Increased Flexibility in Polyimide Aerogel Substrates for Conformal, Lightweight Antennas

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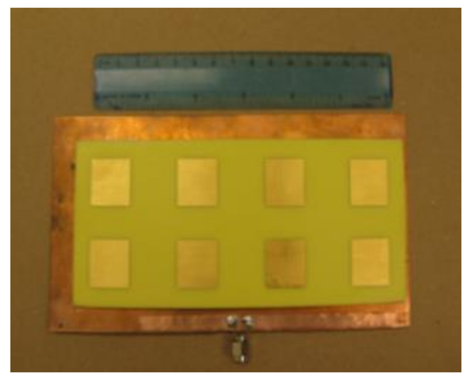
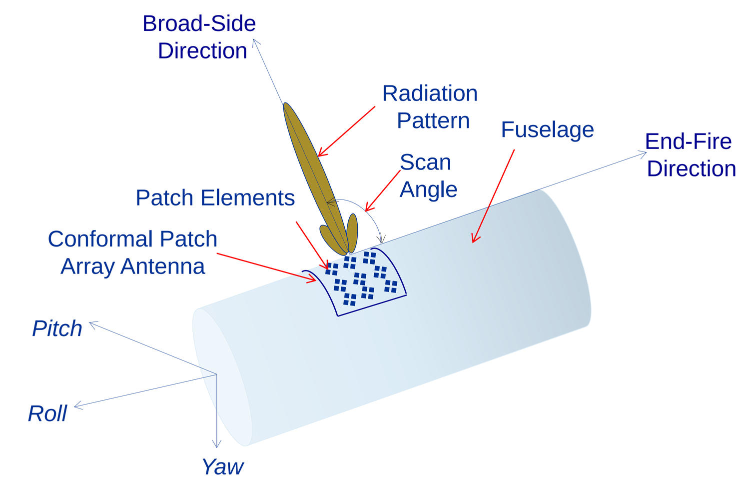
Introduction

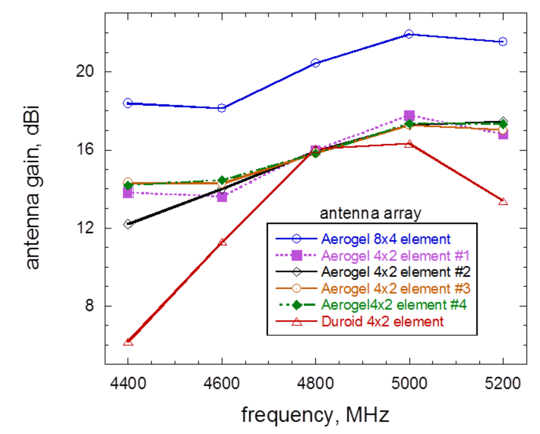
Polyimide aerogels are very lightweight materials made by extracting the liquid portion of a wet gel and replacing it with a gas. They are primarily comprised of air, up to 97 % porous, resulting in a material that has an extremely low density, low thermal conductivity, high internal surface area, and good mechanical strength. Aerogels also posses low dielectric constants, approaching that of air, making them suitable for various electronic applications, such as antenna substrates. The objective of this research is to increase the flexibility of polyimide aerogel substrates, 2 – 3 mm thick, by incorporating a diamine containing aliphatic linkages and aromatic rings. A previous approach used either 1,4-bis(4-aminophenoxy)butane (BAP4), 1,6-bis(4-aminophenoxy)hexane (BAP6), or 1,10-bis(4-aminophenoxy)decane (BAP10), more generally referred to as BAPx, in conjunction with 2,2'-dimethylbenzidne (DMBZ) and 3,3',4,4'-biphenyltetracarboxylic dianhydride (BPDA), and cross-linked with 1,3,5-triaminophenoxybenzene (TAB).[1] In this study, we replace BAPx with 1,3-bis(4-aminophenoxy)-2,2-dimethylpropane (BAPN), to further improve dielectric constant, mechanical properties, and hydrophobicity.

Approach

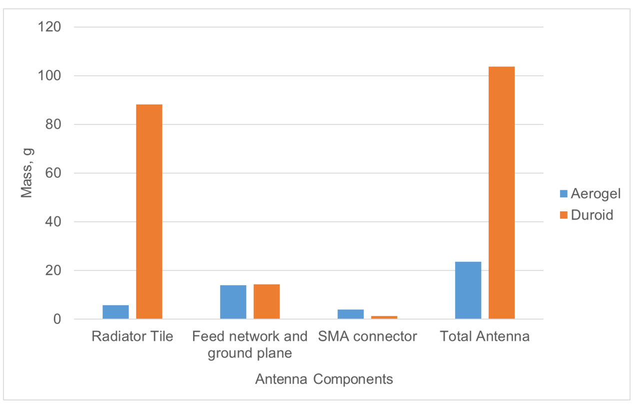




- Conventional antennas with fixed sidelobe patterns cause unacceptable interference with ground stations
- New phased array antennas using electronic beamforming redirect sidelobe energy away from the ground
- Conformal design to reduce drag and weight, and save space



Antenna Gain for Aerogel and Duroid Antenna Arrays[2]



Mass Comparison Between 2 x 4 Aerogel Antenna and its Duriod Counterpart[2]

- Low dielectric allows for reduced radio frequency losses as well as broader bandwidth and higher gain

References

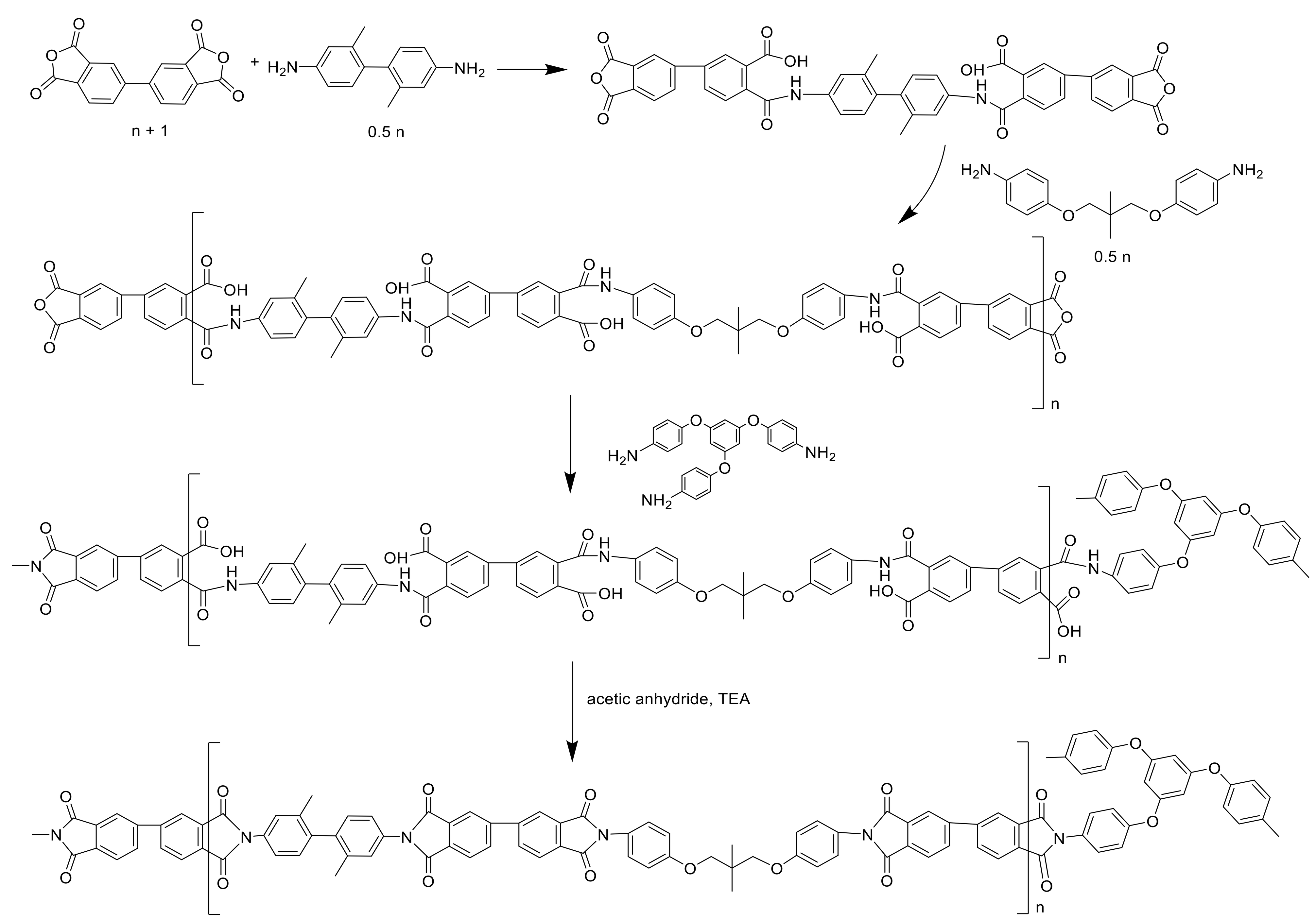
[1]Pantoja, M.; et al. Increased Flexibility in Polyimide Aerogels Using Aliphatic Spacers in the Polymer Backbone. *ACS Appl. Mater. Interfaces* **2019**, 11, 9425-9437

[2]Meador, M. A. B.; Miranda F. A. *Design and Development of Aerogel – Based Antennas for Aerospace Applications: A Final Report to the NARI Seedling.* Technical Report to NARI Seedling Fund. NASA TM-2014-218346, August 2014

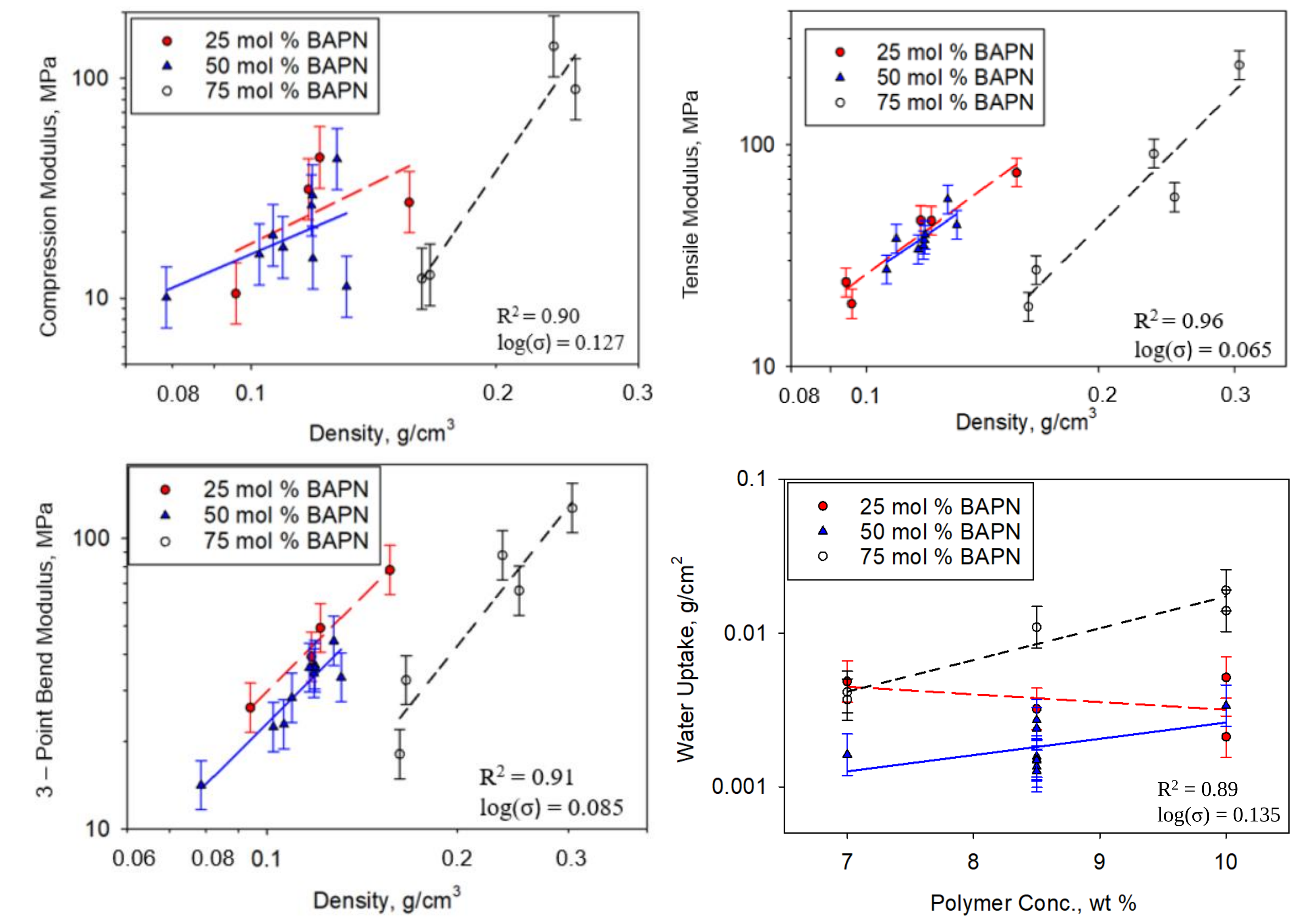
Design of Experiment

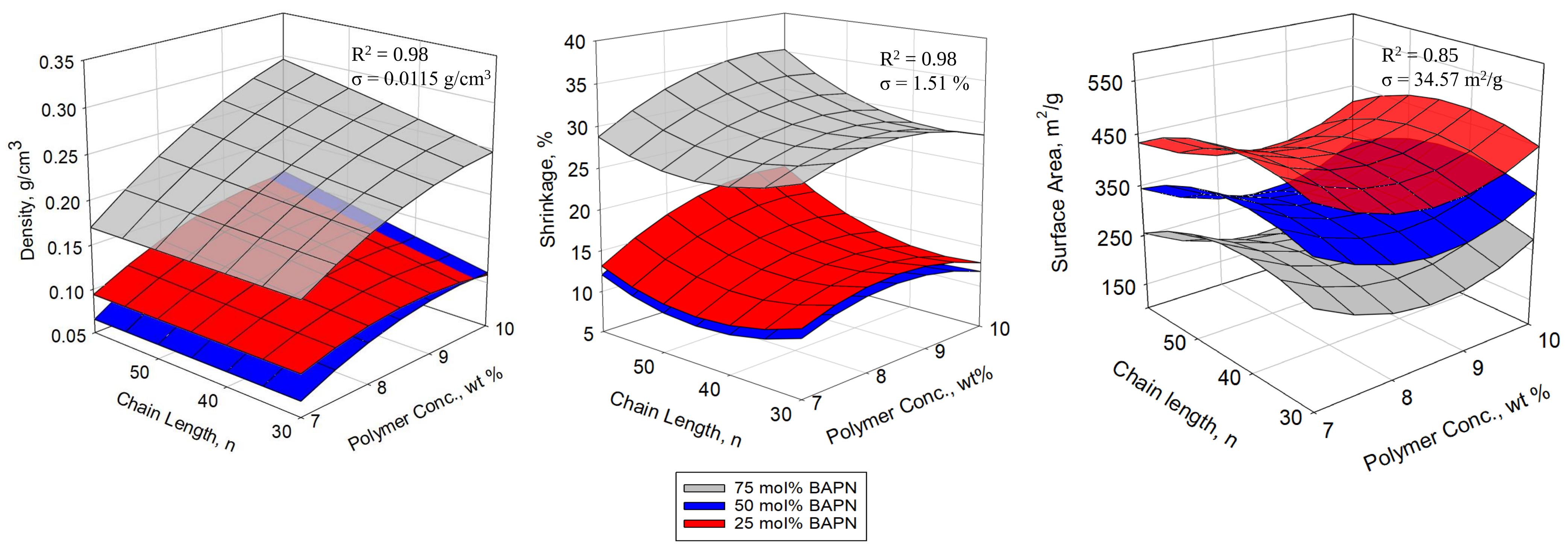
- Polymer concentration: 7-10 wt %
- Diamines used: BAPN/DMBZ
- BAPN mole fraction: 25 - 75 %
- Chain length, n: 30 - 60

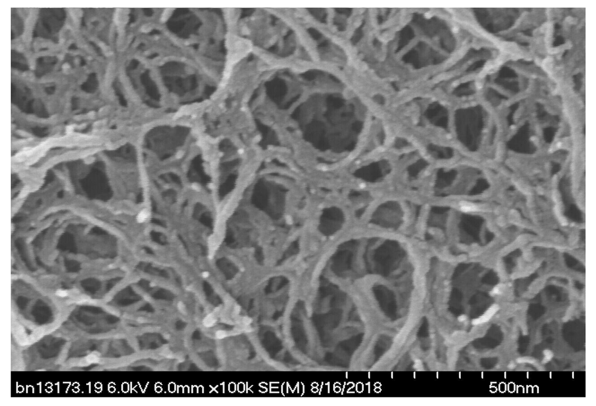
Scheme

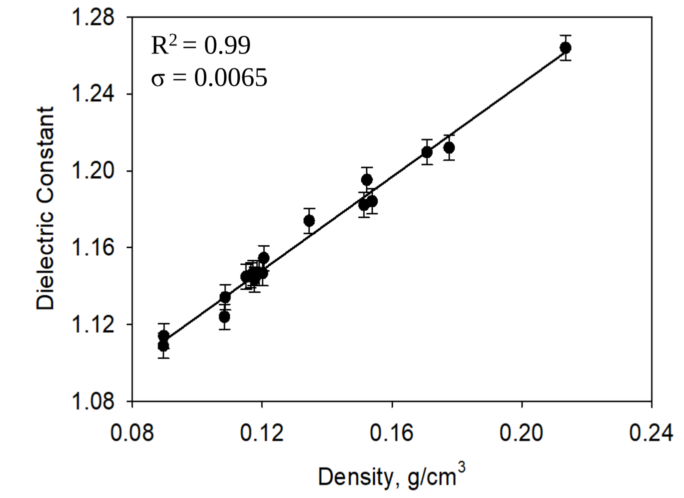


Results









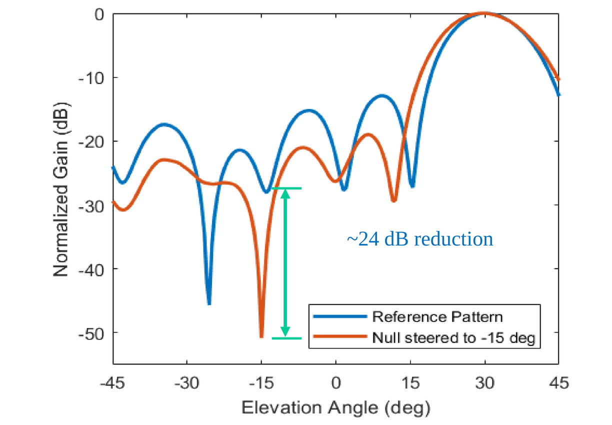
Conclusion

Formulations containing either 25 mol % or 50 mol % BAPN, n = 30, and 7 wt % have the lowest density, smallest dielectric constant and good mechanical properties, including flexibility. When comparing the ideal BAPx formulation, 25 mol % BAP10[1], to ones made with 25 or 50 mol % BAPN, we see lower dielectric constant, greater hydrophobicity, and comparable flexibility.

Optimal Formulation

7 wt % polymer concentration, 25 mol % BAPN, n = 30

- Density = 0.096 g/cm^3
- Porosity = 93 %
- Dielectric constant = 1.11
- Bend radius: approximately 1 inch for a substrate 2 mm thick
- Low viscosity – easy to process



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