Editorial

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Fire is a world-wide problem, resulting in thousands of lives and over 1% of GDP lost each year.^{1,2} And, in the United States, residential fires continue to be the most disruptive natural disaster. In 2018, fire departments responded to over 1.3 million fires in the United States.³ These fires resulted in 3655 civilian fire fatalities, 15 200 civilian fire injuries and an estimated \$25.6 billion in direct property loss.³

In recent years, there has been much research into mitigating loss in wildland–urban interface (WUI) communities. This is in part because WUI fires accounted for about half of the property losses due to fire³ and in part because of the increases in wildfire risk brought about by climate change and warmer, drier conditions. However, WUI communities are not the only fire concern for residents. As the population increases, urban communities become increasingly congested, with structures becoming closer together. This increases the risk of building-to-building flame spread. Large urban fires can occur after a major earthquake, under extremely windy conditions or even after tsunami attacks along the coastal areas. And, there has been an increase in the use of composite materials both in home furnishings and in the construction of the buildings themselves. Composite materials are often used in products with strict fire codes, such as wiring, electronics, and furniture. Combustible composite materials are increasingly used in insulation and building facades. The use of vinyl siding, oriented strand board, sandwich panel insulation and aluminium composite rainscreen cladding all lead to increased risk of flame spread and flashover. The recent fires at Grenfell Tower and Abbco Tower show how devastating these fires can be.

Historically, flame and fire retardants have been used to mitigate some of the losses due to fire. However, there is growing concern over their effects on environmental and health safety. In particular, the recent studies showing the prevalence of brominated flame retardants inside the home has increased public scrutiny into the risk–reward ratio of using flame retardants. Regardless, regulatory and public perception pressures have increased the need to examine alternative technologies.

One of the approaches with promise is the development of new flame/fire retardants derived from natural materials. One of the earlier approaches to reduce the flammability of polymers was the use of natural clays. Since then, a large number of other natural

materials have been used as flame retardants for composites. Among other materials, wool, chicken feathers, phytic acid, tannic acid, isosorbide, lignin, chitosan, alginate, carrageenan, dopamine and DNA have been used as sustainable flame-retardant additives in composites. Previously, this journal has reported on a few of these naturally occurring flame-retardant materials.^{4–6} In this themed issue, six experts report on some of their latest developments in sustainable flame-retardant materials.

In the first paper, Ngo provides an overview of flame retardants and flammability testing.⁷ It provides the general mechanisms of the primary classes of flame retardants. The development of phosphorous-containing cellulose, lignin and chitosan represent some of the newer approaches to flame-retarding polymers. The paper also discusses the primary flammability tests used to evaluate the flame retarded materials.

In the second paper, Patra *et al.* examine the use of phytic acid for flame-retarding cotton.⁸ The effects of replacing the protons with common cations was also examined. Using a flame spread test, thermogravimetric analysis and nuclear magnetic resonance, the charring mechanisms were elucidated.

In the third paper, Kolibaba *et al.* use a layer-by-layer (LbL) approach to fire-protect wood.⁹ Chitosan and vermiculite were used to delay ignition and reduce the combustion of the wood. Pretreatment of the wood surface was studied to improve LbL adhesion and optimize the fire performance of the coatings. In addition to flammability, the effects of the coatings on the mechanical properties of the wood was examined.

In the fourth paper, Bellayer *et al.* screen alternative, natural product additives to replace diethylphosphite as a flame retardant for sol–gel coated foam.¹⁰ UL 94 and mass-loss calorimetry tests were used to examine the reaction to fire of the different formulations. In addition to the flammability, the morphology and mechanical properties of the coated foams were examined.

In the fifth paper, Korey *et al.* use tannic acid to enhance intumescence in epoxy thermosets.¹¹ The effects of tannic acid concentration on the composite structure was examined.

Maintaining the structural integrity of tannic acid was critical to the synergistic flame-retardant behavior of the molecule.

In the last paper, Fox *et al.* examine the use of polydopamine coating to protect flammable materials from burning.¹² Natural product additives were used to enhance the self-extinguishing characteristics of the coated samples. Dopamine was found to intercalate between clay layers to form uniform coatings.

I hope you find that this themed issue provides examples of state-of-the-art approaches to designing new fire/flame retarded materials. There are many new opportunities to increase the sustainability of flame retarded materials to mitigate some of the ever-present fire dangers while addressing the environmental concerns of legacy compounds. I look forward to seeing future developments spurred by these studies.

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