Asian Journal of Chemistry Vol. 17, No. 1 (2005), 434–438

Effect of Deposited Stannous Chloride on the Flame-Retardancy Imparted to Cotton Fabric

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The effect of stannous chloride as a non-durable finish on the flammability of 100% cotton fabric (cotton woven construction, weighing 178 g/m^2) has been investigated. The laundered bonedried weighed fabrics were impregnated with suitable concentrations of aqueous stannous chloride solutions by means of squeeze rolls and dried at 65°C for 4 h. Afterwards they were cooled in a desiccator, weighed with analytical precision and kept under ordinary conditions before the fulfilment of the vertical flame test. The optimum add-on values to impart flame retardancy expressed in g anhydrous salt per 100 g fabric was about 5.0–7.71 g. The results with the impartation of stannous chloride into the cotton fabric are in favour of Free Radical Theory and also Vapour Phase Theory[1–3].

Key Words: Flammability, Flame-retardancy, Char length.

INTRODUCTION

As far as the domestic environment is concerned, residental fires annually kill between 15 and 20 thousand people in the United States alone[1]. It is noteworthly that the elderly are at greater risk of fatality due to clothing fires. While deaths due to ignition of clothing are obviously linked with the flammability of textile material, there are other hazards caused by fires. It is stated that over half of the fatalities were due to the combined effects of smoke and toxic gases[2]. These days the need for reduced flammability in various textiles has been increased by governmental legislations in many countries. Hence the incorporation of flame-retardants into consumer products such as fibres, fabrics, plastics etc. has gained great importance.

It is noticeable that the flame-retarding component[3, 4] is intended to prevent a small fire from rapidly developing into a major catastrophe[1]. Therefore a flame-retarded material is believed to be combustible in the harsh ignition circumstances.

It is mentionable that the value of chemicals sold for use as flame-retardants in Europe in 2003 was forecast by the split of income between the three main categories[5–7]: phosphorus-based chemicals 38%, inorganic compounds including $Mg(OH)_2$, $ZnSnO_3$, Sb_2O_3 and borates 36% and halogen-based organics 26%. The aim of this study is to investigate the effect of deposited stannous chloride as a non-durable finish on the flame-retardancy imparted to cotton fabrics.

EXPERIMENTAL

All fabrics were a "woven" construction, weighing 178 g/m^2, unfinished 100% cotton, laundered and dried. They were 22 cm by 8 cm strips cut along the waft direction and pre-washed in hot distilled water. The specimens were dried at 110°C for 30 min in an oven, cooled and weighed in an analytical balance.

Bath Treatment: With the exception of the first bunch, all other specimens were impregnated with suitable concentrations of stannous chloride at 20°C. Afterwards they were squeeze-rolled and dried horizontally in an oven at 65°C for 4 h (avoiding the unfair acidic effect of salt into the fabrics); then they were cooled in a desiccator and weighed with analytical precision so as the suitable add-on presented into the samples were obtained.

Flammability Test: The vertical flame test also described in the previous investigations[8–9] has been used. It is similar to the procedure described in DOC FF 3-71[10]. The conditions of the specimens and environment were in average *temperature ranged between 20° and 22°C, and the* average of relative humidity (RH) ranged between 65 and 67%. After an ignition time of three seconds at the bottom edge, the total burning time was measured at the nearest 0.1 second and the char length was measured to nearest centimetre.

The aforementioned tester is an aluminium frame: two strips of 3 mm aluminium double-sheet, 22.5 by 1.5 cm were cut, perforated and welded at right angles to a shorter 9 cm strip. The samples were pinned tightly to the frame and held vertically in a retort stand by clamps with the lower edge 1.9 cm above the top of a three centimetre yellow flame of a Bunsen burner so as the harsh ignition circumstances is avoided.

Repeatability of burning time was ±5% for untreated fabric. This repeatability for salt treated specimens was much lower. In fact the pad squeeze process gave a certain amount of variability.

RESULTS AND DISCUSSIONS

The experimental results are listed synoptically in Table-1. Vertical flame test was carefully conducted to determine the burning times in seconds (column 4). In column 5 the states of the specimens (after the tests) are given. CB means completely burned, FR means flame-retarded. The char lengths are given in centimetres in column 6. Fabrics were considered flame-retarded when a char length of less than 2.0 cm was obtained. In column 7, the burning rates are calculated by means of dividing the length of the specimens (22 cm) by the burning time (in seconds). It is noticeable that the add-on values for the same treating solution show a variability of 10% as usual (column 3). It can be concluded from the aforementioned experimental results that a range of 5.0–7.71% stannous chloride is quite sufficient to impart flame-retardancy for cotton fabric.

TABLE-1
THE EFFECT OF DEPOSITED STANNOUS CHLORIDE ON THE FLAME-RETARDANCY IMPARTED TO COTTON FABRIC
(woven 178 g/m^2)

Test No.*	Treating solution molarities	Per cent add-on anhydrous salt (drying at 110°C and weighing)	Burning time (s)	State of the fabric	Char length (cm)	Burning rate (cm/s)
1	Untreated fabric	—	37.5	CB	—	0.59
2	0.225	4.35	18.5	CB	—	1.19
3	0.250	5.00	—	FR	1.1	—
4†	0.350	7.71	—	FR	1.0	—

* Average of 5 tests.
†Confirmatory tests using excessive amounts of additives.

In recent years, the author has tested selected inorganic compounds to investigte their capability to be used as flame-retardants on cotton fabrics[7, 9, 10]. Hereby he declares that stannous chloride is one of the desirable inorganic flame-retardants which complies with the Free Radical Theory[2, 11, 12].

According to the Free Radical Theory, the mechanism taking place in the gas phase during combustion is belived to involve the generation of high-energy OH, H, O and the like radicals formed during combustion which can support the above-mentioned process, so that their removal can help to suppress the flame. To achieve this it would be ideal if these active radicals could be converted to less active ones. One example of this suppression is belived to occur when bromine or chlorine compounds are used as flame-retardants:

$$RX + H \longrightarrow HX + R \quad (X = Cl \text{ or } Br)$$

where R is a less active radical than H. It is noticeable that this effectiveness varies in different types of compounds. Although fluorinated organics show very good flame resistance (teflon needs 95% oxygen to burn), organo-fluorine compounds are not good flame-retardants because of the high carbon-fluorine bond strength. Iodine compounds due to their instability and their lack of resistance to UV light are not recommended for the flame-retardancy of materials[2, 13]. The chain reactions which occur in the combustion zone are described as follows:

$$H + O_2 \longrightarrow OH + O \quad (1)$$

$$O + H_2 \longrightarrow OH + H \quad (2)$$

The halogen retardant RX initially breaks down:

$$RX \xrightarrow{heat} R + X \quad (3)$$

where X is either Cl or Br. The halogen radical reacts to form the hydrogen halide as described in reaction (4):

$$X + RH \longrightarrow HX + R \quad (4)$$

The hydrogen halide interfereres with the radical chain mechanism as described in reactions (5) and (6):

$$HX + H \longrightarrow H_2 + X \quad (5)$$

$$HX + OH \longrightarrow H_2O + X \quad (6)$$

Therefore the high energy H and OH radicals are removed and converted by reactions with HX and replaced with less active and low energy X radicals. The hydrogen halide consumed in reactions (5) and (6) may be regenerated by reaction with hydrocarbon shown in reaction (7):

$$X + RH \longrightarrow R + HX \quad (7)$$

Therefore less active radicals like R are generated; however, inert products such as R_2 may be formed as described in reaction (8):

$$2R \longrightarrow R_2 \quad (8)$$

Ultimately the hydrogen halide generated in reactions (4) and (7) acts as a negative catalyst and the target of flame-retardancy is achieved.

The aforementioned theory bears a close resemblance to the Vapour Phase Theory, which attributes the generation of H_2O and regeneration of HCl during the combustion. According to the aforesaid theory the action of certain flame-retardants is to give off noncombustible gases like HCl, H_2O etc. in the vicinity of the inflamed fabric. Therefore the atmosphere around the inflamed specimen is modified and the flammable gases produced during the combustion are diluted so far as the role of a blanket which prevents or makes very difficult the access of oxygen is fulfilled.

Although several authors have pointed out that halogen containing flame-retardants are also effective in the condensed phase[14–16]. However, it does not seem that stannous chloride plays the same role. This is due to the appearance of the phenomenon described as "glow" observed in the inflamed specimen, *i.e.*, fabrics continued to glow after they had ceased to flame, leaving a little ash.

In general, the use of tin-based chemicals as flame-retardants is increasing in importance. The aforementioned flame-retardants appear to have a great potential future: they are non-toxic, apparenthy producing none of the hazardous side effects of the widely used phosphorus-based materials[8].

Conclusion

In this paper the action of stannous chloride deposited as flame-retardant into the cotton fabric has been investigated and commented. This salt has demonstrated a desirable flame-retardancy; however, no glow proofing performance has been observed from its impartation. This behaviour is hypothesized due to its accomplishments in favour of Free Radical Theory and Vapour Phase Theory.

The deposited salt could not hinder the generation of glow, hence the implication of "Condensed Phase Retardation" cannot be justifed by its application.

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(*Received*: 1 May 2004; *Accepted*: 3 September 2004) AJC-3549