FIRE PERFORMANCE OF PHTHALONITRILE RESINS/COMPOSITES

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ABSTRACT

Phthalonitrile composites, under development at the Naval Research Laboratory (NRL), offer promise as high performance, high temperature composites for aerospace and advanced marine applications. Phthalonitrile polymers are thermosets derived from bis-phthalonitrile monomers and a variety of curing additives. The structures of the monomer and the curing additive used in this investigation are shown in Figure 1. The advantages and versatility of the phthalonitrile polymers may be realized in terms of processability and superior properties. For instance, the cure reaction is not accompanied by evolution of volatile byproducts, therefore, void-free components can be fabricated easily. Additionally, a prepolymer (B-staged) resin may be prepared and stored with an indefinite shelf life under ambient conditions. The polymerization rate is also easily controllable as a function of curing additive and processing temperature. This enables conventional autoclave curing as well as short time reaction injection molding (RIM) processes. As far as the thermal properties are concerned, the cured resins do not show a glass transition temperature (T_g) up to 450°C and exhibit good property retention at elevated temperatures. In addition, they retain about 65-70% char upon pyrolysis to 1000°C under inert conditions.

Phthalonitrile composites with carbon and glass reinforcements have been investigated for fire performance characteristics. High performance composites that meet the Navy's flammability requirements of MIL-STD-2031 have not been available to date. When compared to other high performance composites, phthalonitrile-based composites are the only materials that satisfy the Navy's fire performance acceptance criteria for using lightweight polymeric composites for submarine applications. For instance, the time to ignition (T_{IG}) and peak heat release (PHR) values at 100 kW/m^2 heat flux for phthalonitrile/carbon composite are 75 sec. and 118 kW/m^2,

respectively, and those of phthalonitrile/glass fabric composite are 60 sec. and 106 kW/m^2. The corresponding values for vinyl ester/glass marine composite are 24 sec. and 187 kW/m^2. The superior fire performance of phthalonitrile composites may be attributed to the highly aromatic polymer backbone that confers high thermal stability as well as the ability to form a char on burning. Smoke and combustion gas analyses reveal that the properties of phthalonitrile/glass panels are far superior to vinyl ester/glass composites. The optical density as well as the relative concentrations of toxic gases such as CO, HCN and HCl are significantly lower for phthalonitrile/glass composites. The water uptake when immersed under ambient conditions for 100 days is less than 1%. All these attributes render phthalonitrile-based composites useful as fire barriers in advanced marine applications.

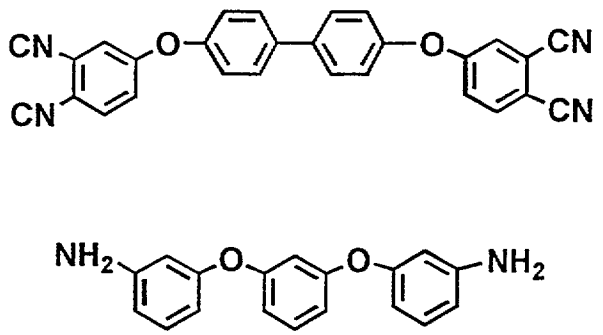

Figure 1: Structures of phthalonitrile monomer (top) and curing additive (bottom)

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