

Innovative Polyimide Materials with Self-Healing and **Shape Memory Properties for Space Applications**



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Summary

Polyimides-based materials with intrinsic self-healing and shape memory properties have recently emerged as critical alternatives to traditional materials to improve the durability of equipment and habitats used in lunar missions. Such materials would enable autonomous repair against several types of damage, such as surface abrasion caused by lunar dust. A combination of boric acid (BA) and polysiloxane polymers (PDMS) is used to enable self-repair of the PI materials through the creation of a supramolecular dynamic network interlaced with the PI network. Following a more sustainable approach, the polyimide precursor, polyamic acid (PAA), is synthesized in a green solvent (dimethyl isosorbide) and imidization is obtained by thermal treatment to avoid the use of toxic reagents typically employed in chemical imidization.

Methodology

Step 1: Synthesis of poly(amic acid) (PAA)

Aromatic dianhydride is added to a solution of aromatic and fluorinated diamine in dimethyl isosorbide (DMI) (green solvent)

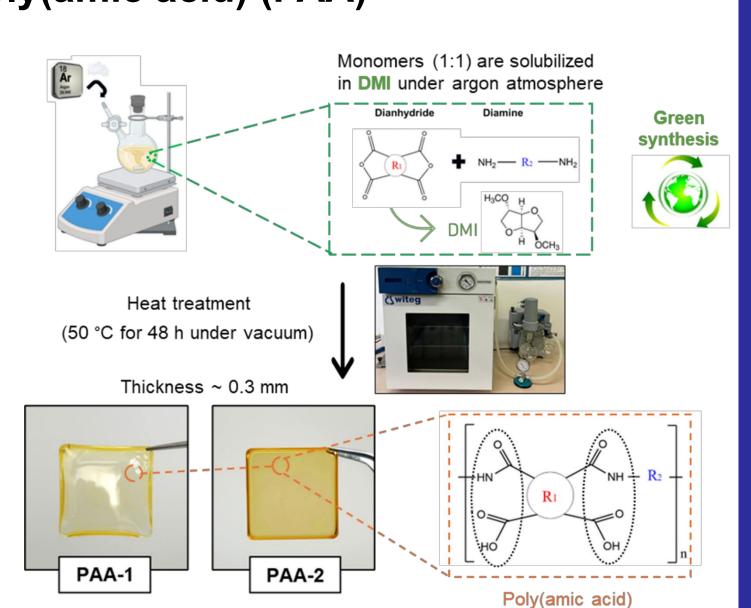
PAA-1



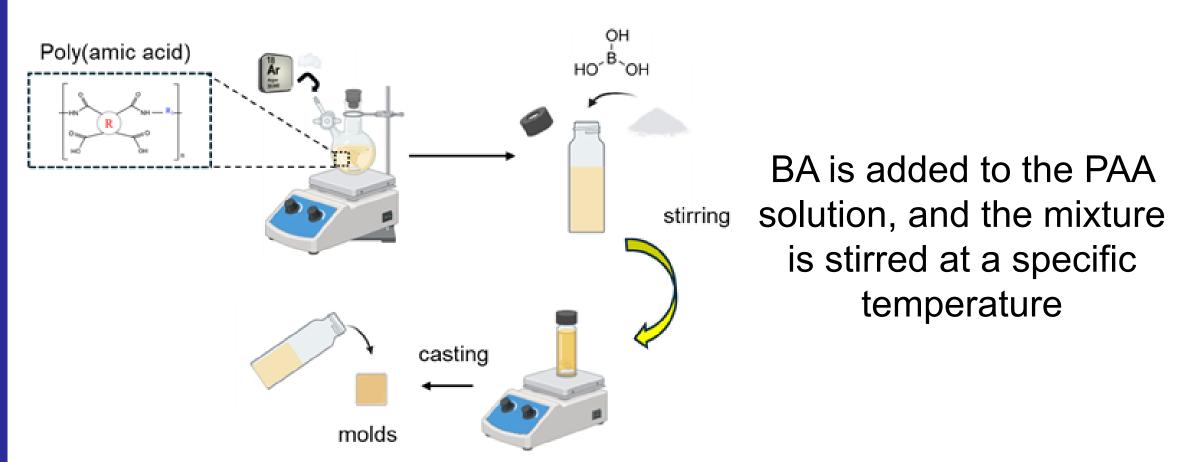
dianhydride is not fluorinated



both monomers contain -CF₃

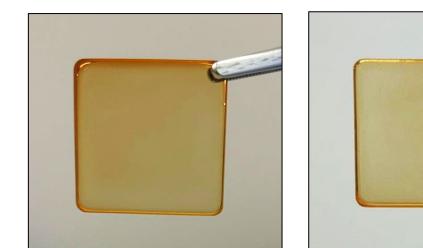


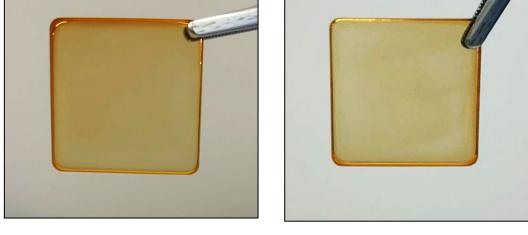
Step 2: Synthesis of the mixture of PAA and BA



Step 3: Thermal treatment in oven

PAA with BA is heat-treated under the same conditions as pristine PAA





Density Measurement

BA (wt%)	Density (g/cm³)		
	PAA1	PAA2	
0	1.359 ± 0.008	1.364 ± 0.016	
5	1.356 ± 0.020	1.381 ± 0.028	
10	1.361 ± 0.006	1.396 ± 0.017	
15	1.374 ± 0.010	_	

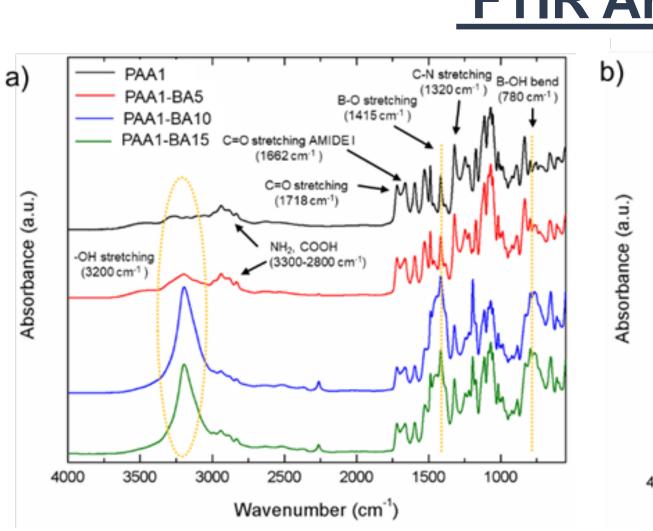
- ✓ The density increases slightly as the concentration of BA increases
- The presence of BA does not significantly change the physical properties of the starting materials

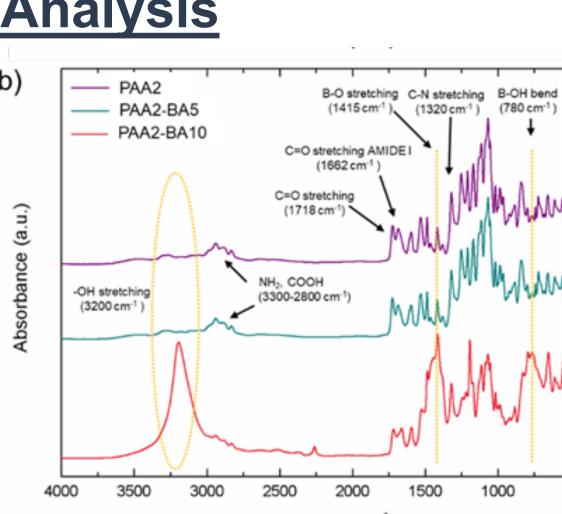
Wettability Properties

Type of	SFE (mJ/m²)	Y ^d	Y ^p
membrane		(mJ/m²)	(mJ/m^2)
PAA1	33.46	25.84	7.62
PAA1-BA5	33.97	28.20	5.77
PAA1-BA10	33.48	28.42	5.06
PAA1-BA15	34.19	29.84	4.35
PAA2	34.11	27.84	6.27
PAA2-BA5	33.25	27.87	5.38
PAA2-BA10	32.98	27.89	5.09

✓ The addition of BA to the polymer progressively lowers its hydrophobicity due to the presence of the hydroxyl functional groups

FTIR Analysis C-N stretching B-OH bend PAA2 PAA1-BA5 PAA2-BA5





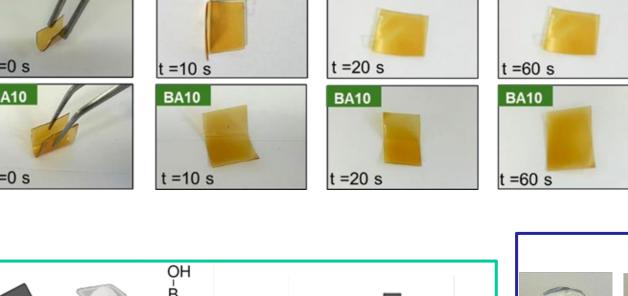
Wavenumber (cm⁻¹)

- ✓ FTIR spectra confirm the successful formation of PAA and the incorporation of BA
- Characteristic absorption peaks corresponding to amide bonds and BA are observed

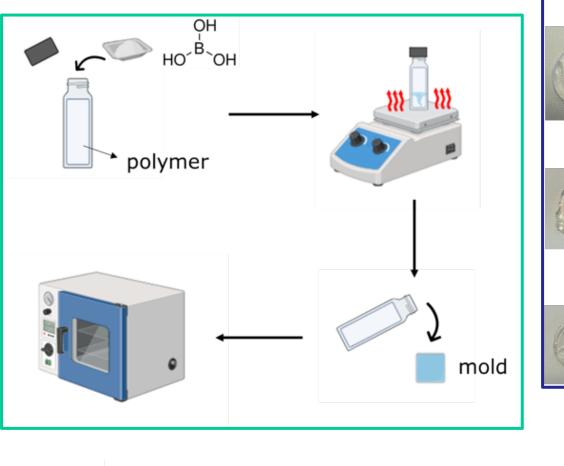
TOWARDS SELF-HEALING ABILITY

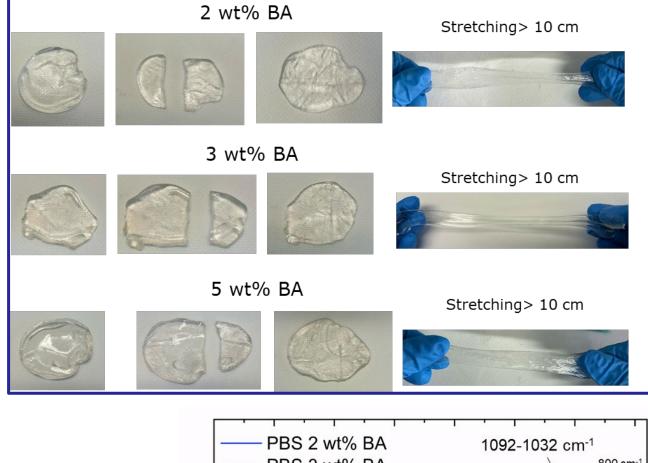


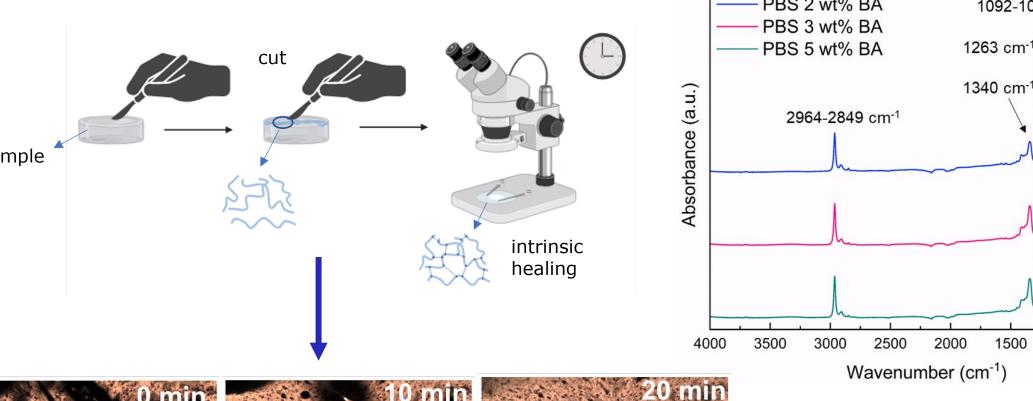
The images show a complete return to the original shape for both types of materials without external stimuli in less than two minutes

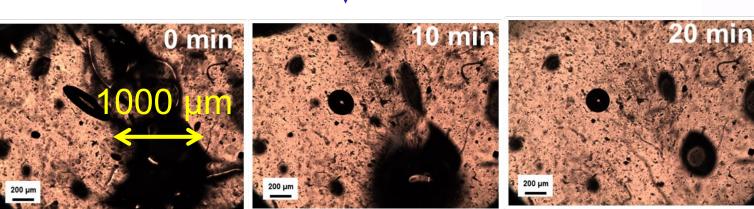


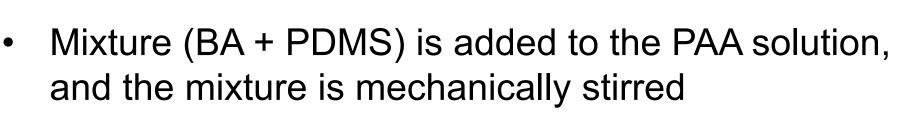












The mixture shows no phase separation after days

Conclusions

- Flexible PAA membranes, with and without BA, are prepared starting from the same fluorinated diamine and different dianhydrides
- The synthesis is carried out using a non-toxic solvent, DMI
- Various concentrations of BA are added to the polymer solutions to confer self-healing and shape memory properties, which are important in view of a potential use of these materials for lunar exploration missions