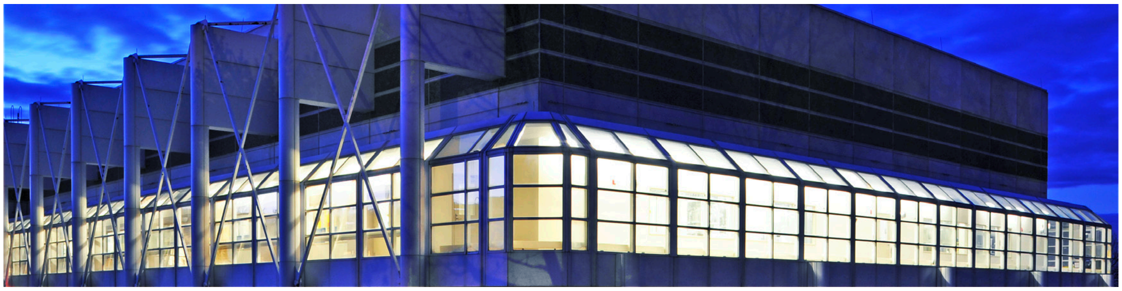
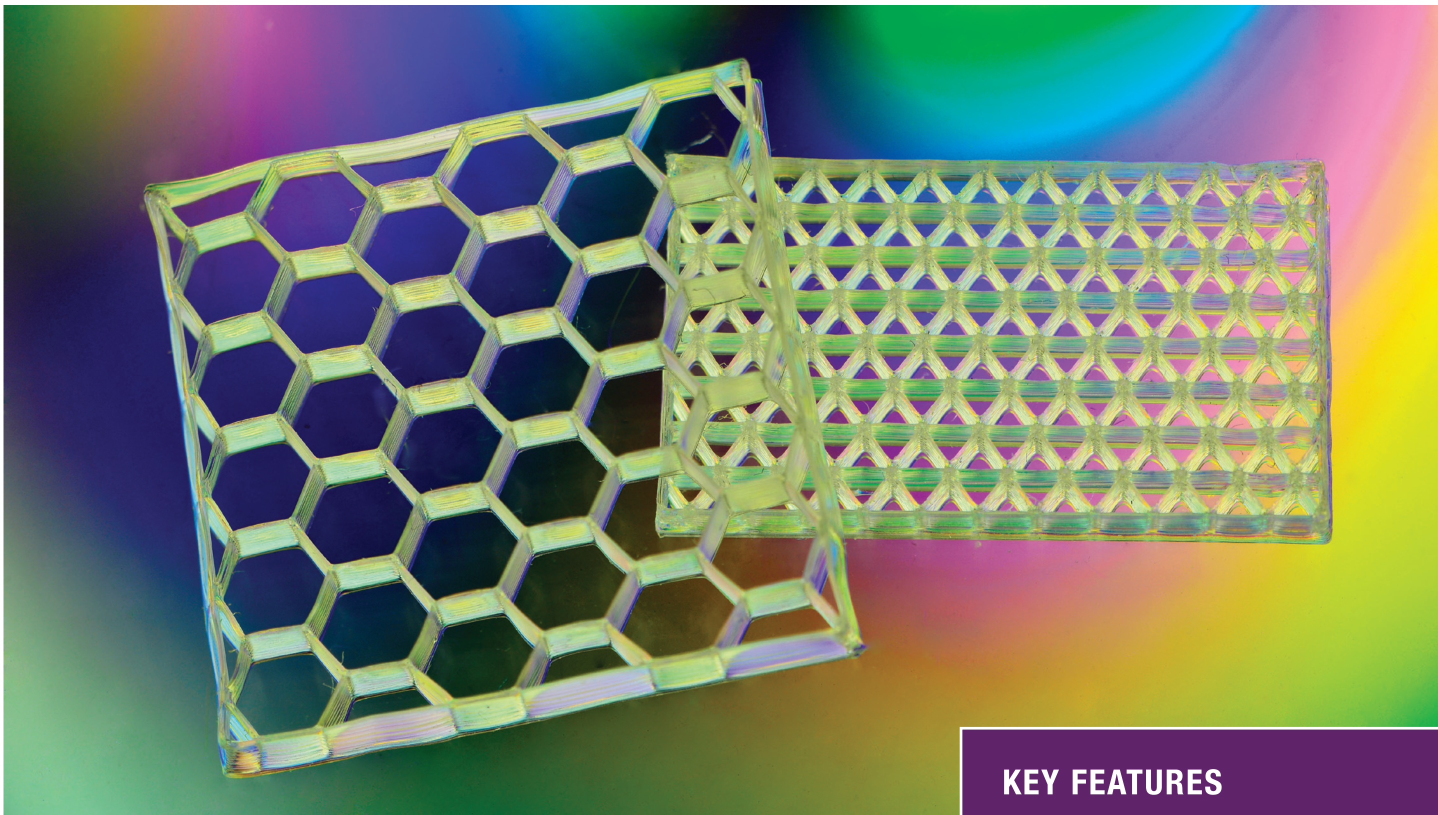


SPOTLIGHT ON

3D Printing of RF Materials

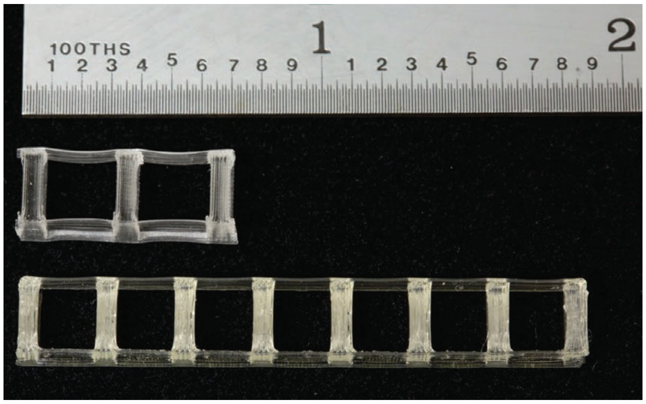


Hybrid dielectric test structure.

Lincoln Laboratory has developed a styrenic triblock copolymer material and a high-dielectric-constant material for 3D printing of small components used in high-bandwidth communication systems that operate in the K_a radio frequency band. This band is an attractive alternative to the more commonly used lower-frequency band because its shorter wavelength enables the use of small, lightweight components. High-resolution 3D printing of components can replace laborious traditional machining.

KEY FEATURES

- 3D-printed low-loss polymeric dielectric test devices with measured RF performance identical to that predicted by simulation. Dielectric ($e' = 2.3–2.6$) and loss ($e''/e' = 0.5–2.0 \times 10^{-3}$) measured at K_a band (26.5–40 GHz)
- Hybrid dielectric test structure composed of 41 vol % aluminum oxide with increased permittivity ($e' = 4.6$) and low loss ($e''/e' = 1.0–3.0 \times 10^{-3}$)

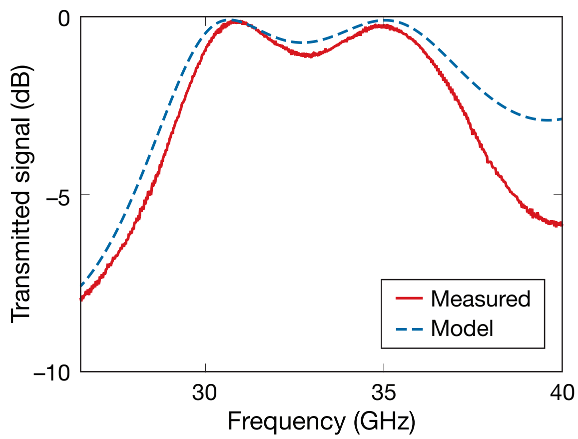


(a)

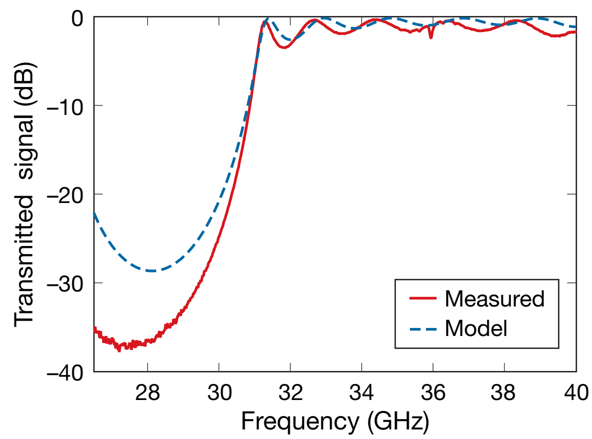
Styrenic Triblock Copolymer Material

The 3D-printable inks made from styrenic triblock copolymers demonstrated resolution down to 10 μm. To reduce objects' shrinkage resulting from solvent evaporation, we replaced aromatic solvents with monomers, which are then cross-linked using ultraviolet light during printing. Measurements of the dielectric properties of printed objects, made across the K_a band, established the copolymers' viability as low-loss dielectric materials. To demonstrate the utility of these printable inks, we created simple waveguide resonator filters and a lens, and measured their ability to achieve the required RF performance. Styrenic triblock copolymers, containing polystyrene end blocks and an aliphatic midblock, can have various commercial uses.

Printed filter devices. (a) Three- and eight-block filter devices printed from copolymer inks. (b) Transmission of the three-block filter device. (c) Transmission of the eight-block filter device. The blue dotted lines are the predicted responses, and the red solid lines are the actual measurements.



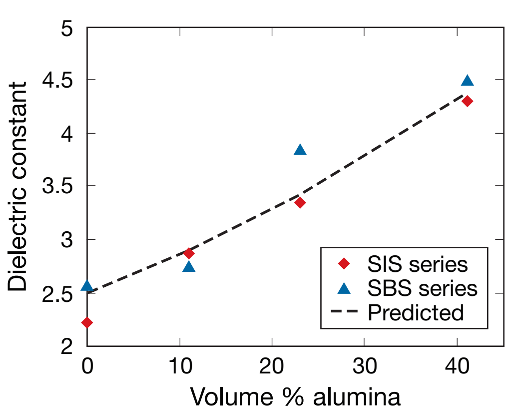
(b)



(c)

Ceramic-Polymer Hybrid Materials

Lincoln Laboratory also demonstrated a 3D-printable dielectric nanocomposite. Alumina nanoparticles were combined with styrenic block copolymers and solvent to create printable inks. Particle loadings of up to 41 vol % were achieved. After drying, the highest-performing of these materials has a permittivity of 4.6 and a loss tangent of 0.003 in the K_a band. These nanocomposite materials were used to print a simple resonator device with predictable pass-band features.



Experimental measurement of the dielectric constant as a function of alumina content is shown. The dielectric constant can be predicted by employing the Lichtenecker equation.

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