Effect of Polyvinyl alcohol on Burning Rate for Flexible PVC with Addition of Magnesium hydroxide and Aluminum tri-hydroxide

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Abstract

In this research study the effect each of Polyvinyl alcohol, magnesium hydroxide, Aluminum trihydroxide on Polyvinyl chloride combustion speed used in the manufacture of electrical cables. Several composite samples were manufactured using the twin screw extruder. Combustion speed measured by the specification (ASTM D 635-03) as been studying composite samples surfaces using scanning electron microscope technology. The results that the parent used three additives reduce the combustion speed and turning the surface of fine to coarse.

Keywords : Polyvinyl chloride , Polyvinyl alcohol , Magnesium hydroxide , Aluminum tri-hydrate , Burning rate , Flame retardant .

الخلاصة :

في هذا البحث تم دراسة تأثير كل من البولي فينيل الكحول، هيدروكسيد المغنسيوم و ثلاثي هيدروكسيد الألمنيوم على سرعة احتراق البولي فنيل كلورايد المستخدم في تصنيع الكبيلات الكهربائية. عدة عينات تم تصنيعها باستخدام الباثق الحلزوني المزدوج وقيست سرعة الاحتراق حسب المواصفة العالمية (ASTM D 635-03)، كما تم دراسة سطوح العينات باستخدام تقنية مجهر المسح الإلكتروني .أضهرت النتائج أن المضافات الثلاث المستخدمة تقلل من سرعة الاحتراق وتحول السطح من ناعم الى خشن .

الكلمات المفتاحية:بولي فنيل كلوريد ، بولي فنيل الكحول ، هيدروكسيد المغنيسيوم ، ثلاثي هيدروكسيد الالمنيوم، معدل الاحتراق، معيقات اللهب .

1. Introduction

PVC is a thermoplastic polymer that can be processed by a variety of techniques like injection molding, extrusion, blow molding, and compression molding. PVC is an amorphous, rigid polymer due to the large side group (Cl, chloride) with a T_g of 75 to 105ºC and softens at about 85°C. Also in rubbers, PVC are sometimes added in order to improve the impact strength. It is fairly weak and extermely notch-sensitive but has excellent resistance to chemicals [Brede *et.al.,* 2003 , Miley ,1996 , wakil , 1998].

PVC is one of the largest volume commodity plastics produced in the world and is expected to continue with a good high growth rate. PVC is a rigid plastic in un-plasticized state, but, in the presence of plasticizers, PVC is a flexible plastic. PVC is used in a wide range of applications because of its combined properties of high modulus, ease of fabrication, low flammability and low cost. [Yu, 2010]. The low thermal resistance of PVC considered the primary limitation to the use it in applications that required high thermal resistance ; hence an important way to increase their power to resist flame and improve the heat and thermal resistance properties is treated it with flame retardant . [Bhattacarjee *et.al* .,2013]

The main applications of PVC are: pipes, gutters, front panels of buildings, cables,toys, dinnerware, bottles, floor tiles and credit cards. A much softer and more flexible material is obtaind by blending plasticizers: soft or plasticized PVC is being used in artificial leather, tubes and hoses, footwear, rainwear, films, and as insulating coatings on wires [Brede *et.al.,* 2003 , Miley ,1996]

2. Experimental

2.1 Materials

Flexible Polyvinyl chloride (PVC) was used as basic materials in the preparation of composite , was obtained from Reagent World (USA); Polyvinyl alcohol (PVA) powder was obtained from Yonghui chemical Holdings Limited Company, china, used as additives to improve the compatibility between metal hydroxide and polyvinyl chloride (PVC), and at the same time as a flame retardant material. Magnesium hydroxide (MH) powder was obtained from Central Drug House (CDH) company, India and Aluminum tri- hydrate (ATH) powder was obtained from Himedia company, India, were using as additives to improve the flame retardancy of polyvinyl chloride (PVC).

2.2 Testes

Flame Test

Burning rate of specimens is calculated according to the Standard (ASTM D 635-03) in a horizontal Position. In this test The specimens are cutting in dimension (125)mm long by (13)mm wide, then mark each specimens with two lines perpendicular to the longitudinal axis of the samples (25)mm and (100)mm from the end that is to be ignited. Clamp the specimen at the end farthest from the (25)mm reference mark, after clamping of specimen apply the flame at (45^5) for (30)sec without changing its position, place the burner remote from the specimen, ignite, and adjust it to produce a blue flame 20 mm high. Adjust the gas supply and the air ports of the burner until a 20-mm yellow-tipped blue flame is produced. After removing the flame , record the elapsed time (t), in second and measured the burned length in millimeters ,see figure (1) . Calculate the burning rate (v)mm/sec, according to the following equation[ASTM D 635-03 1998] :

$$V= 60\ L / t$$

where:

L = the burned length, in millimeters.

t = the time, in seconds.

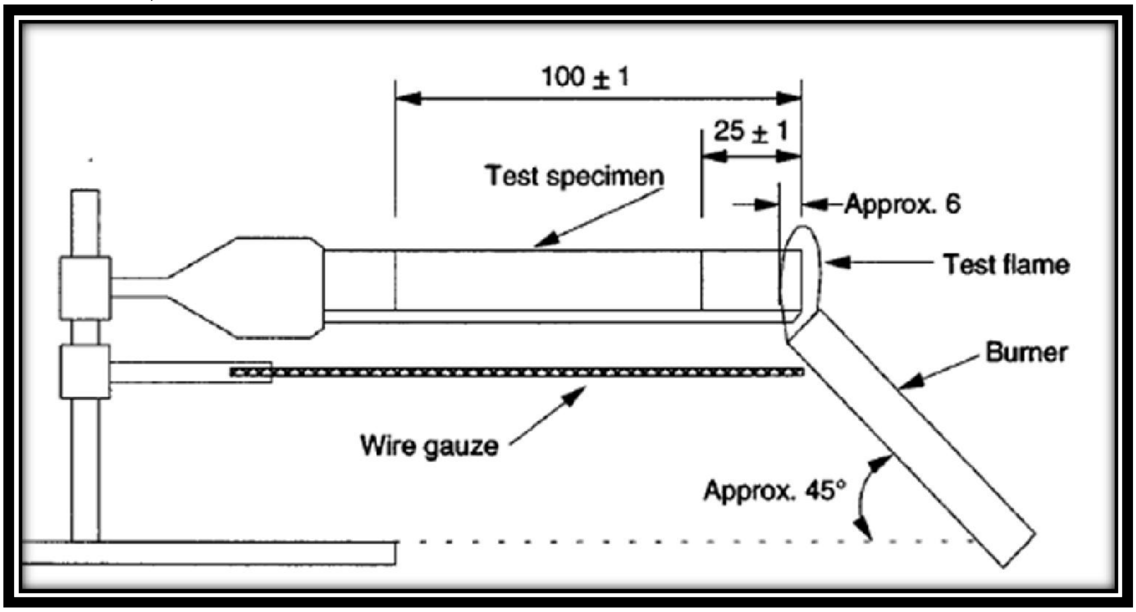


Figure (1) Test Fixture

Scanning electron microscopy (SEM)

The scanning electron microscope (SEM) is one of the most versatile instrument available for the examination and analysis of the microstructure morphology and chemical composition characterizations and considered kind of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition [Zhou *et.al.,* 2007] , see figure (2). The electron beam is generally scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image. Non-conducting samples are usually coated with a thin layer of carbon or gold in order to prevent electrostatic charging. SEM can achieve resolution better than 1 nanometer [Goldestin *et.al.,* 2012].

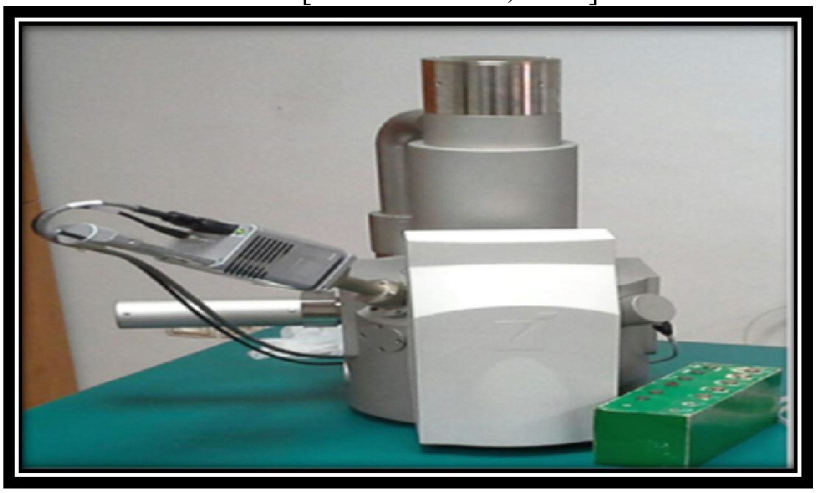


Figure (2): The Scanning Electron Microscopy Machine.

2.3 PVC Composite Preparation

PVA was dissolved in deionized water at 100 ^{5}C by using magnetic stirrer until obtaining transparent and thick solution like glue, then MH, ATH and MH+ATH as shown in tables 1-4were added to the solution of PVA, then PVC was added with good mixing until obtaining homogeneous dough. The homogeneous dough was feed to the co-rotating twin screw extruder model (SIJ-30A) at (145-160)^{5}C , (25 – 38) rpm . The extruded material pass through the rolls to obtain sheets with 3mm thickness, then the sheets were cut .

Table (1) : polyvinyl chloride and magnesium hydroxide with polyvinyl alcohol.

PVC (Phr)	MH (Phr)	PVA (Phr)
100	5	2
100	10	4
100	15	6
100	20	8
100	25	10
100	30	12

Table (2) : polyvinyl chloride and aluminum tri-hydrate with polyvinyl alcohol.

PVC (Phr)	ATH (Phr)	PVA (Phr)
100	15	6
100	30	12
100	45	18
100	60	24

Table (3) : polyvinyl chloride ,magnesium hydroxide and aluminum tri-hydrate with polyvinyl alcohol.

PVC (Phr)	MH (Phr)	ATH (Phr)	PVA (Phr)
100	30	60	36

Table (4) PVC composite without PVA.

(PVC)Phr	(MH)Phr	(PVC)Phr	(ATH)Phr	(PVC)Phr	(MH+ATH)Phr
100	10	100	15	100	90

3 . Results and discussion

3.1 Flame Test

Figure (3) shows the results of burning rate (v) that obtained from the flame test (ASTM D 635-03) of PVC composites that contain MH with PVA those shown in table (1) .

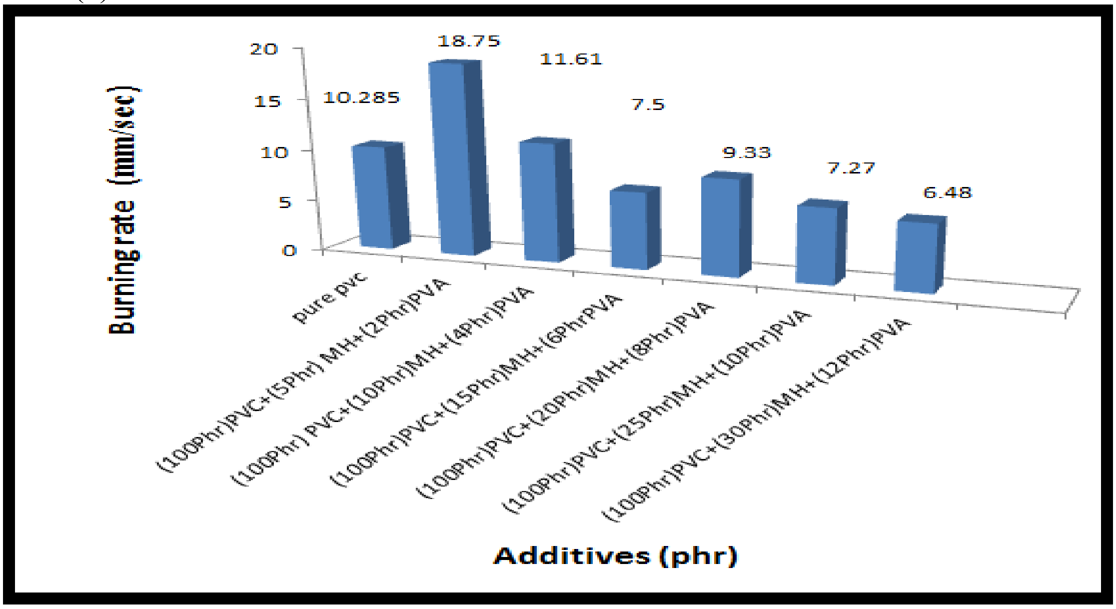


figure (3) : Burning rate for composites consist of PVC ,MH and PVA .

From figure (3) , it can see that pure PVC can be easily ignited in air condition ; Addition of (5 , 10) phr from MH accelerate the burning of PVC , because quantity of it is little therefore there is no effect of it on burning rate of PVC ; but with increasing MH amount, the burning rate of PVC composites decreases gradually. When the amount of MH reach to 30 phr, the burning rate of PVC composite decreases obviously. Generally , these results showed that the increasing in the amount of Magnesium hydroxide leads to high decreases in burning rate of PVC composites.

This is because that the (MH) absorbed the energy from the fire . this lead to reduce the total energy and enhance the reaction which regard as retarded for composition . this reaction (eq 1 , Hollingbery *et.al.,* 2010) liberates the water molecules and enhance the self-extinction.

$$Mg(OH)_2 \xrightarrow[+\ 1300\ kJ\ /\ kg]{300\ ^{\circ}C} H_2O + MgO \quad\text{———}\quad 1$$

Figure (4) show the results of burning rate (v) of composites those contain PVC, ATH , PVA.

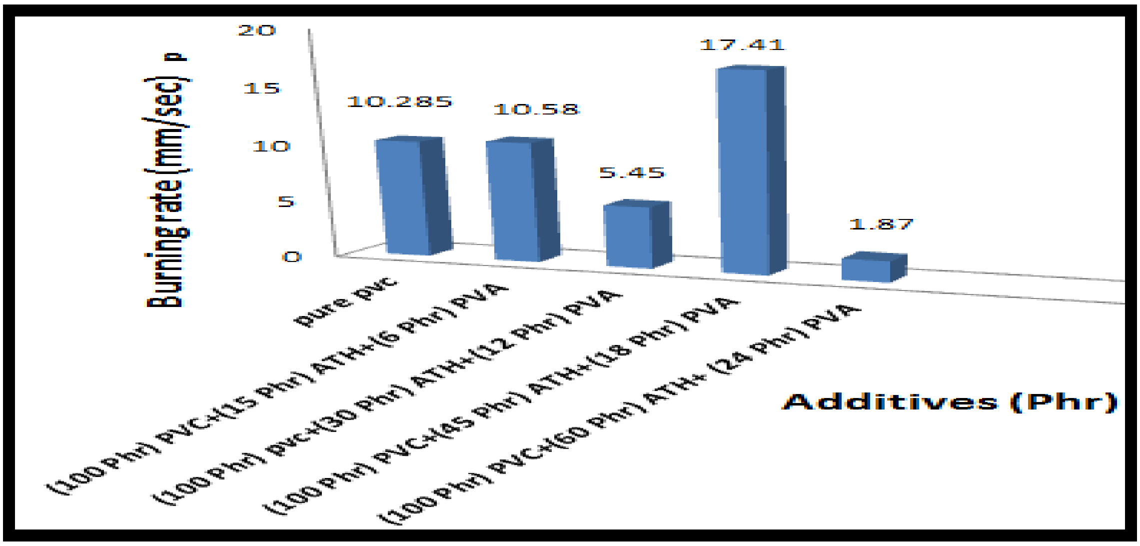


figure (4) : Burning rate for composites consist of PVC, ATH and PVA.

It is clear from figure 4, (15Phr) from ATH has no effect on fire behavior of PVC ; While increasing the amount of ATH to (30) phr , The burning rate of PVC composite is decreases obviously from (10.58) to (5.45) mm/sec . When the amount of ATH is reach to (60) phr , The burning rate reached to the minimum value (1.87) mm/sec.

The mechanism of flame retardancy of (ATH) depends on breakdown of it in temperature range 180-200 . After absorbing the energy from the fire, ATH will convert to aluminum oxide. This taking place in an endothermic reaction with release the water vapor. As a result of the endothermic breakdown of (ATH), the PVC composite is cooled , and thus fewer pyrolysis product are formed. The aluminum oxide formed on the substrate acts as an insulating protective layer as shown in equation (Hollingbery and Hull ;2010) .

$$2\,Al(OH)_3 \xrightarrow[+\,1050\ kJ\,/\,kg]{200\ ^\circ C} 3\,H_2O + Al_2O_3 \qquad \text{———} \qquad 2$$

figures (5) to (6), show the differences between the effects of polyvinyl alcohol on burning rates of polyvinyl chloride with magnesium hydroxide, aluminum tri-hydrate and the mix of MH and ATH.

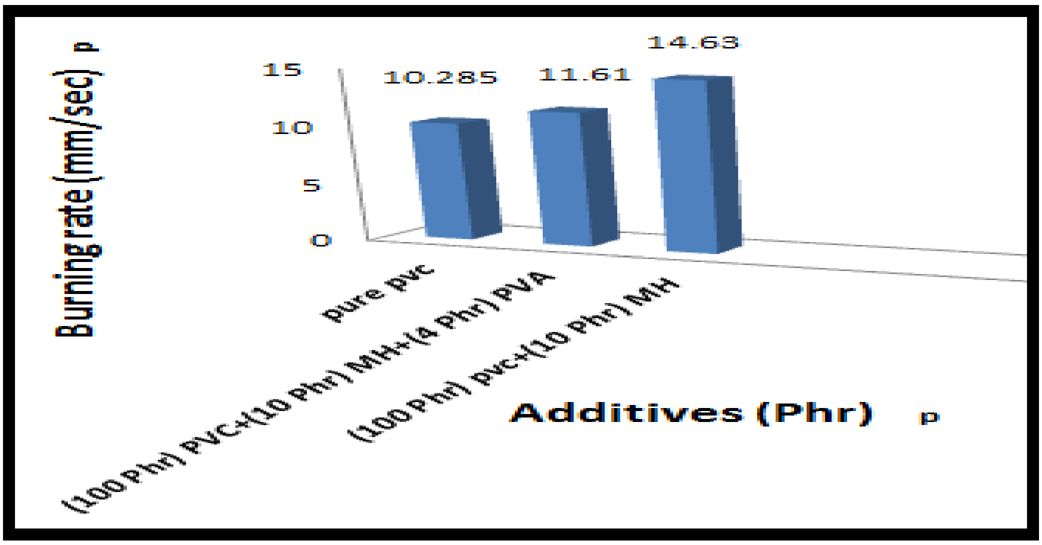


Figure (5) : Burning rate of PVC composites that contain MH with, and without PVA.

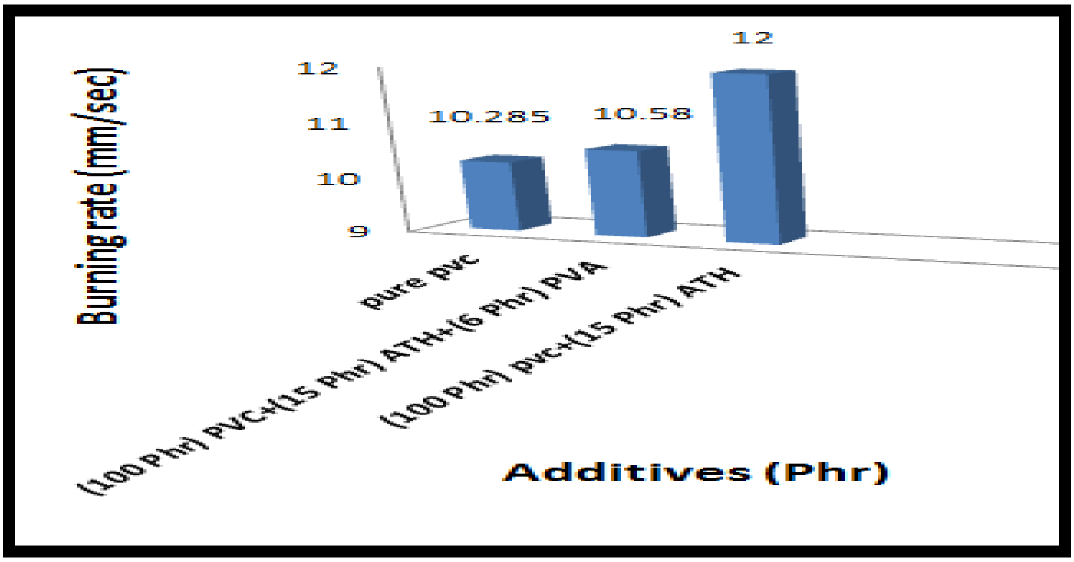


Figure (6) : Burning rate of PVC composites that contain ATH with, and without PVA.

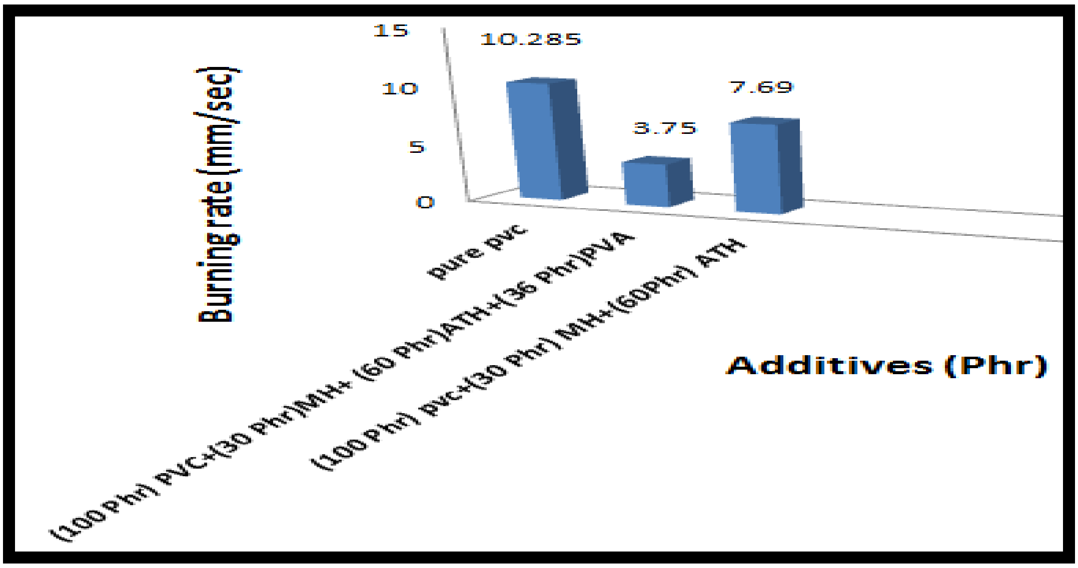
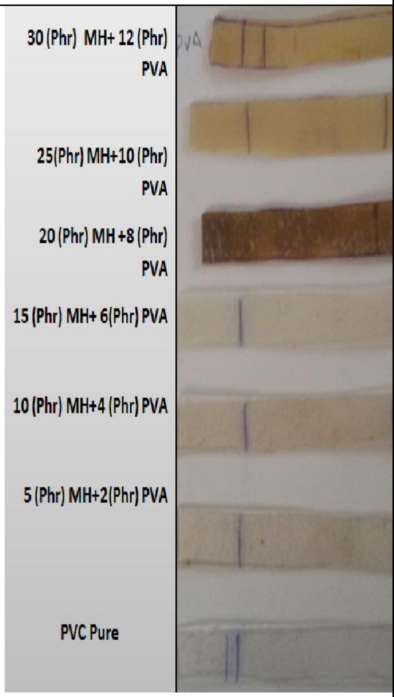
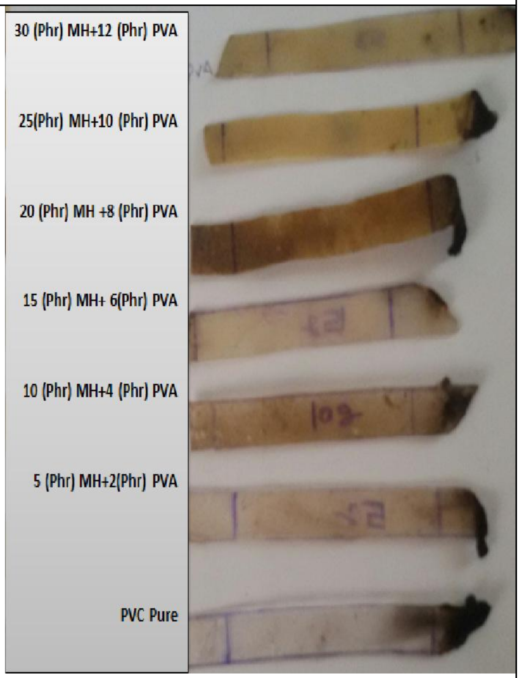


Figure (7) : Burning rate of PVC composite that contain MH and ATH with, and without PVA.

From figures 5 to 7 , PVC composites those contain PVA has lower burning rate than without (PVA). This is, because most composition of (PVA) is hydroxyl group which is when exposed to heat , it begin to hydrolysis and release high quantity of water which extinguish the fire and lowered the burning rate. The burning rate for PVC composite that contain magnesium hydroxide without polyvinyl alcohol is (14.63)mm/sec was decreased to to (11.61)mm/sec when added PVA to same quantity of MH and PVA. Also burning rate of PVC composite that contain aluminum tri-hydrate is lowered from (12)mm/sec to (10.58) mm/sec when added PVA . The burning rate for PVC composite that contain mix of (MH+ATH) is recorded higher reduction from (7.69)mm/sec to (3.75)mm/sec when added polyvinyl alcohol than without.

Table (5) photographic image of the flame test samples before and after the flame test.

<table>
<tr><td>PVC composite composition</td><td>Before test</td><td>After test</td></tr>
<tr><td>PVC+MH+ PVA</td><td>
</td><td>
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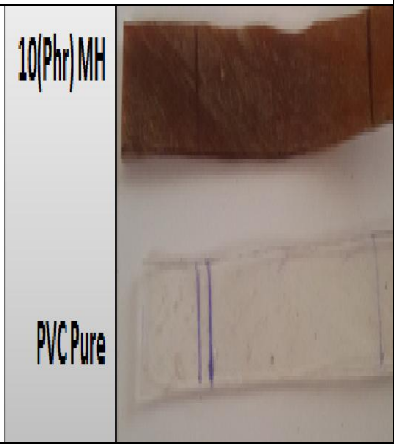
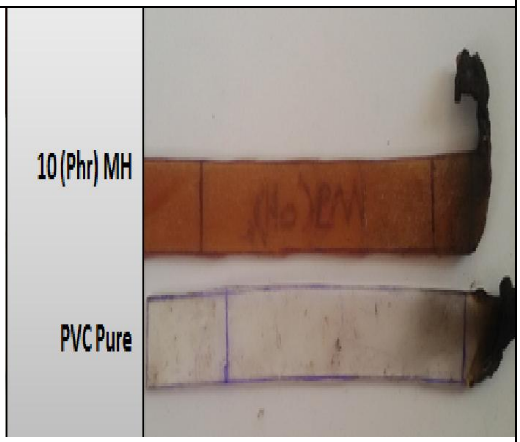
<tr><td>PVC+MH</td><td>
</td><td>
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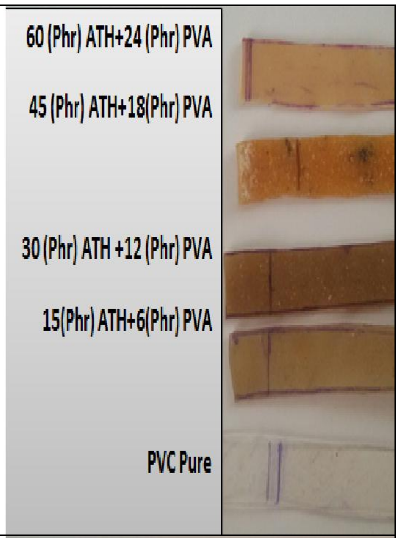
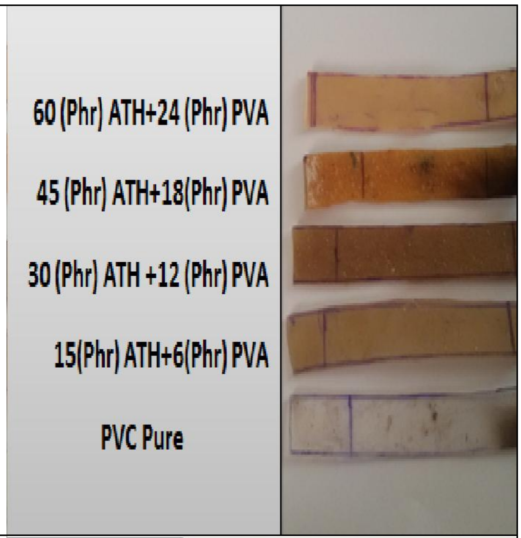
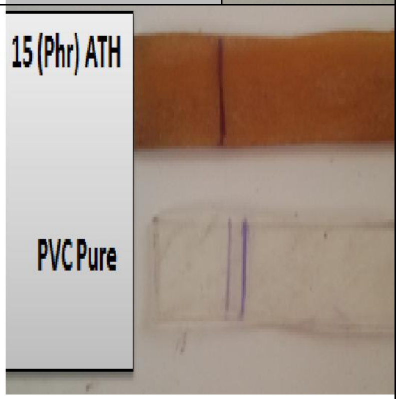
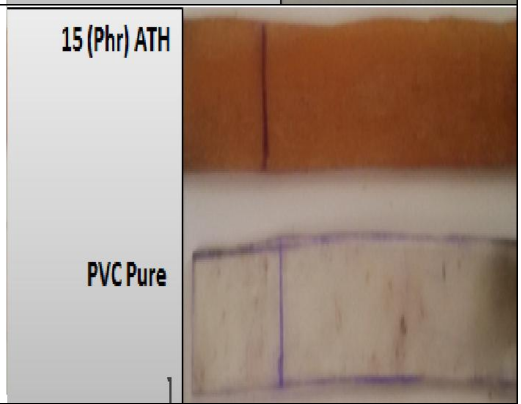
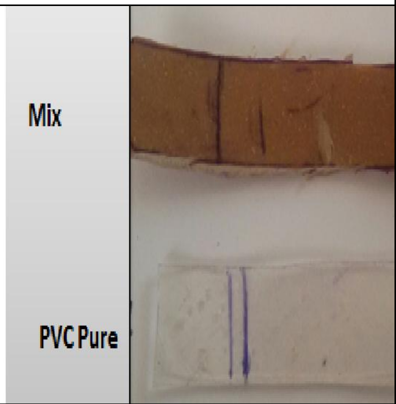
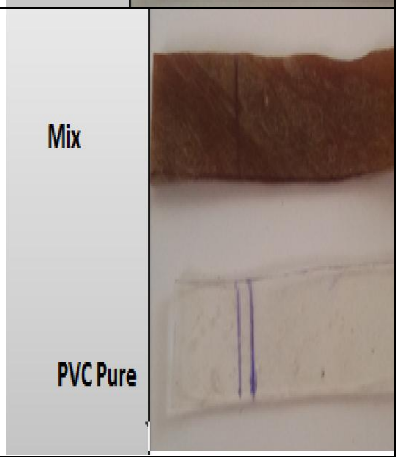
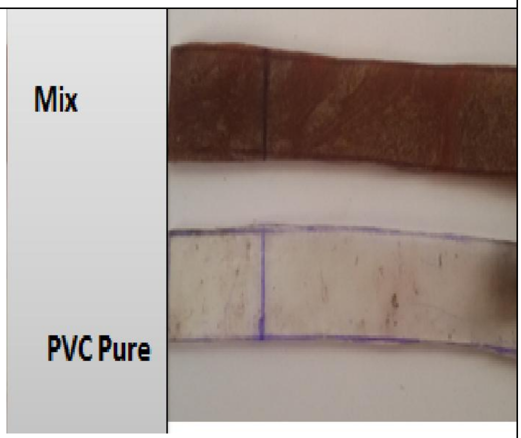
</table>

PVC+ATH +PVA		
PVC+ATH		
PVC+MH+ ATH+PVA		
PVC+MH+ ATH		

3.2 Scan Electron Microscope (SEM) Test:

Figure (8) to (11) show the SEM images of pure PVC and PVC composites that contain metal hydroxide and polyvinyl alcohol , It is clear from figure (8) that the morphology of pure PVC, is smooth surface .

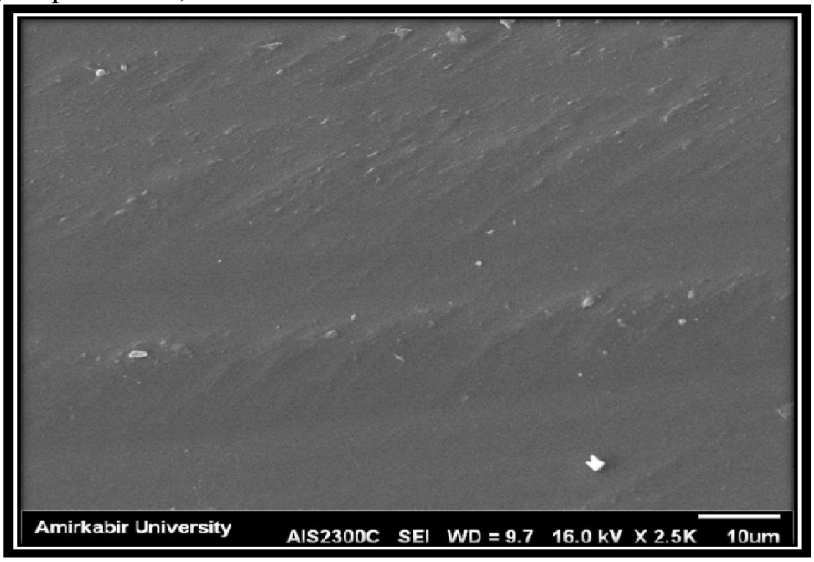


Figure (8) : SEM image of pure PVC .

Figure (9) , shows the SEM image of (PVC+MH+PVA) composite , It is clear that this composite with rough surface. This create good mechanical adhesion between MH and PVA with PVC. Also, it clear that both MH and PVA molecules imbedded in PVC matrix.

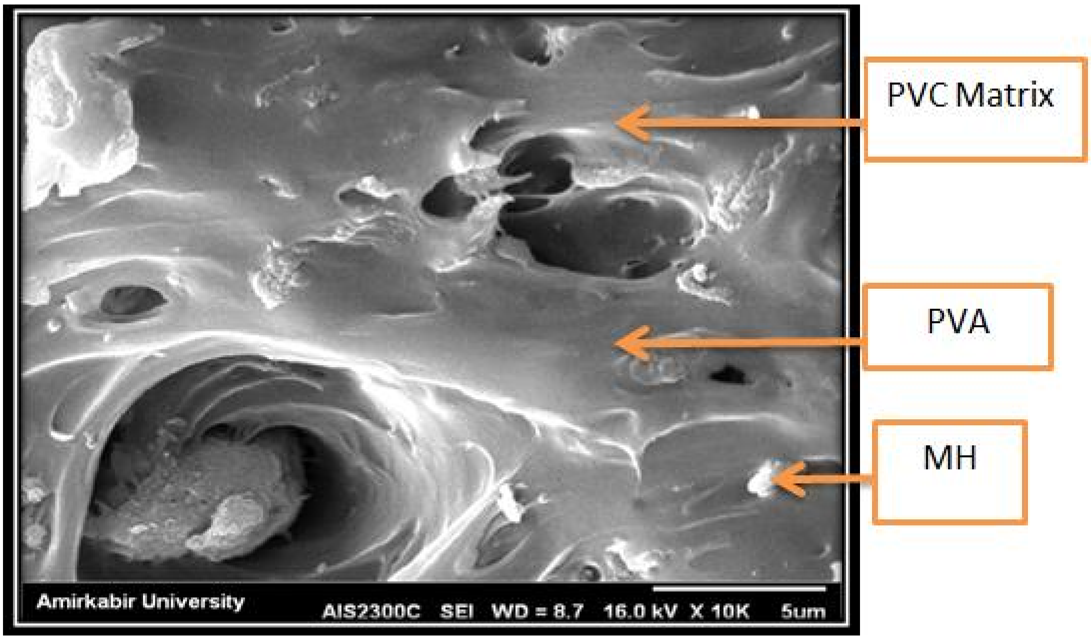


Figure (9) : SEM image of PVC composite containing (MH+PVA).

Figure (10) , shows SEM image of (PVC+ATH+PVA) composite .

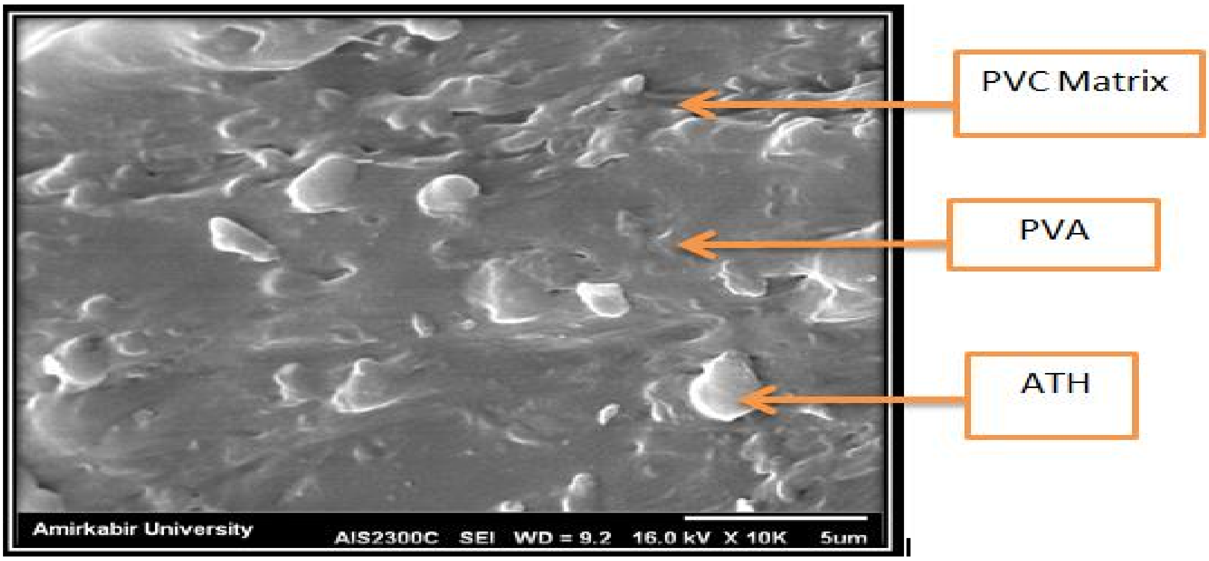


Figure (10) : SEM image of PVC composite containing (ATH+PVA).

Figure (11) shows SEM image of PVC composite containing (MH+ATH+PVA), It is clear from this figure that there is a phase separation between the components. Also , the surface become more rough .

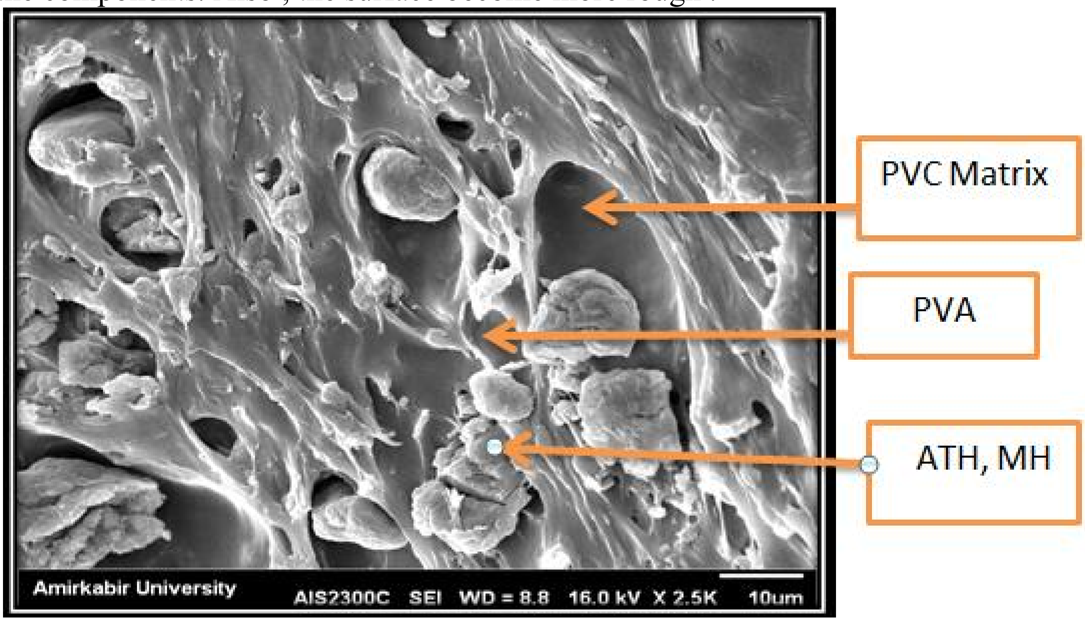


Figure (11) : SEM image of PVC composite containing (MH+ATH+PVA).

4. Conclusion

Flame –retardant systems composed of polyvinyl chloride and intumescent flame retardant IFR system (magnesium hydroxide and aluminum tri-hydrate) with polyvinyl alcohol were processed by using co-rotating twin screw extruder. Results showed that polyvinyl alcohol has significant influence on burning rate of PVC composite, where the burning rate of both PVC/MH and PVC/ATH composites are more lowering when added PVA. Also the burning rate continue to decreasing when increase the amount of (MH,ATH,PVA). SEM results showed that the addition of PVA, MH and ATH change the PVC surface from smooth to rough surface .

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