Thermostable Polycyanurate Foams

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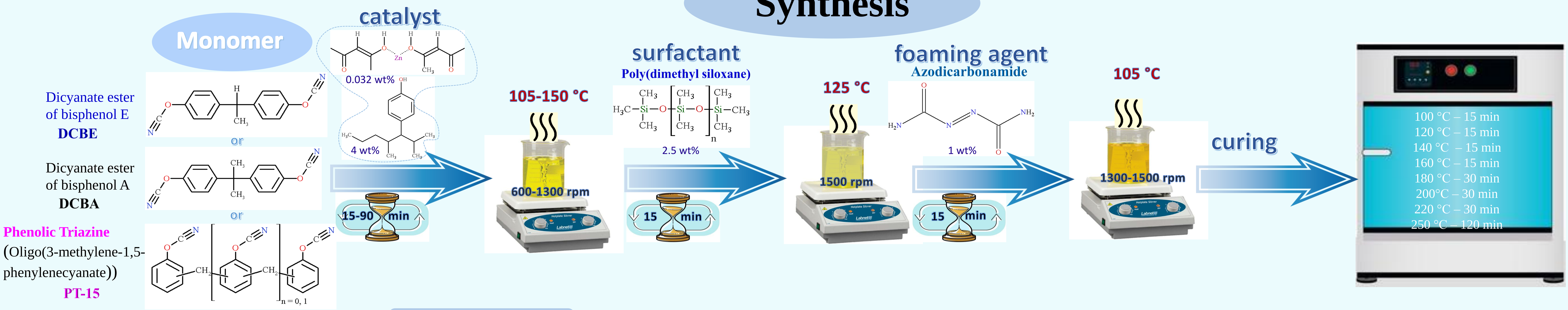
The development of modern technology is unimaginable without polymer composite materials (PCMs). In particular, developers in the aerospace and aviation industries have long relied on PCMs and impose high requirements on their properties. Special attention is given to heat-resistant polymer materials that combine high tensile and compressive strength, low density, good damage tolerance, low thermal conductivity, and a low dielectric constant. These materials are used in engineering structures for marine and aerospace applications.

Polymer foams are among such materials.

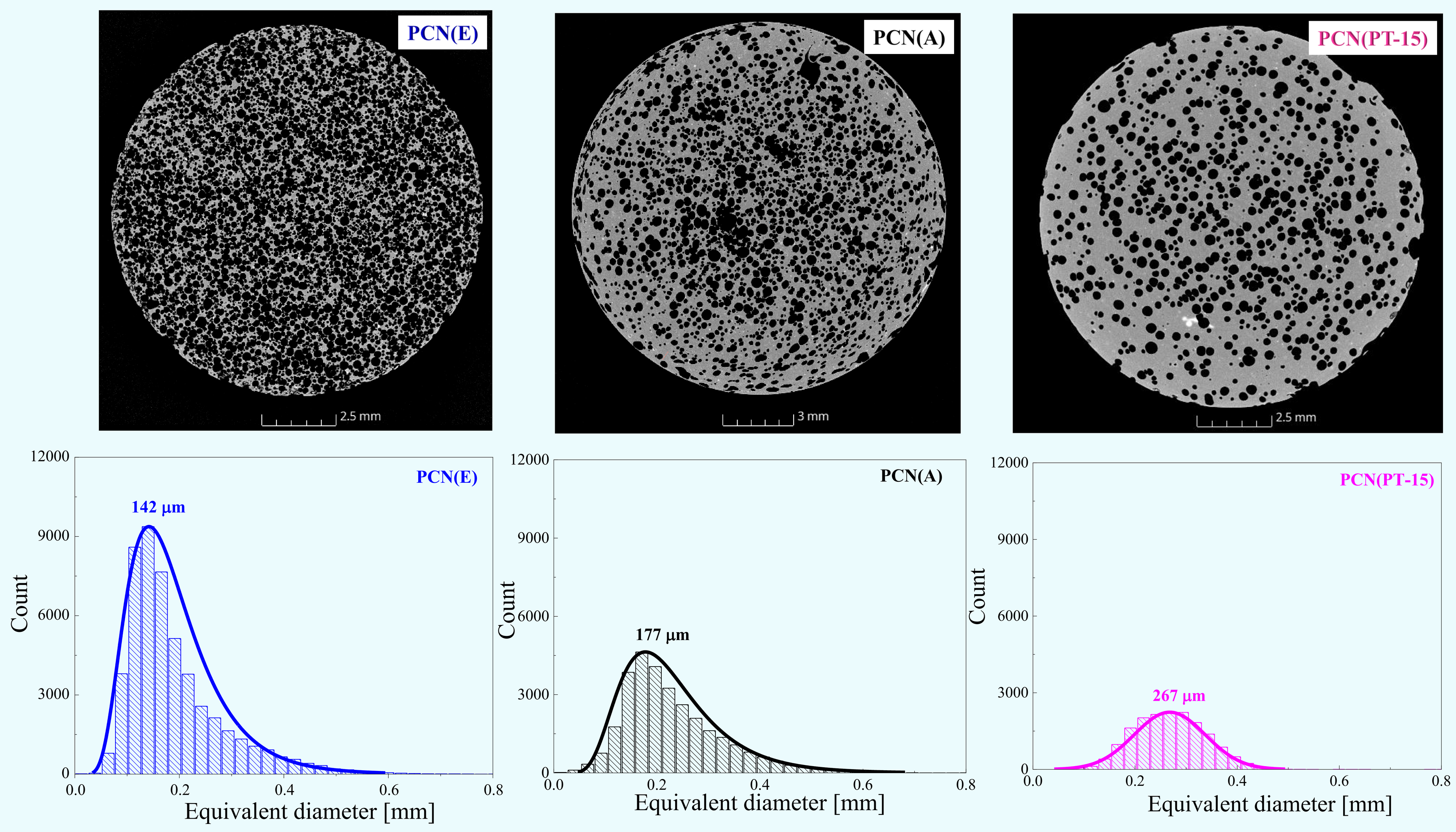
Polycyanurate networks (PCNs), produced through high-temperature polycyclotrimerization of cyanate ester resins (CERs), are thermally stable and densely cross-linked polymers with a unique combination of properties, including high thermal stability (> 400 °C), high glass transition temperature (> 250 °C), excellent fire, radiation, and chemical resistance, strong adhesion to metals, glass, and carbon fibers, low water absorption (< 2%), and low dielectric loss ($\varepsilon \approx 2.6$–3.1). Due to this valuable combination of properties, PCNs are used as high-temperature adhesives, sealants, potting resins, and polymer matrices for composite materials in modern industries, such as microelectronics, aerospace, and automotive manufacturing.

In this work, a method for synthesizing thermostable foams based on polycyanurates of various chemical structure is developed, and the chemical and phase structure, morphology, and physico-chemical properties of the synthesized materials are investigated.

Synthesis

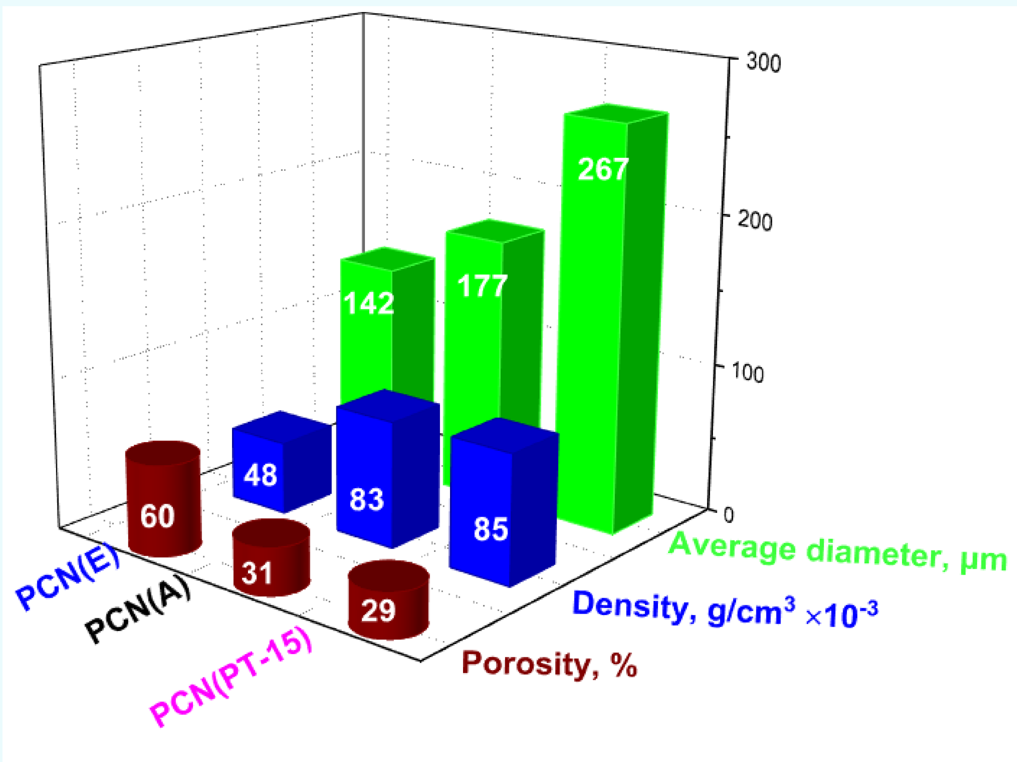


Morphology

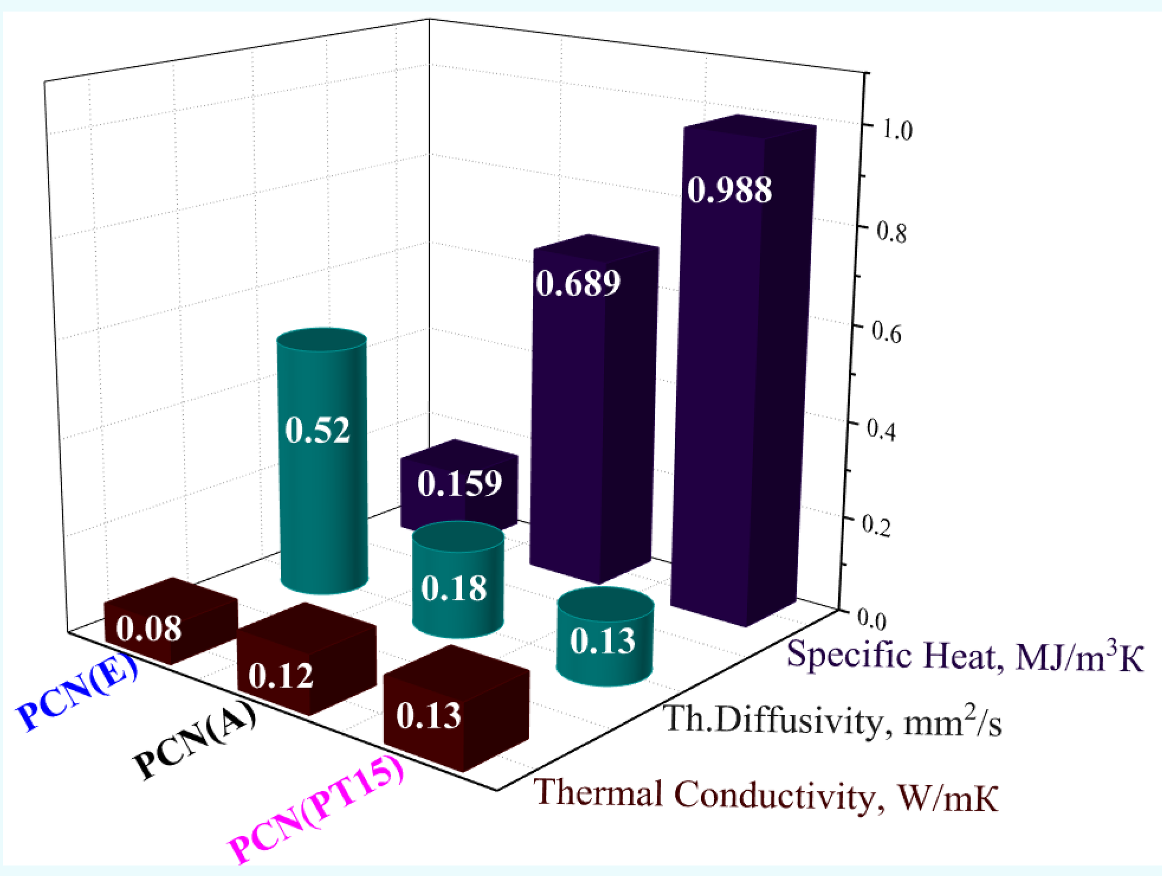


- A well-developed porous structure with a large number of pores is formed in all the samples studied.
- The average pore diameter of the synthesized foams increases from 142 µm for PCN(E) to 177 µm for PCN(A), and reaches 267 µm for PCN(PT-15).
- The density of all foams varies within the range of 0.48–0.85 g/cm³, which is significantly lower compared to monolithic cyanate samples, whose density is 1.20–1.25 g/cm³.
- The porosity of the resulting foams varies significantly depending on the type of dicyanate ester monomer used, ranging from 29% for PCN based on PT-15 to 60% for the foams obtained from DCBE.

Foam characteristics

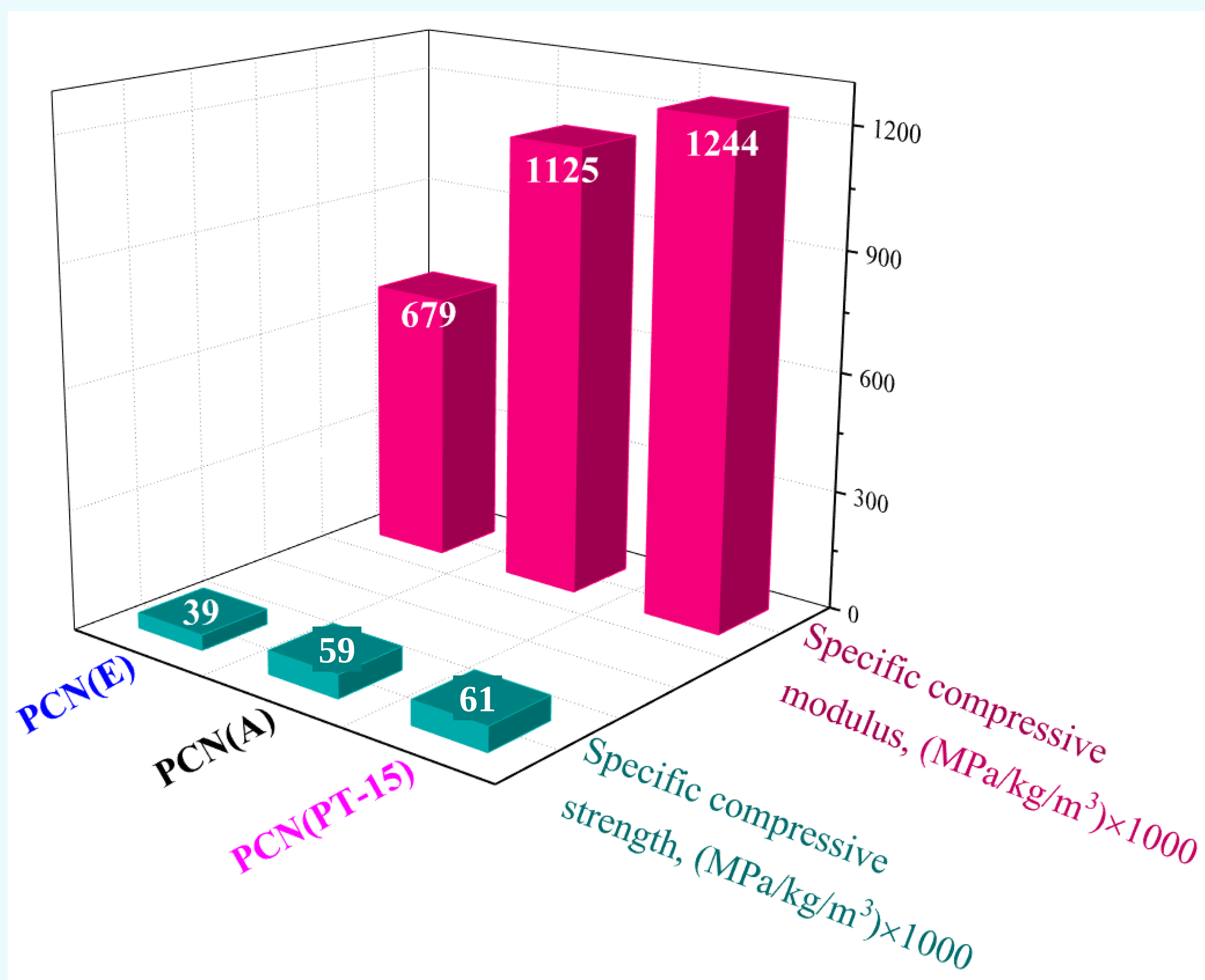


Thermal insulation behavior



- All the PCN foams obtained exhibit low thermal conductivity values ranging from 0.08 to 0.13 W/m·K, indicating excellent thermal insulation performance.
- The specific heat capacity per volume unit varies from 0.159 to 0.988 MJ/m³·K, confirming the significant heat absorption capacity of the foams produced.
- With thermal diffusivity values between 0.13 and 0.52 mm²/s, the foams demonstrate reduced thermal responsiveness and effective resistance to rapid temperature fluctuations.

Mechanical properties



- The specific compressive strength and modulus of the foams increase proportionally with density, indicating a direct correlation between structural compactness and mechanical performance.
- The compressive properties are comparable or even better to those of other thermosetting foams.

Conclusions

- A versatile synthetic approach for the preparation of foam materials based on various cyanate ester monomers is successfully developed and implemented, enabling the formation of polycyanurate (PCN) foams with controllable porosity and morphology.
- The compressive strength and modulus of the foams are found to be directly proportional to the density. Cyanate ester foams demonstrate better compressive properties in comparison to similar foams of other thermosets.
- The combination of low thermal conductivity, low thermal diffusivity, and relatively high volumetric heat capacity confirms that the developed PCN foams possess excellent thermal insulation, high thermal inertia, and effective heat storage capacity, making them ideal candidates for energy-efficient and thermally stable applications.

Acknowledgements

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