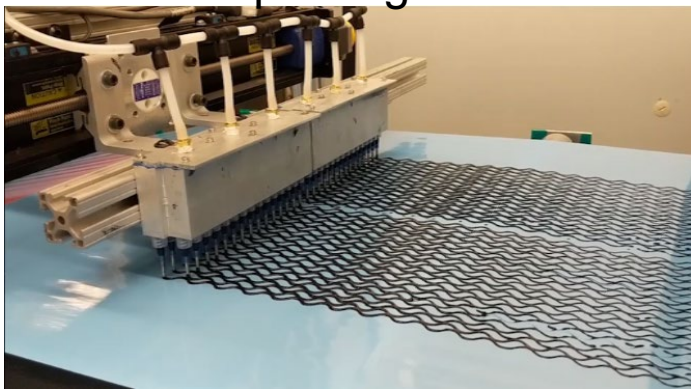


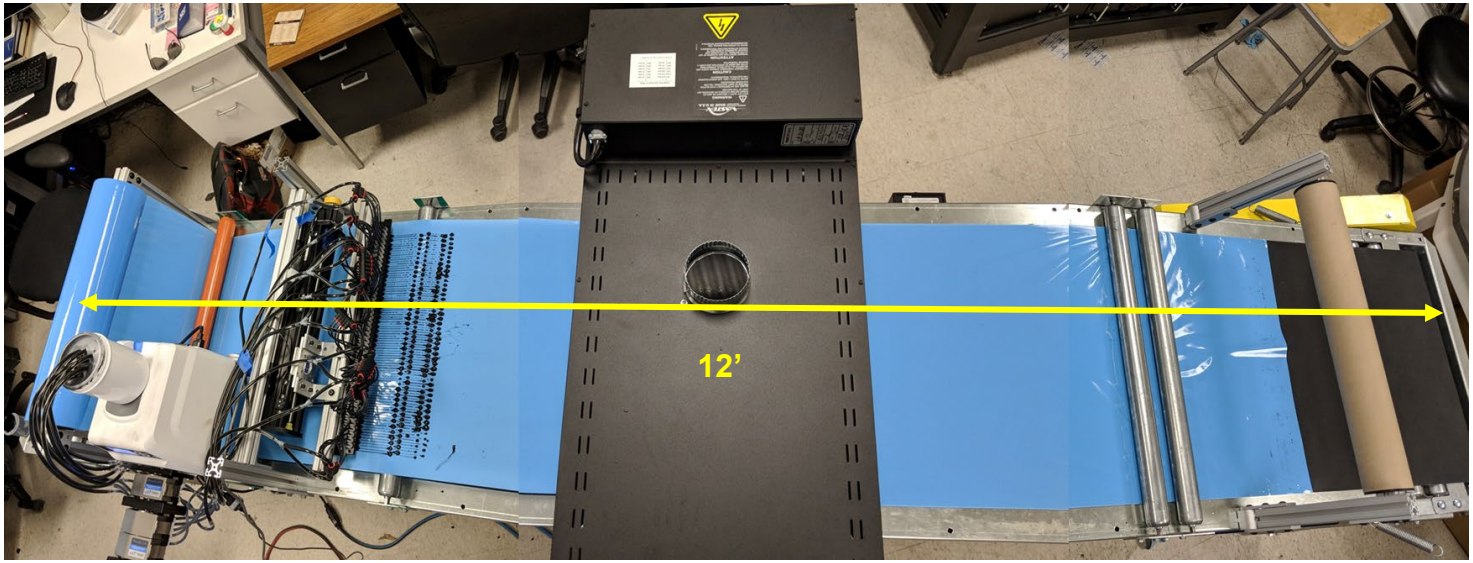


Scalable manufacturing process for printing of functional inks within a structural composite

Printing Step

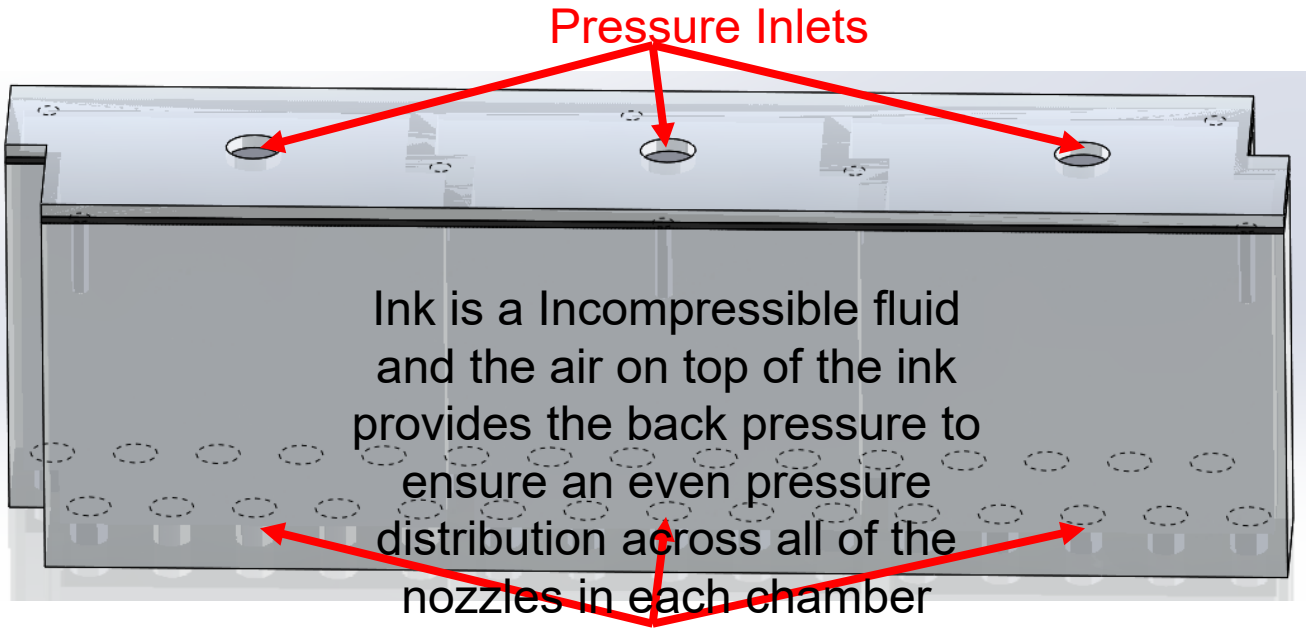
New printing method





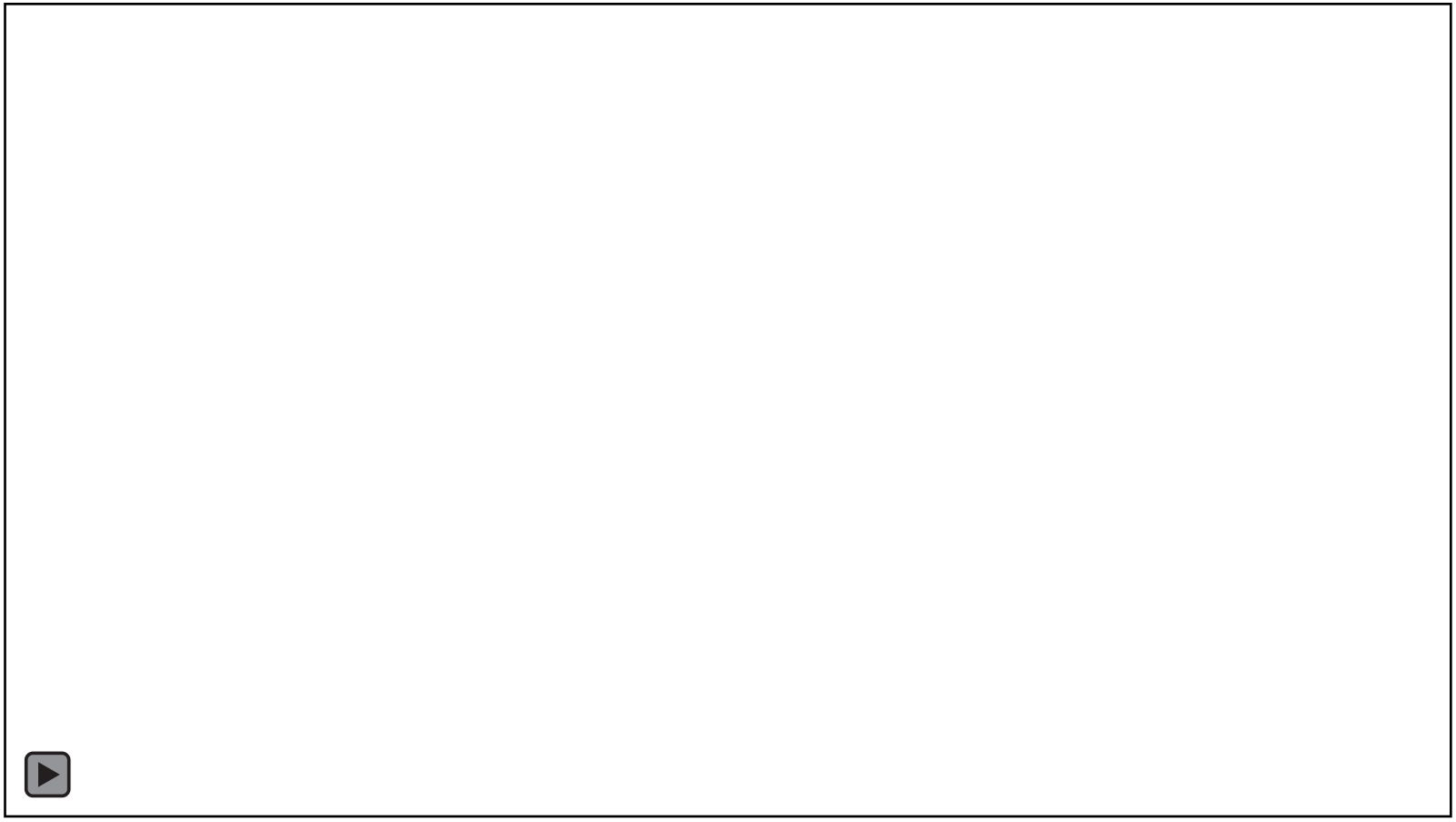
Scalable manufacturing process for printing of functional inks within a structural composite

New Nozzle Design



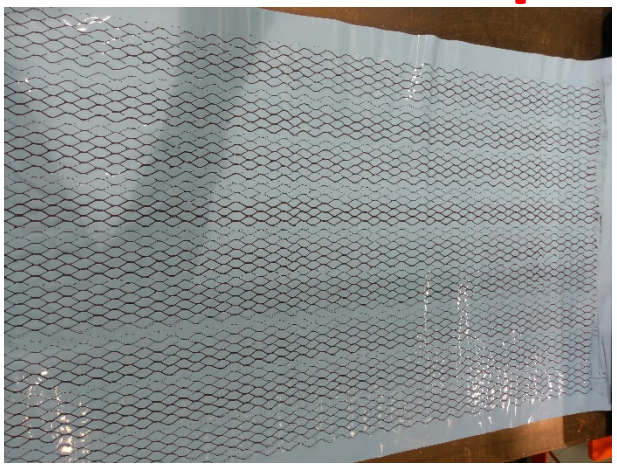
Scalable manufacturing process for printing of functional inks within a structural composite

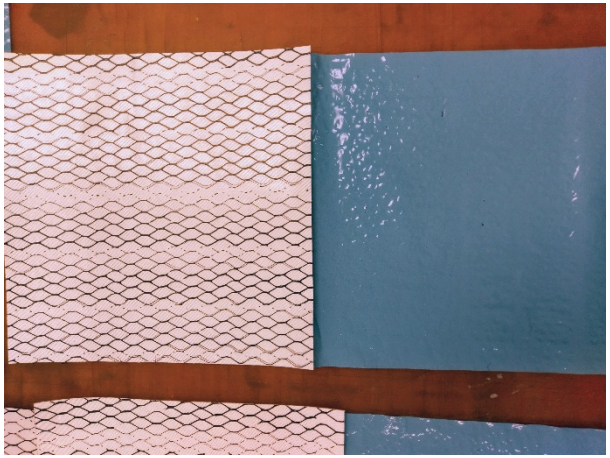
Transfer Step

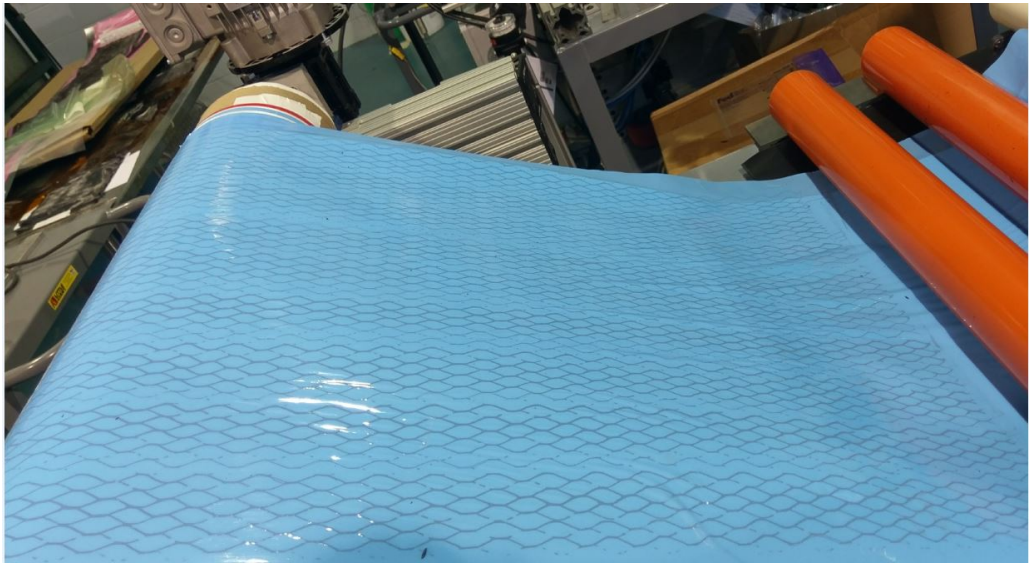


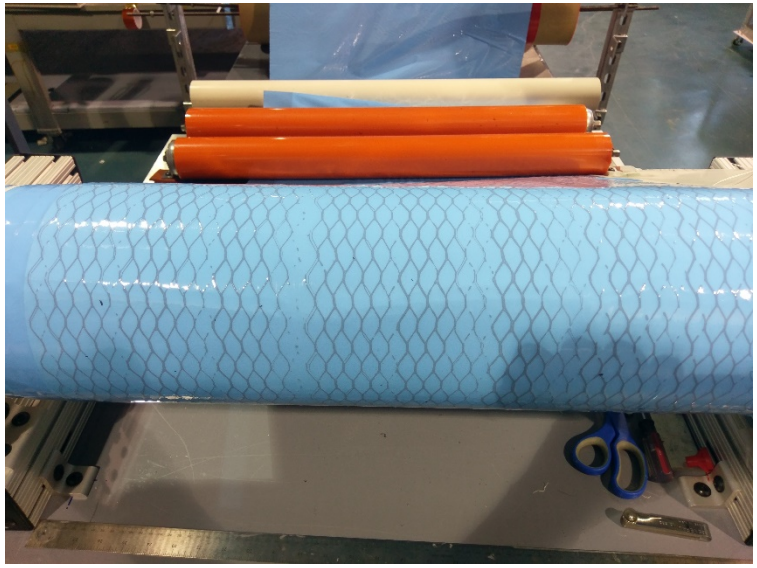
Scalable manufacturing process for printing of functional inks within a structural composite

Transfer Step





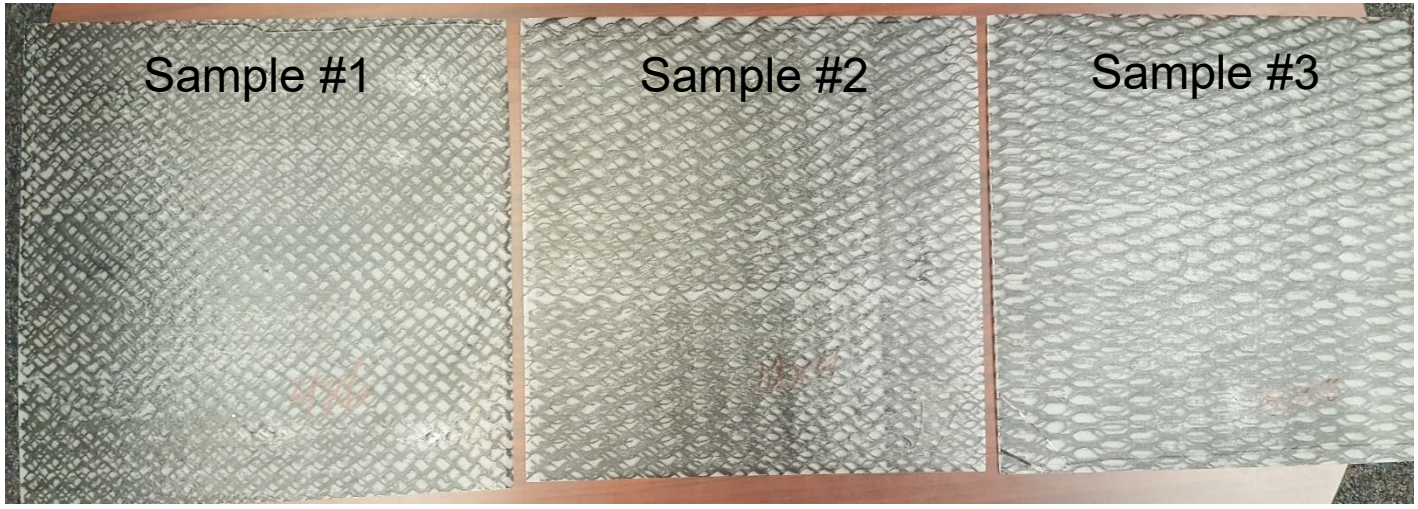




Scalable manufacturing process for printing of functional inks within a structural composite

Composite Post-Processing

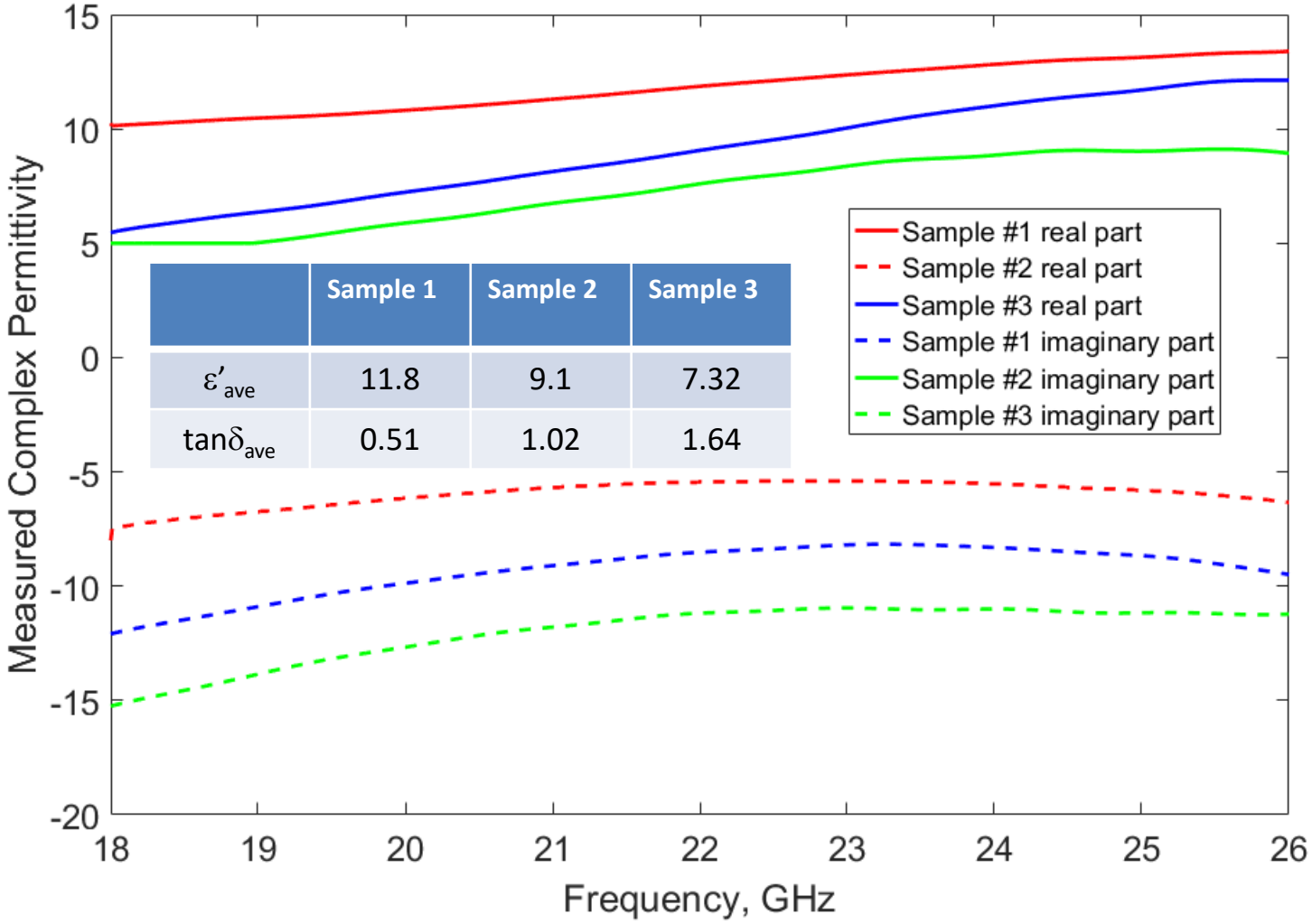
- 5 printed layer stack using E-glass/epoxy
- Each layer rotated 0/90 to remove polarization dependence)
- 3 samples of various print head speed and conveyor speed (ink pressure was constant)



Scalable manufacturing process for printing of functional inks within a structural composite

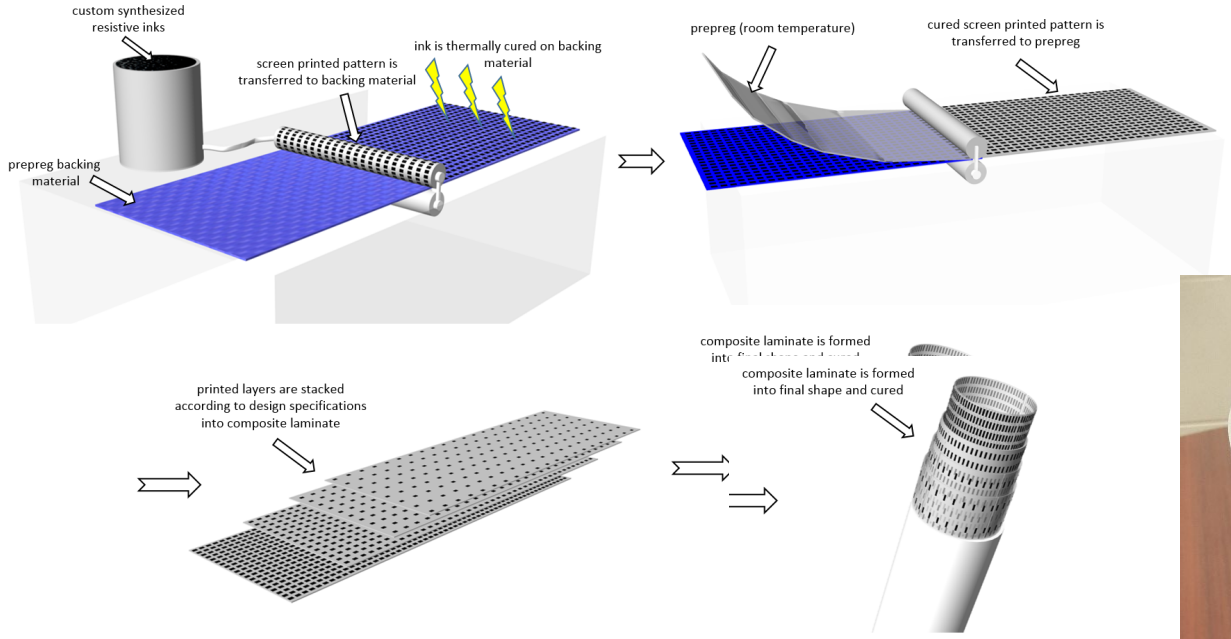
Measured Results

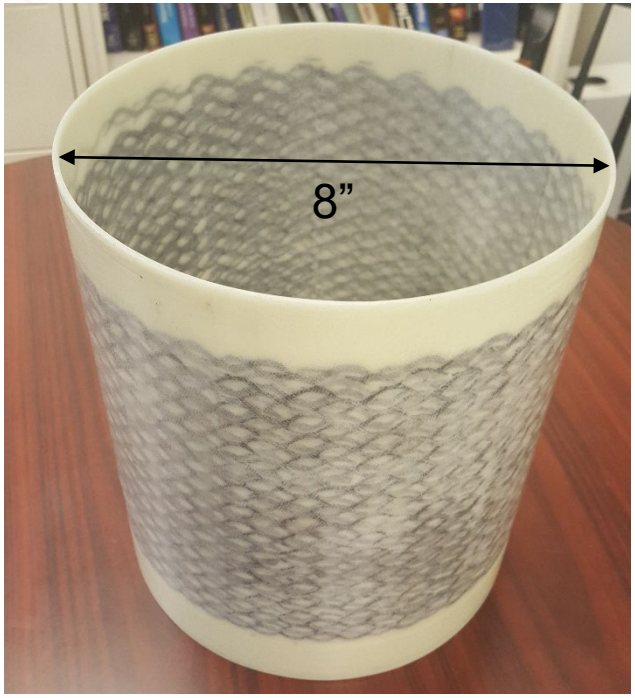
	Sample 1	Sample 2	Sample 3
ε'_{ave}	11.8	9.1	7.32
$\tan\delta_{ave}$	0.51	1.02	1.64



Scalable manufacturing process for printing of functional inks within a structural composite

Non-planar Geometry





- Three printed layer stack using E-glass/epoxy
- Single unprinted layer on inside and on the outside
- Goal was to determine if the transferred ink pattern maintained its geometry in non-planar configurations.

Manufacturing approach for integration of metasurfaces within a structural composite

Concept

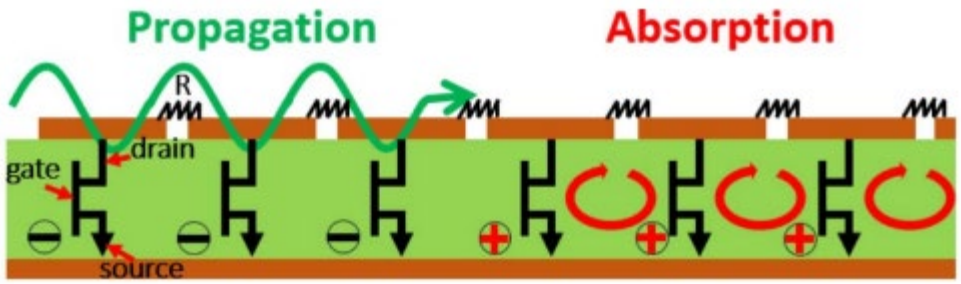
Metasurface "circuit"

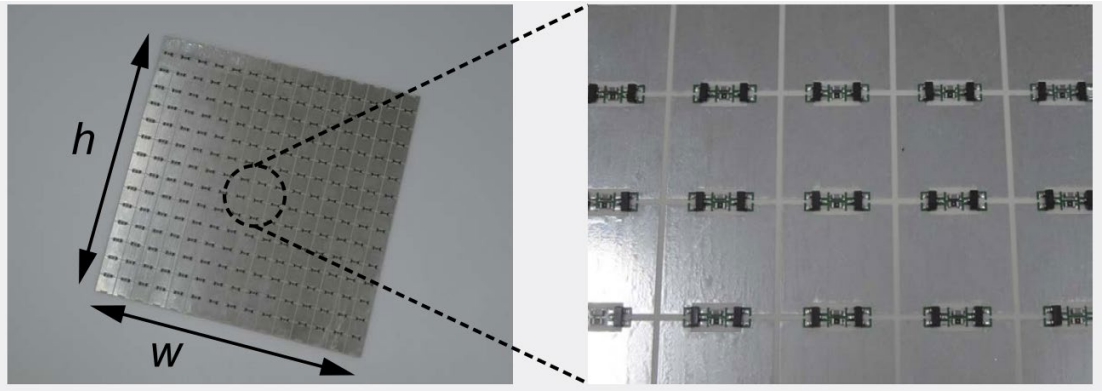
Physical realization

2810 IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, VOL. 65, NO. 8, AUGUST 2017

High-Power Transistor-Based Tunable and Switchable Metasurface Absorber

Aobo Li, *Student Member, IEEE*, Sanghoon Kim, *Student Member, IEEE*, Yong Luo, Yunbo Li, Jiang Long, *Member, IEEE*, and Daniel F. Sievenpiper, *Fellow, IEEE*





Manufacturing approach for integration of metasurfaces within a structural composite

Concept

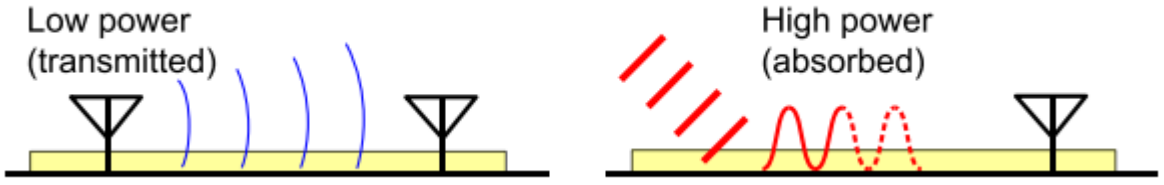
Metasurface "circuit"

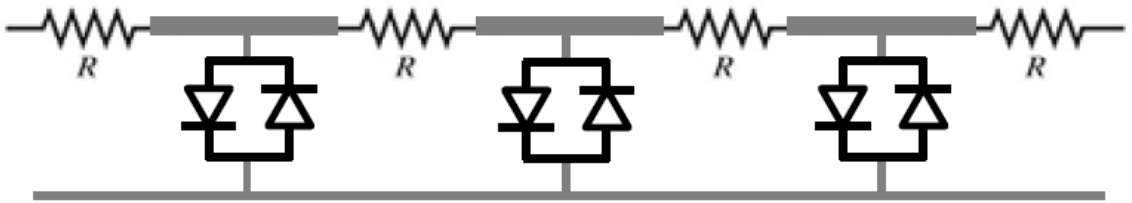
Physical realization

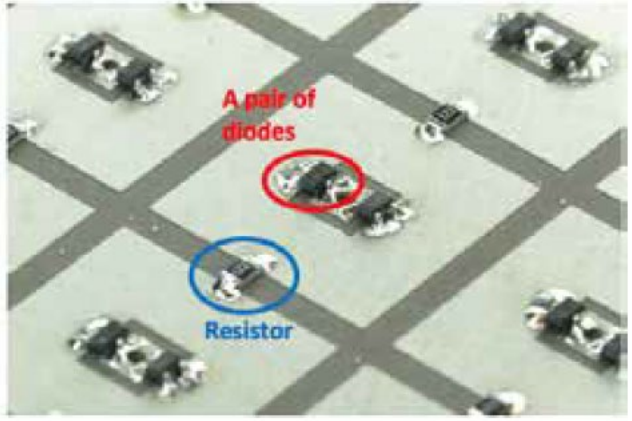
APPLIED PHYSICS LETTERS **102**, 214103 (2013)

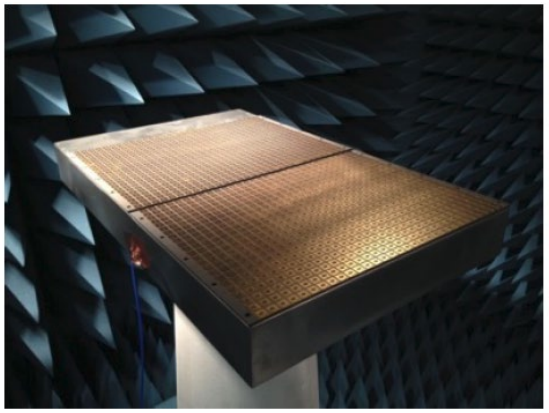
Circuit-based nonlinear metasurface absorbers for high power surface currents

Hiroki Wakatsuchi,[a] Sanghoon Kim, Jeremiah J. Rushton, and Daniel F. Sievenpiper[b]
Applied Electromagnetics Group, Electrical and Computer Engineering Department, University of California, San Diego, California 92093, USA



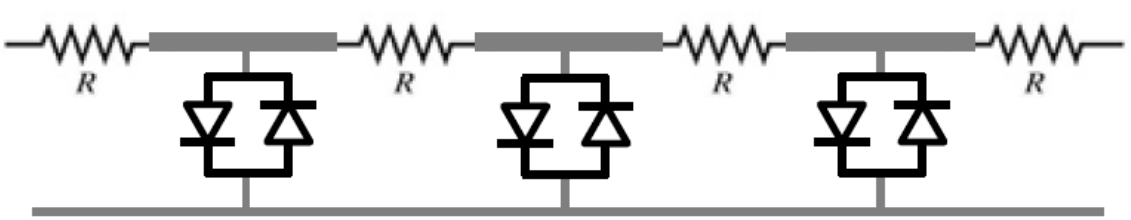




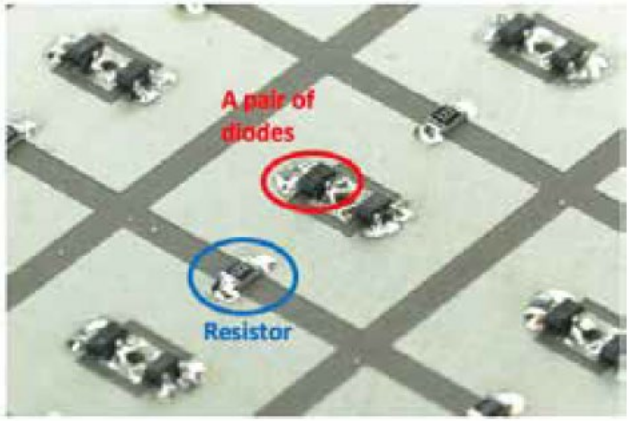


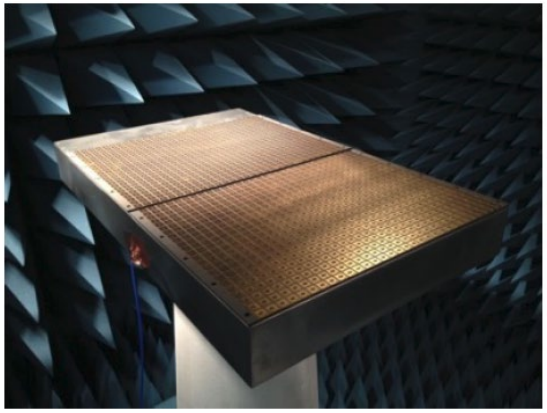
Manufacturing approach for integration of metasurfaces within a structural composite

Metasurface "circuit"



Standard lithography





AM on composite prepreg