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Chemistry of char forming mechanism of spirophosphates

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Abstract

The spirophosphates are an important class of intumescent system, which produces effective voluminous char to protect the underlying materials. The char developed during the intumescent process play vital role in the flame retardant mechanism. Six different spirophosphates were synthesized, by treating spirodichlorodiphosphate with phenol, cresols (o-, m- and p-isomers), di- and tri-methyl phenols and their char forming chemistry were investigated. The residual char acquired by subjecting the synthesized intumescent materials to isothermal pyrolysis at 300°C, 400°C, 500°C and 600°C were investigated by FTIR and SEM analysis. FTIR analysis indicated the formation of structurally similar chemical entities from these intumescent materials when they were subjected to isothermal pyrolysis at different temperatures. The formation of phosphate rich carbonaceous complexes was identified. SEM analysis showed that the char produced was having considerably a compact structure.

Keywords: Spirophosphates, Intumescence, Char, Condensed phase mechanism, Phosphoric acids.

Introduction

Intumescent materials have been used for polymers, wood articles, metals, etc., for protection against fire due to their action in both the vapour and condensed phases. Intumescent materials on fire situation produce non-oxidizable multicellular char, which reduces the oxygen entry into the underlying substrate[1-3].

The chemistry of intumescent mechanism is difficult to understand, due to the multifunctional character of the intumescent materials, since, here dehydration of carbon rich compound is triggered by the acid molecules released during heating. Continuously and simultaneously, the spumific agent present in the intumescent system releases gaseous molecules and is responsible for the enlarged foaming action of the intumescent materials.

In few cases, the addition of intumescent materials alone has not given the required effect. Hence researchers introduced some additives as synergistic agent along with the intumescent materials to increase or to achieve the required effect. The thermal resistance and barrier properties of the char bonded structure formed during intumescence will depend on the resistance of char to oxidation, thermal insulation and mechanical resilience of char. These properties are generally determined by the physical and chemical structures of the char formed[4-11].

Few researchers have paid much attention to the chemical process takes place during intumescence and they developed several models to study the heat transfer mechanism to the underlying materials. Intumescent flame retardants are characterized by molecular structure, thermal, flame retardant properties and char studies. Each one of these analyses will give its own results about the intumescent flame retardants. The char formed during intumescence has the properties of reducing volatile mass, acting as thermal insulation, obstructing the release of combustible gases and increasing the thermal insulation capacity.

Hence it is of equal importance to study in detail the char formation mechanisms. Wang and Chen[12] study indicated that the effectiveness of flame retardancy of the material depends on the cellular char developed during intumescence. It is needed to reacts phosphorus based flame retardants with polymers to promote charring. Levchik[13] et al reviewed the phosphorus flame retardants for plastics and foams.

The addition of synergistic gents like nitrogen compounds to the phosphorus flame retardants promotes charring efficiently with noncharrable polymers[14]. The study of the char forming chemistry and both the structure and morphology of the carbon char produced during intumescence will definitely help to understand the much complex intumescent mechanism. The need of investigation of char structure and properties are clearly described by Zhang et al[15]. The most widely studied intumescent flame retardant systems are ammonium polyphosphates (APP)/pentaerythritol (PER)/melamine (MEL)