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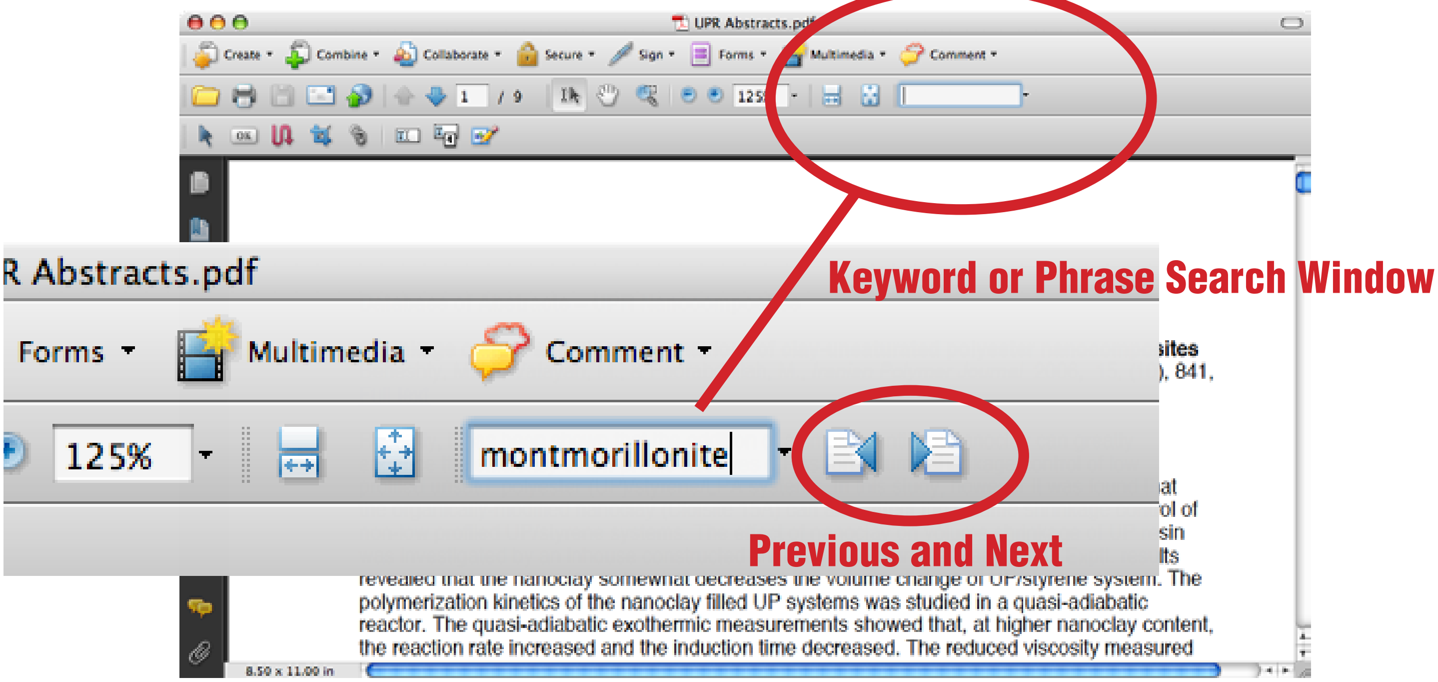

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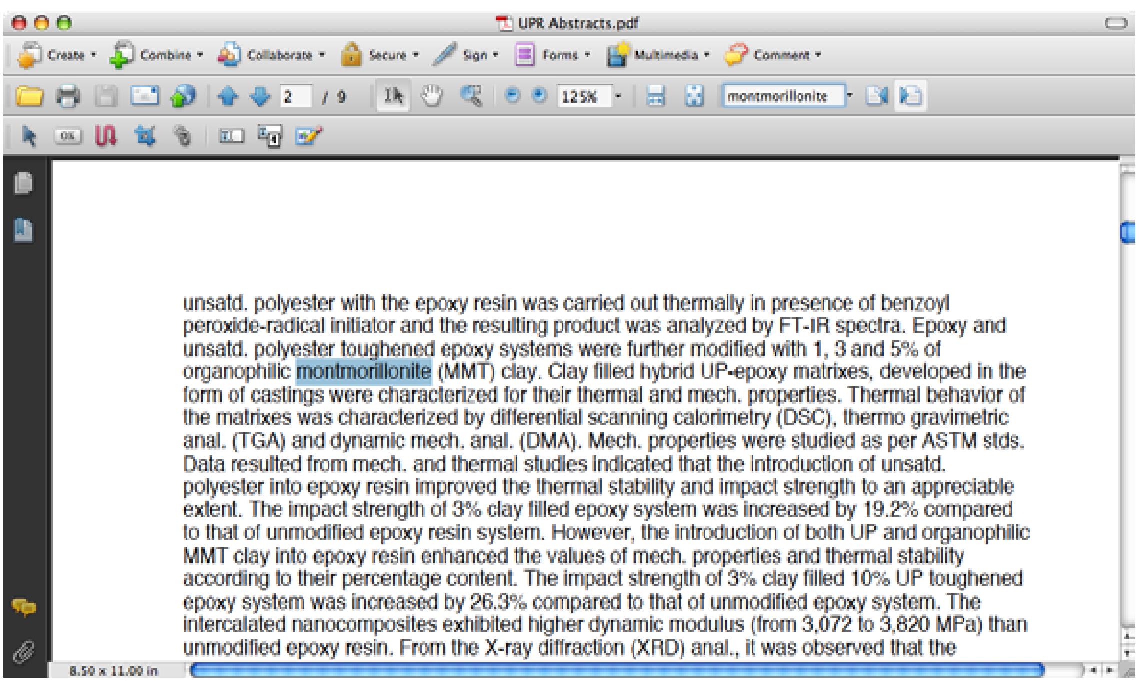

Database of Abstracts – Fire Retardant Nanocomposites

Performance of nanoclay in a flame-retardant jacket compound
Castenada, Sergio; Parra, Octavio; Ramirez, Eduardo; Sanchez, Saul; *Wire Journal International,* 2009**,** 42, (2), 70, Full Text

Nanoclay modified fillers have been found to be effective at reducing the amount of retardants needed to provide required flammability protection levels as well as improving processability without diminishing cable performance.

Smoke, CO, and CO_2 measurements and evaluation using different fire testing techniques for flame retardant unsaturated polyester resin formulations
Nazare, S., Kandola, B. K., & Horrocks, A. R., *Journal of Fire Sciences,* 2008**,** 26, (3), 215, Full Text

Smoke is considered to be the main fire hazard but its production depends on major variables, principally the chemical character and the burning rate of the polymer plus the availability of oxygen and hence ventilation. The main aim of this work is to study the effect of smoke suppressants on flammability and smoke production of flame retarded unsatd. polyester resin-nanocomposites using four different testing regimes representing different fire scenarios. Samples containing zinc borate, zinc stannates, ammonium polyphosphate with and without nanoclay are analyzed for smoke generation using cone calorimetry (well-ventilated fire), a tube furnace (fully developed fire), and a smoke d. chamber (under-ventilated fire). Carbon monoxide (CO) and carbon dioxide (CO_2) measurements using thermogravimetry-evolved gas anal. (TG-EGA), cone calorimetry, and tube furnace have also been analyzed and compared. Results have confirmed that the production of smoke, CO, and CO_2 depend upon smoke suppressants and fire conditions used during testing samples. From this study it is evident that tin additives have very little influence on flammability of unsatd. polyester resin but they reduce smoke formation. The slight flame retardant action of the Res/APP/ZB sample is due to enhanced crosslinking of APP in the presence of zinc borate, whereas zinc stannates do not promote crosslinking of APP and hence show no improvement in flame retardancy. Finally, the presence of nanoclay in flame retarded resin shows significant reduction in smoke formations in both well-ventilated and under-ventilated fire condition. However, in the presence of smoke suppressants used in this study, the nanoclay is not instrumental in further suppressing smoke formation.

Flame retardancy of highly filled polyamide 6/clay nanocomposites
Aravind Dasari, Zhong-Zhen Yu, Yiu-Wing Mai and Songlin Liu, *Nanotechnology* ***18*** *(2007) 445602 (10pp),* 2007, Full Text

To obtain an in-depth physical knowledge of the protective barrier stability and uniformity under fire conditions, we prepared highly filled polyamide 6/organoclay nanocomposites and characterized their thermal and flammability properties. The objectives were to identify a critical composition that is needed to form a stable char with no apertures or cracks and to gain a thorough understanding of the mechanisms of flame retardancy. It was shown that there is no need for higher percentages of clay and even smaller amounts of clay (<10 wt%) should be enough to achieve good fire performance. Factors such as incoherency, poor stability and non-uniformity of the char or the presence of large cracks and formation of island-like structures were insignificant in slowing down the heat release and mass loss rates. Nevertheless, there was no stage during the flammability test where the fire completely extinguished even when the protective layer was stable and free from major cracks/apertures. Based on these results, new insights and approaches to process better flame retardant polymer nanocomposites are discussed. (Some figures in this article are in colour only in the electronic version)

Characterization of the performance of an intumescent fire protective coating
M. Jimenez, S. Duquesne, S. Bourbigot, *Surface & Coatings Technology 201 (2006) 979–987,* 2006, Full Text

The aim of this work is to study the efficiency of different intumescent formulations designed to protect steel in the case of hydrocarbon fire. The coating is based on a thermoset epoxy–amine resin system into which fire retardant agents, boric acid and ammonium polyphosphate derivative have been incorporated. The first part of the study evaluates, using large scale industrial furnace tests, the behavior of the thermoset resin containing alone or in combination with additives. It is revealed that in this epoxy resin, the combination between ammonium polyphosphate and boric acid leads to the best protective results. The second part of the study attempts to investigate more precisely the effect and the mode of action of the additives in terms of thermal stability, mechanical resistance and rheological properties using small scale lab tests, to explain why this combination works better than using the two fire retardants used separately. The experiments show that this combination leads to the smallest decrease of viscosity when the resin degrades, the highest mechanical resistance and the highest expansion.

Multiscale Experimental Approach for Developing High-Performance Intumescent Coatings
M. Jimenez, S. Duquesne and S. Bourbigot, *Ind. Eng. Chem. Res.* ***2006,*** *45, 4500-4508,* 2006, Full Text

The goal of this work is to combine small-scale screening tests permitting, during the laboratory research phase of a development, the optimization of intumescent mastic coatings formulated to protect steel in the case of hydrocarbon fire. This type of coating, applied on steel plates, beams, or columns, is usually evaluated in large industrial furnaces. Such experiments are, however, expensive and time-consuming. The use of such tests, if they are essential since they give a good simulation of a real fire, is a break for the development of
new intumescent high-performance intumescent coatings. The original combination of small-scale laboratory tests, such as thermogravimetric analyses and rheological measurements, provides, through a rapid screening of a large number of formulations, a very interesting preliminary tool for the development of new intumescent coatings. A statistical approach involving principal component analysis has been successfully used to correlate the results of the industrial furnace tests with those from the laboratory-scale analyses.

Flame retarded polymer layered silicate nanocomposites: a review of commercial and open literature systems
Morgan, A. B., *Polymers for Advanced Technologies,* 2006**,** 17, (4), 206, Full Text

This is a review of polymer nanocomposites used for flame retardancy applications, including com. materials and open literature examples. Where possible, details on how the nanocomposite and flame retardant work together will be discussed. The key lesson from this review is that while the polymer nanocomposite can be considered to be flame retarded (or a flame retardant) by definition, these materials by themselves are unable to pass regulatory fire safety tests such as UL-94 V. Therefore, addnl. flame retardants are needed in combination with the polymer nanocomposite to pass these tests. In multiple examples, the nanocomposite works with other flame retardants in a synergistic or cooperative manner to lower the polymer flammability (heat release rate). Finally, a discussion on research needs and outlook for polymer nanocomposite flammability research is included.

Flame-retardant unsaturated polyester resin incorporating nanoclays
Nazare, S.; Kandola, B. K; Horrocks, A. R., *Polymers for Advanced Technologies,* 2006**,** 17, (4), 294, Full Text

This work reports the use of polymer-layered silicate nanoclays as potential flame retardants in unsatd. polyester resins. Preparation, characterization and flammability properties of polyester-clay hybrids have been studied. X-ray diffraction studies have provided evidence that dispersion of functionalized clays in the polymer matrix depends on the type of functional group of the organic modifier used. Flammability properties studied using cone calorimetry suggests that incorporation of nanoclays (5% weight/weight) reduces peak heat release rate (PHRR) by 23-27% and total heat release (THR) values by 4-11%. The fire growth rate index is also reduced by 23-30% following nanoclay inclusion. While incorporation of condensed-phase flame retardants such as ammonium polyphosphate, melamine phosphate and alumina trihydrate reduce the PHRR and THR values of polyester resin, the inclusion of small amts. of nanoclay (5% weight/weight) in combination with these char-promoting flame retardants causes total redns. of the PHRR of polyester resin in the range 60-70%. Ammonium polyphosphate, in particular and in combination with polyester-nanoclay hybrids show the best results compared to other flame retardants.

Role of montmorillonite in flame retardancy of ethylene-vinyl acetate copolymer
Szep, Andrea; Szabo, Andras; Toth, Nikoletta; Anna, Peter; Marosi, Gyoergy, *Polymer Degradation and Stability,* 2006**,** 91, (3), 593, Full Text

The effects of non-treated (MMT), organophilic (OMM), and olefin/silicone polymer intercalated (IMM) montmorillonites on the thermal stability of ethylene-vinyl acetate copolymer (EVA) and on the flammability of magnesium hydroxide filled EVA were studied. The influence of various treatments on the delamination of montmorillonites in EVA was detected by rheol. measurements and by Raman microscopy. The latter was a unique method for rapid detection of the dispersion also in highly filled EVA. Enhancement of thermo-oxidative stability of EVA and flame-retarded EVA could be observed by thermal anal. in the presence of variously treated montmorillonites. The flame-retardant efficiency of magnesium hydroxide was improved by simultaneous application of MMT and IMM. The increased performance of magnesium hydroxide was explained by the rheol. effect of the IMM, catalytic effect of MMT and chemical interactions of montmorillonites with the metal hydroxide.

Effect of layered silicate nanocomposites on burning behavior of conventionally flame-retarded unsaturated polyesters
Kandola, B. K.; Nazare, S; Horrocks, A. R., *Polymeric Materials: Science and Engineering,* 2004**,** 91, 34, Full Text

This work reports that when organically modified nanoclays are used in unsatd. polyester resin and tested with cone calorimeter, the peak heat release values are reduced, ease of ignition unaffected and burning times are increased compared to the neat resin. In order to develop acceptable levels of flame retardancy, the nanoclays are used with conventional char forming flame retardants such as ammonium polyphosphate. Laminates of resin containing 5% organically modified clays with and without 20% flame retardants are cast. Their flammability properties are studied with thermal anal. and cone calorimetric techniques and results discussed in terms of effect of additive components on various cone parameters of neat resin.

Nanocomposites: a new nanotechnology concept for flame retardant polymers and cables
Beyer, Guenter; ADDCON 2004, International Plastics Additives and Modifiers Conference, 10th, Amsterdam, Netherlands, Sept. 28-29, 2004
Full Text

A review. Nanocomposites are a new class of polymer systems. Modified layered silicates as fillers are dispersed at a nm-level within a polymer matrix. For nanocomposites new and extraordinary properties are observed The thermal stability and the flame retardancy of polymers forming nanocomposites are improved. The flame retardancy mechanism of layered silicate nanocomposites is based on the char formation and its structure; the char insulates the polymer from heat and acts as a barrier, reducing the escape of volatile gases from the polymer combustion. The cone calorimeter is a very useful tool to investigate the properties of flame retardancy.

Preparation and properties of halogen-free flame-retarded polyamide 6/ organoclay nanocomposite
Song, L. H., Yuan; Lin, Zhihua; Xuan, Shanyong; Wang, Shaofeng; Chen, Zuyao;Fan, Weicheng, *Polymer Degradation and Stability,* 2004**,** 86, (3), 535, Full Text

Halogen-free flame-retarded polyamide 6/organoclay (PA6/OMT) nanocomposite was prepared by using magnesium hydroxide (MH) and red phosphorus (RP) as a flame retardant and organoclay (OMT) as synergist via a melt blend technique. The morphol. was characterized by x-ray diffraction and TEM. The effects of organoclay on the mech. properties and flammability of the PA6 were studied. The results show higher mech. and flame-retarded properties of the nanocomposite as compared with flame-retarded PA6 and a synergistic effect among OMT, MH and RP.

Flammability of polymer-clay and polymer-silica nanocomposites
Yang, Feng; Yngard, Ria; Nelson, Gordon L., *Journal of Fire Sciences,* 2004**,** 23, (3), 209, Full Text

A comprehensive discussion on the flammability of org.-inorg. nanocomposites is presented based on different fire testing methods. Based on various flammability tests, reduced peak heat release rate, an increased oxygen index, and an enhanced thermal stability were observed, while faster burning rates were found when the nanocomposites underwent horizontal and vertical burning tests, suggesting that nanocomposites themselves cannot be considered as sufficiently flame-retardant materials. However, when traditional flame-retardant additives were added to the nanocomposites, less additive was required to achieve the same level of flame retardancy.

Effects of organoclay Soxhlet extraction on mechanical properties, flammability properties and organoclay dispersion of polypropylene nanocomposites
Morgan, Alexander B.; Harris, Joseph D., *Polymer,* 2003**,** 44, 2313, Full Text

The organic treatment on a layered silicate used in nanocomposite synthesis is the interface between the hydrophilic layered silicate (clay) and hydrophobic polymer in the case of polypropylene. However, the typical synthesis of an organoclay can result in excess organic treatment which can hinder mechanical and flammability benefits. This excess organic treatment may result in plasticization of the polymer matrix, possibly removing some of the mechanical and flammability property benefits provided by the nanocomposite. In this paper, the effects of using Soxhlet Extraction on the Organoclays after synthesis was investigated. Soxhlet extraction times on organoclays were found to have an effect on the mechanical and flammability properties of the resulting polypropylene nanocomposite. The removal of excess organic treatment by Soxhlet extraction resulted in improvements in flex modulus, improved clay dispersion, delayed time to ignition, and lowered heat release rate during burning.

Nanocomposites - a new concept for flame retardant polymers
Beyer, G., *Polymer News,* 2001**,** 26, (11), 370

A review. Nanocomposites are a new class of polymer systems. Modified layered silicates as fillers are dispersed at a nm-level within a polymer matrix. For nanocomposites new extraordinary properties are obsd. The thermal stability and the flame retardancy of polymers forming nanocomposites are improved. The flame retardancy mechanism of layered silicate nanocomposites is based on the char formation and its structure; the char insulates the polymer from heat and acts as a barrier, reducing the escape of volatile gases from the polymer combustion. The Cone calorimeter is a very useful tool to investigate the properties of flame retardancy.

Phenolic Cyanate Ester Clay Nanocomposites: Effect of Ammonium Structure on Flammability and Nano-dispersion.
Jeffrey W. Gilman, R. H. H., Jr., Catheryn L. Jackson, Alexander B. Morga, Lori D. Brassell and Douglas L. Hunter, *Polymeric Materials: Science and Engineering,* 2000**,** 82, 276, Full Text

Layered silicate minerals (clays) have been investigated for decades to gain a better fundamental understanding of their unique properties, and to develop them for a variety of applications. Currently, many groups are involved in research on polymers intercalated into the gallery spaces of layered silicates, due to the superior properties of the polymer-clay nanocomposites (PCN). Several groups have developed the methods to achieve molecular level incorporation of the layered silicate (montmorillonite) into the polymer by addition of a modified, or pristine silicate: either prior to or during the polymerization,1,2,3,4,5 to a solvent-swollen polymer,6 or to the polymer melt.7,8 We have recently found that PCNs have reduced flammability.9 This is particularly significant since reduced polymer flammability using additives is often done at the expense of physical properties. We report here on the use of montmorillonite (MMT) dispersed at the nanometer level, in phenolic cyanate ester (CE) resins for reduced flammability. We show that the use of alkyl ammonium-treated MMT reduces the peak heat release rate (HRR) by over 50 %. We also show that the choice of ammonium treatment used to compatibilize the clay with the matrix can dramatically alter the nano-dispersion and the flammability properties. Specifically, we report on two methods used to “tether” the clay to the cured phenolic triazine matrix.

Nanocomposites: a revolutionary new flame retardant approach
Gilman, Jeffrey W.; Kashiwagi, Takashi; Lichtenhan, Joseph D., *SAMPE Journal,* 1997**,** 33, (4), 40, Full Text

To evaluate the feasibility of controlling polymer flammability via a nanocomposite approach, the flammability properties of nylon 6-clay nanocomposites were examd. The fire retardant (FR) properties of this new class of materials, org.-inorg. nanocomposites, are reported. The cone calorimeter data show that the peak heat release rate (HRR), the most important parameter for predicting fire hazard, is reduced by 63% in a nylon 6-clay nanocomposite contg. a clay mass fraction of only 5%. Not only is this a very efficient FR system, but, it does not have the usual drawbacks assocd. with other FR additives, i.e, the phys. properties are not degraded by the additive (clay), instead they are greatly improved. Furthermore, this system does not increase the carbon monoxide or soot produced during the combustion, as many com. fire retardants do. The nanocomposite structure appears to enhance the performance of the char through reinforcement of the char layer. Indeed, transmission electron microscopy (TEM) of a section of the combustion char from the nylon 6-clay nanocomposite (5%) shows a multilayered silicate structure. This layer may act as an insulator and a mass transport barrier slowing the escape of the volatile products generated as the nylon 6 decomps.