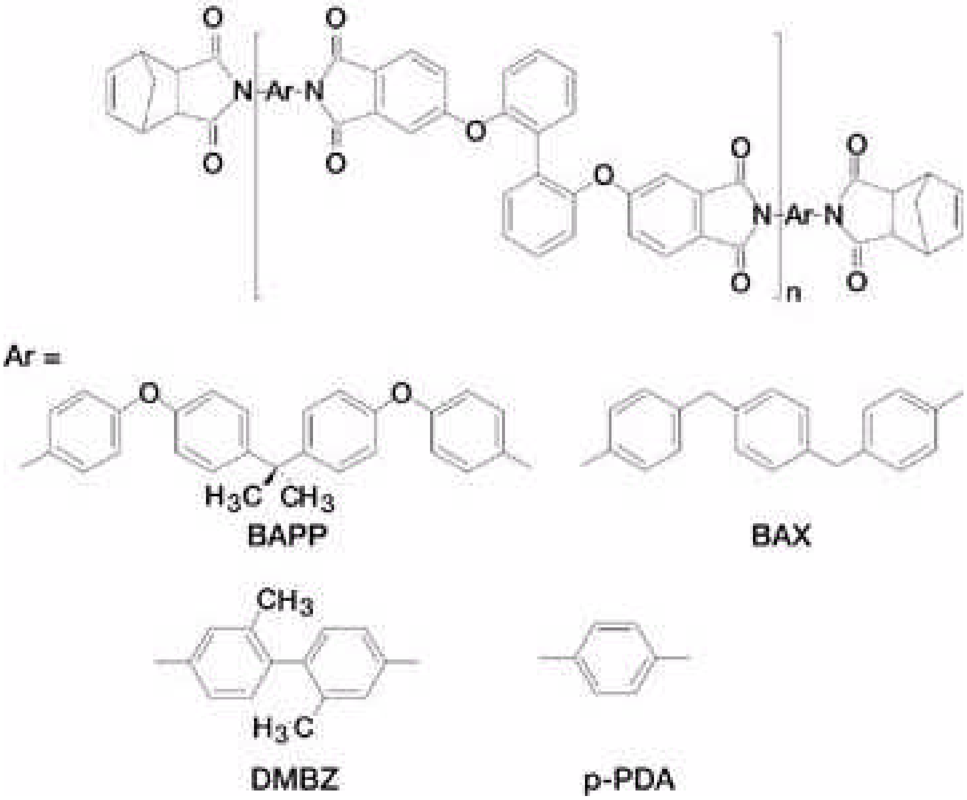
Resin Transfer Moldable Polyimides Developed for High-Temperature Applications

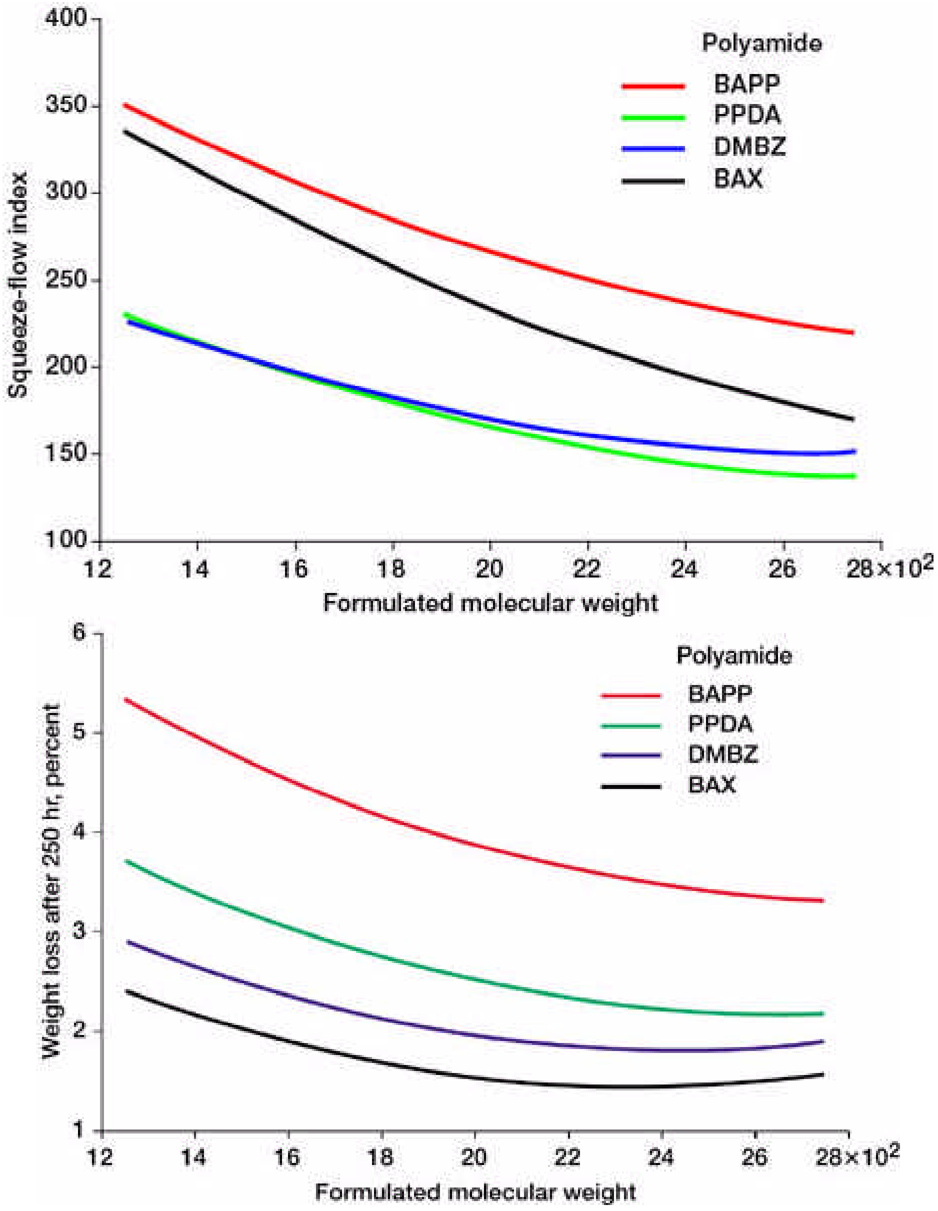
High-temperature polyimides, such as PMR–15 (which was developed at the NASA Glenn Research Center at Lewis Field), are becoming an increasingly important class of materials for a variety of aerospace applications, such as aircraft engine components and propulsion and airframe components for reusable launch vehicles (RLV's). Because of their high specific strength and low density, use of these materials in place of more traditional aerospace materials, such as titanium, can significantly reduce component and vehicle weight, leading to reductions in fuel consumption (and pollutants), increases in payload and passenger capacity, and improvements in vehicle performance.

Typical methods for fabricating components from these high-temperature materials are fairly labor intensive and costly. More cost-effective methods, such as resin transfer molding (RTM), have been developed and successfully employed with low-temperature polymers (use temperatures no higher than 400 °F). RTM processing can lead to as much as a 50-percent reduction in manufacturing costs over traditional fabrication methods. In the RTM technique, a preform, made by weaving or braiding fiber reinforcements, is infiltrated with molten polymer, and the resulting structure is cured at elevated temperatures. To successfully fill the mold and wet out all of the fibers in the preform, the molten polymer must have a melt viscosity no higher than 1000 centipoise (cP)—about the consistency of castor oil. High-temperature polymers, such as PMR–15, have melt viscosities on the order of 200,000 cP—the consistency of peanut butter. The challenge is to develop new polymers that not only have melt viscosities low enough to enable RTM processing but have the stability and properties necessary for operation at temperatures above 450 °F (232 °C).



Low-melt-viscosity PMR polyimides.

A recent collaboration between researchers in Glenn’s Polymers Branch and the University of Akron’s Institute of Polymer Science led to the development of a new family of PMR polyimides (see the chemical diagrams) with melt viscosities low enough for RTM processing. Melt viscosities of these imide oligomers were measured by pressing 0.5 g of resin powder between two 12- by 12-in. sheets of Kapton in a heated press (500 °F, 260 °C) at 170-psi pressure. Areas of the resulting resin "splots" (Squeeze Flow Index) were measured and are shown in the next graph as a function of formulated molecular weight. Those resins with Squeeze Flow Indexes greater than 220 cm^2 have melt viscosities below 1000 cP. Most of the resins prepared from BAPP and BAX diamines have melt viscosities low enough for RTM processing. Neat resin samples were molded from these imide oligomers at 316 °C and postcured for 16 hr at 325 °C. Weight losses for these samples after 250 hr of aging in air at 550 °F (290 °C) are shown in the final graph. Resin samples prepared from the BAX diamine showed the lowest weight losses of all samples tested and indicate good long-term stability at or near 550 °F. Further work is underway to evaluate these materials in carbon-fiber-reinforced composites.



First: Melt flow of PMR polyimides. Second: Weight Loss after 250 hr at 550 °F (290 °C) of low-melt-viscosity PMR polyimides.

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