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15·16 MAY 2019
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FIRE RESISTANCE vs ENVIROMENTAL CONCERNS IN ENGENEERING THERMOPLASTIC POLYMERS

Micaela Lorenzi
Ethel Garlaschi
15-May-2019
ARESE- ITALY

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- POLYMERS THERMAL DEGRADATION MECHANISM
- FLAME RETARDANT MECHANISMS: *1) WATER DEVELOPMENT HF, 2) GAS PHASE Br-Sb vs HF,3) DRIPPING Br vs HF, 4)CHAR HF, 5)INTUMESCENT HF*
- ENGENEERING POLYMERS FR: PA, PBT-PET, PC, PC/ABS, PPO/HIPS, ABS, HIPS.
- CHOICE CRITERIA
- CONCLUSIONS

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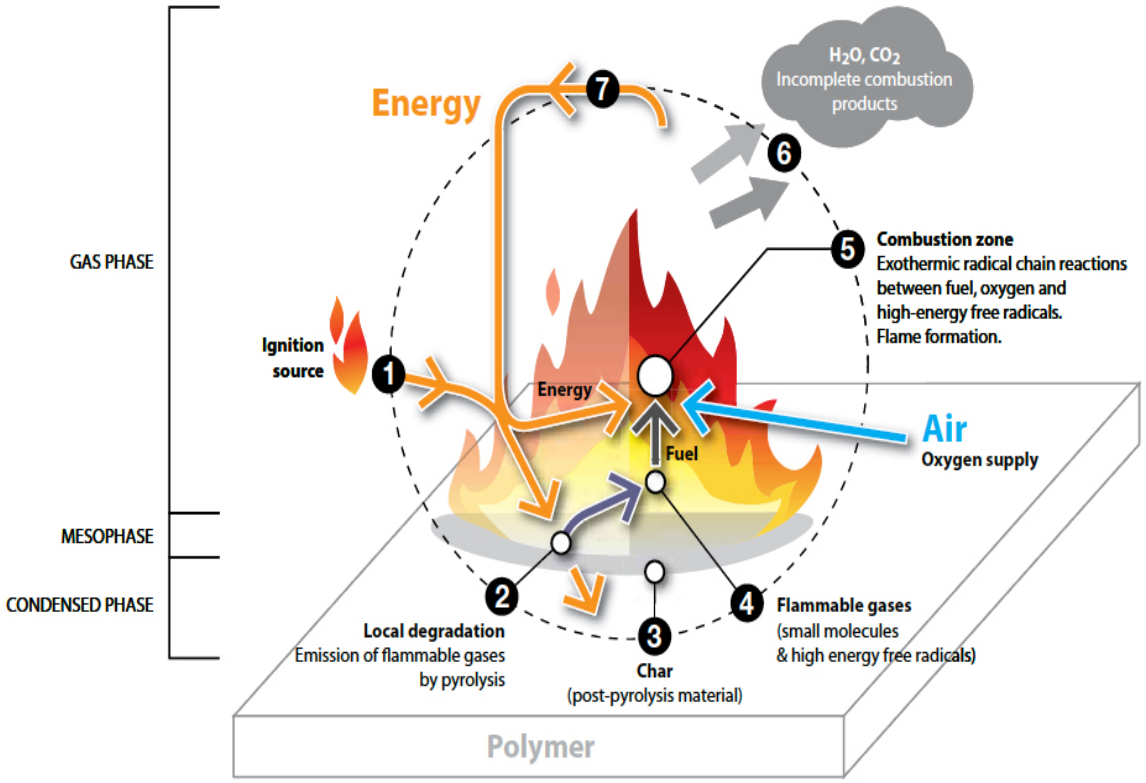
COMBUSTION



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OXIDATION CHEMICAL REACTION

Development: HEAT
FLAMES
SMOKE AND GAS

STEPS OF COMBUSTION:

HEATING
DECOMPOSITION
IGNITION
COMBUSTION
PROPAGATION

RADICAL REACTION

Oxigen is used by H• for radical chain degradation:

$H\bullet + O_2 \rightarrow OH\bullet + O\bullet$
$CO + OH\bullet \rightarrow CO_2 + H\bullet$

LOI: Limiting Oxigen Index

LOI: It is the minimum oxygen percentage needed to make a polymer burning

Polymer	Oxigen Index(% O_2)
PMMA	17.3
PP	17.5
PS	17.8
Paper	18.2
ABS	18.8
PET	20.0
NORYL	24.3
PA 6,6	24.3
PC	24.9
Polifenilen ossido	30.0
Polisolfone	38.0
PVC	40.3
PTFE	95.0

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1) WATER DEVELOPMENT MECHANISM

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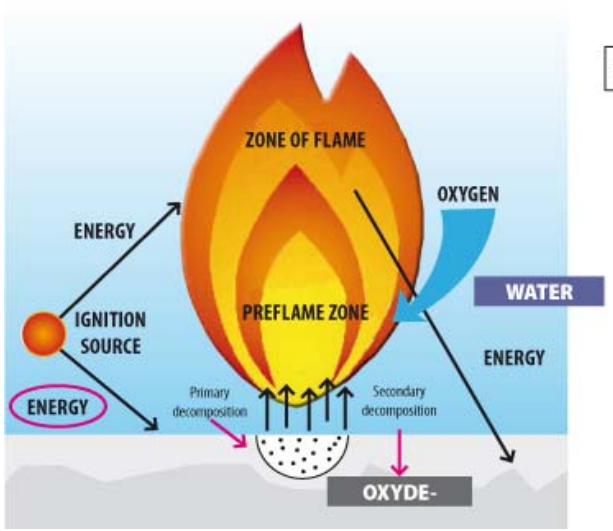
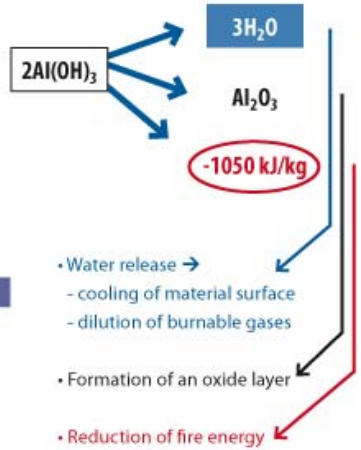
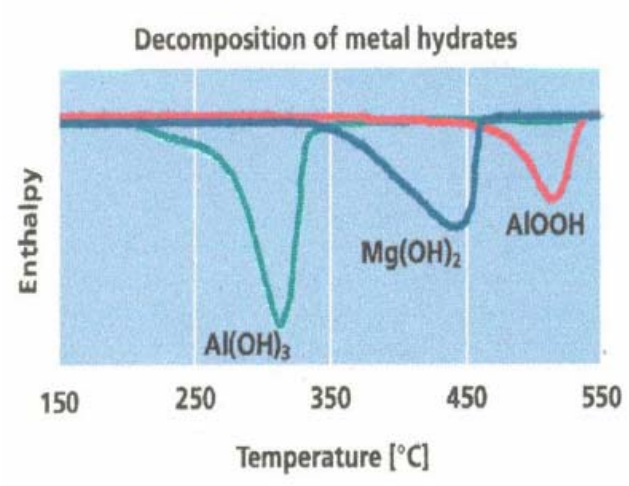
$2Al(OH)_3 + 1075\ kJ/kg \rightarrow Al_2O_3 + 3H_2O$

$Mg(OH)_2 + 1220\ kJ/kg \rightarrow MgO + H_2O$

$2AlOOH + 700\ kj/kg \rightarrow Al_2O_3 + H_2O$







PHISYCAL MECHANISM IN CONDENSED PHASE AND GAS PHASE

Cooling down
Diluition of oxigen, LOI decreasing

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2) MECHANISM GAS PHASE with bromide and Antimony

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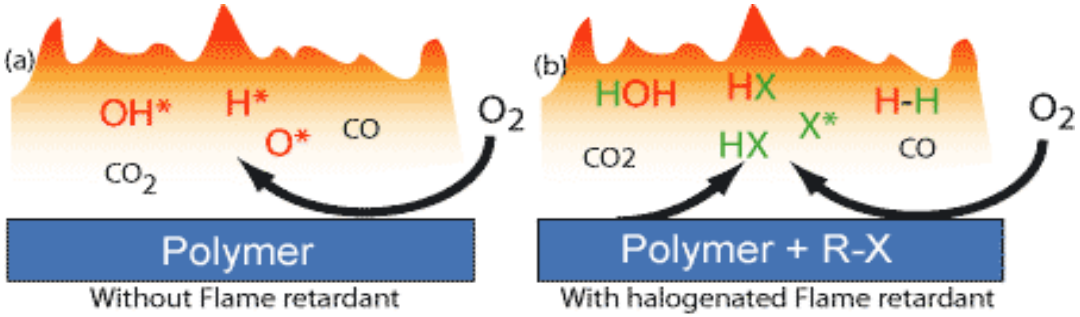
Brominated flame retardants, with help of antimony trioxide, generate HBr and radicals, which block radical chain degradation of polymer during fire. HBr developed, diluite also oxigen and ihnibits fire.



Gas phase radical Br mechanism

Example:

Br-FR + Sb_2O_3

Hydrocarbons burning

$CO + OH\bullet \rightarrow CO_2 + H\bullet$

$RCH_3 + OH\bullet \rightarrow RCH_2\bullet + H_2O$

$RCH_2\bullet + O_2 \rightarrow RCHO + OH\bullet$

$H\bullet + O_2 \rightarrow OH\bullet + \bullet O\bullet$

Br Flame retardant action

$HBr + OH\bullet \rightarrow H_2O + Br\bullet$

$HBr + \bullet O\bullet \rightarrow OH\bullet + Br\bullet$

$HBr + H\bullet \leftrightarrow H_2 + Br\bullet$

$HBr + RCH_2\bullet \leftrightarrow RCH_3 + Br\bullet$

$RBr \leftrightarrow OH\bullet + Br\bullet$

Flame retardant with Sb_2O_3

$Sb_2O_3 + 6HBr \leftrightarrow 2SbBr_3 + 3\ H_2O$

$SbBr_3 + H\bullet \leftrightarrow SbBr_2 + HBr$

$SbBr_2 + H\bullet \leftrightarrow SbBr + HBr$

$SbBr + H\bullet \leftrightarrow Sb + HBr$

$Sb + O\bullet \leftrightarrow SbO\bullet$

$Sb\ O\bullet + H\bullet \leftrightarrow SbOH$

$SbOH + H\bullet \leftrightarrow SbO\bullet + H_2$

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2) MECHANISM GAS PHASE HALOGEN FREE With Phosphorus

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P Flame retardant action in gas phase

$PO\bullet + H\bullet \rightarrow HPO$

$PO\bullet + OH\bullet \rightarrow HPO_2$

$HPO\bullet + H\bullet \rightarrow H_2 + PO\bullet$

$OH\bullet + H_2 + PO\bullet \rightarrow H_2O + HPO$

$HPO_2\bullet + H\bullet \rightarrow H_2O + PO\bullet$

$HPO_2\bullet + H\bullet \rightarrow H_2 + PO_2$

$HPO_2\bullet + OH\bullet \rightarrow H_2O + PO_2$

Not all P molecules are able to react in the gas phase.
Suitable P compounds must be volatile during polymer pyrolysis.
In addition to this, ability of P to act in gas phase is higher, as lower is the oxidation number.

Phosphate>Phosphonate>Phosphinate>Pred

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GAS PHASE: BrSb vs HF-SbF

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BrSb +	BrSb -	HF +	HF -
DOSAGE LEVEL	BROMIDE CONCERN	ENVIROMENTAL FRIENDLY	LOW THERMAL STABILITY
COST	ANTIMONY CONCERN	LOW SMOKE TOXICITY	LOW COMPATIBILITY
AVAILABILIY	LONG TERM AVAILABILITY	EASIER RECYCLING	HIGHER COST AND DOSAGE
DEEP KNOWLEDGE FOR LONG USE	RECYCLING ISSUES		DIFFICUL PHYSICAL FORM

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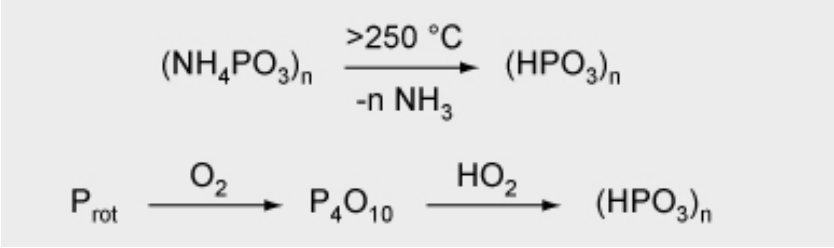
3) MECCANISMO CHAR CONDENSED PHASE

CHEMICAL AND PHYSICAL REACTION IN SOLID PHASE

Polymer char, who ihnibits pyrolisis and reduce oxigen flux to fresh polymer.

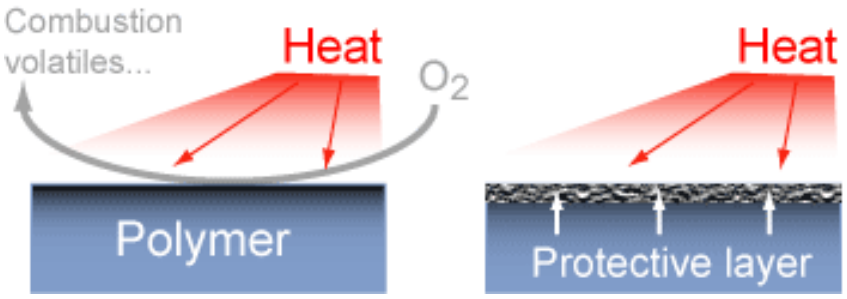
P based products dehydrates polymer and create char layers.



REACTIVE SYSTEM:

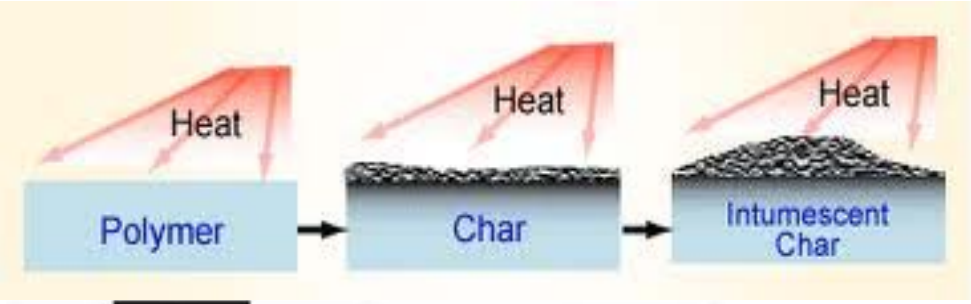
P BASED PRODUCTS

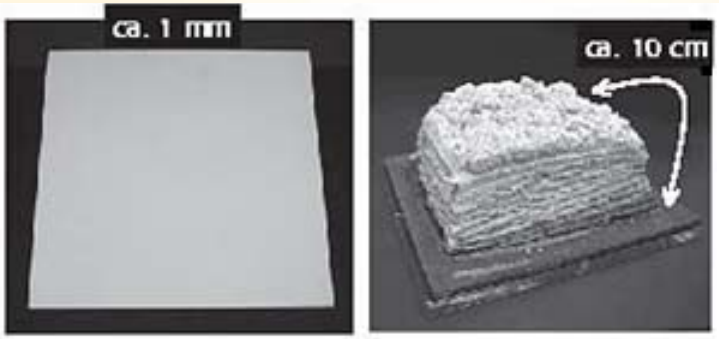
BETTER WITH POLYMERS WITH HETEROATOMS



4) INTUMESCENT MECHANISM

Example of reactive syste:
CHARING AGENT
P BASED INORGANIC ACID
N BASED FOAMING AGENT



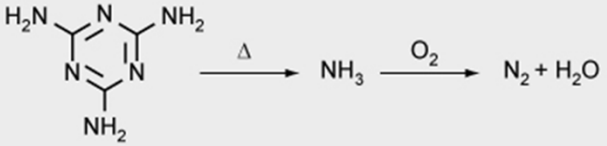


The thickness of the intumescent foam increases 10 to 100 fold that of the originally applied coating and insulates the substrate by its low thermal conductivity.

CHEMICAL ACTION

SOLID PHASE REACTION
Dehydratation and degradation of polymer with char formation.
Protective layer swelling.

GAS PHASE ACTION
Not flammable gas formation.



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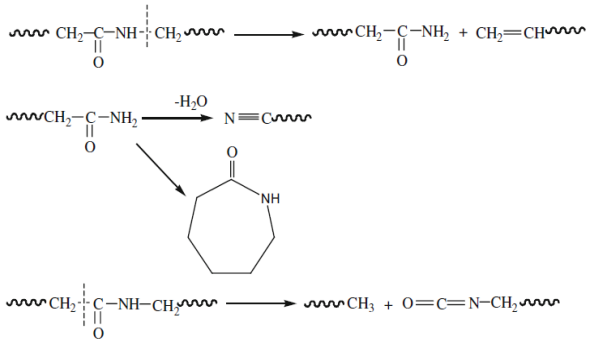
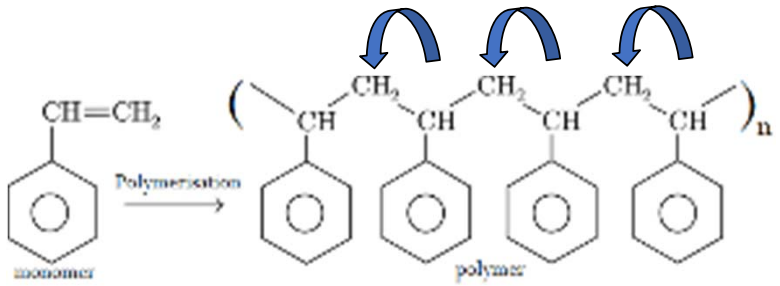
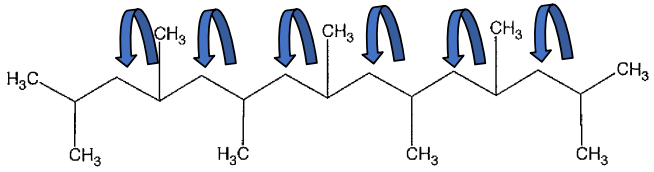
5) DRIPPING OR CHAIN SCISSION MECHANISM

CHEMICAL ACTION IN GAS PHASE

Flame retardant, after heating, generates active radicals, which cut polymer chains, making the polymer from solid to liquid, which is an endothermic reaction.







GC HF 693 PHOSPHONATE

GC HF 693 works with char/intumescent mechanism. It's 20% more active than a phosphate. Extremely thermal stable (1% 350°C). Solid at room T, but easy melting into the polymer.

PROPERTY	VALUE
P	14%
N	7
Density	1,72-1,75 g/cm3
TgA (1% loss)	300°C
Melting point °C	110-117°C

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GC CPP1 and GC CPP2 CYCLIC PHOSPHONATEs

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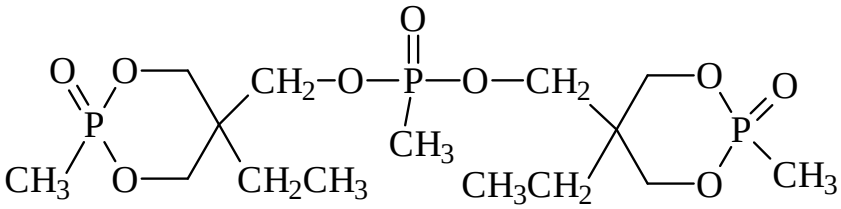
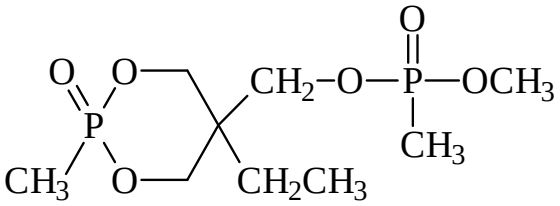
PROPERTY	VALUE
P	> 20%
Apparence	Colorless liquid
Density	1,25-1,27 g/cm3
TgA (1% loss)	300°C
Avarage particle size, µm	5

CPP1 and CPP2 work with char mechanism at lower loading level than phosphate. They can offer very good FR and high thermal stability. This is due to high P content and deydrogenation.
It promotes very thick char at low loading level.





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METAL PHOSPHINATES
Al, Ca, Zn.

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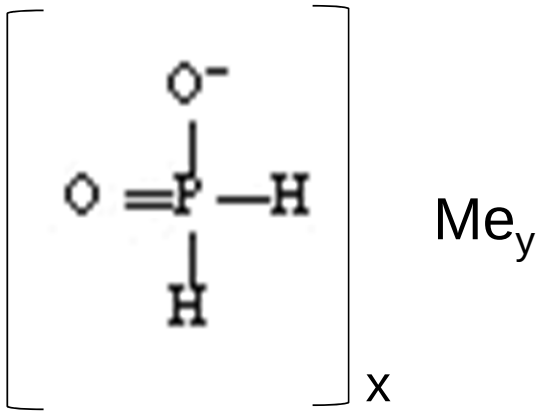
MeP1, as well as other hypophoshites, works in gas phase. Thermal stability is high, and P level is highest in P molecules. Acidity level depends from metal.

PROPERTY	VALUE
P	>19 %
N	>0
Density	1,80 – 1,90 g/cm3
TgA (1% loss) TgA (5% loss(	320°C 360°C
Avarage particle size, µm	5



MELAMINE PYROPHOSPHATE

MPYR is stable phosphate product. Less sensitive to moisture, ideal for intumescent/char formulations.

PROPERTY	VALUE
P	19
N	14
Density	1,80 – 1,90 g/cm3
TgA (1% loss) TgA (5% loss)	300°C 360°C
Avarage particle size, µm	5 µm
pH (10% susp. @ 20°C)	5-6

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GC PIPERAZINE INT

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GC PIPER is a very active P/N flame retardant. When good formulated shows activity at low loading level. Stable and less igroscopic.

PROPERTY	VALUE
P	22
N	21
Density	1,80 – 1,90 g/cm3
TgA (1% loss) TgA (5% loss)	250°C 280°C
Avarage particle size, µm	10 µm
Loss on drying	0,5 max

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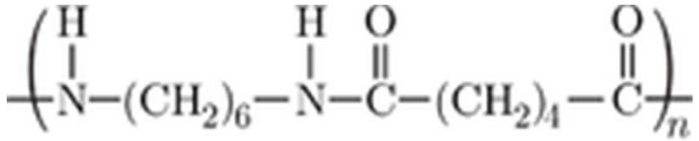
GC MELAMINE IPOPHOSPHITE

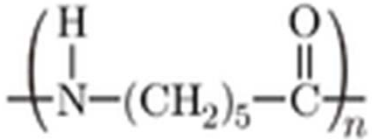
GC MIPO has together properties of ipophosphite and melamine. It very good and active, specially in PO.

PROPERTY	VALUE
P	19
content	99%
Melting range	128 – 133 °C
TgA (1% loss) TgA (5% loss)	250°C 280°C
Avarage particle size, µm	10 µm
Loss on drying	0,5 max

POLYAMIDE



Nylon 66



Nylon 6

LOI	
PE	17
ABS	18
PA	24
PC	27
PTFE	95

HIGH LOI	GOOD FLAME RESISTENCE
N AND O IN CHAIN	LESS FLAMMABLE GASES
HIGH PROCESSING T, 230°C – 280°C	FR MUST BE THERMAL RESISTANT
PRESENCE OF N AND O	CHAR
POLICONDENSATION	DRIPPING
CROSS-LINKING ABILITY	CROSS-LINK

POLYAMIDE	TEST	+	-	GREENCHEMICALS PURE PRODUCT	GREENCHEMICALS BLENDS OR MASTERBATCHES
METAL HYDROXIDE	-	NO HEALTHY AND ENVIROMENTAL PROBLEMS	HIGH DOSAGE	GC Mg(OH)2	MB EVA MGOH
DECA-OXIDE/ Sb_2O_3 ($ZnBO_3$)	UL94 V0	LOW DOSAGE LOW COST	KILLED FOR HEALTHY AND ENVIROMENTAL PROBLEMS	GC DECA 83 Antimony trioxide,	MB EVA DATO 41 MB EMBA DATO 41
DECA ETHANE /Sb_2O_3 ($ZnBO_3$)	UL94 V0	LOW DOSAGE LOW COST GOOD COLOR	BROMINE ANTIMONY POOR THERMAL STABILITY	GC DPE 81 AntimonyTrioxide	MB EVA DETO 41 MB EMBA DETO 41
PBS/Sb_2O_3 ($ZnBO_3$) (BEO)	UL94 V0	LOW DOSAGE LOW COST GOOD THERMAL STABILITY GOOD MECHANICAL PROPERTIES	COST BROMINE ANTIMONY	GC BPS 67, GC BPS 310 Antymomy trioxide GC Zinc Borate GC FR 3100	Compacted version EVA TRIX 90-80
P red	UL 94 V0	LOW COST HALOGEN FREE LOW DOSAGE	RED COLOR EXPLOSIVE		MB PA P RED 50/60
PHOSPHINATE/MC/MPP /$ZnBO_3$	UL94 V0	HALOGEN FREE WHITE COLOR GOOD MECHNICAL PROPERTIES	COST HEAT STABILITY DOSAGE PROCESSABILITY	GC MC25 GC MPP GC HF 693, GC MPYR GC ZINC BORATE GC ME PHOSPHINATE	GC HF V0 PAP1 GC HF V0 PAP6 GC HF EP 730 C
MELAMINE CYANURATE	UL94 V2 (V0)	LOW COST LOW DOSAGE HALOGEN FREE	NO Vo IF FG FILLED	GC MCA SERIES	MB PA MC25 40
REACTIVE HF	UL94 V2 V0	LOW DOSAGE VERY HIGH MECHANICS HIGH RECYCLE	ONLY IN POLIMERIZATIO NOT ALWAYS POSSIBLE OR LIMITED	GC CEPPA GC RE DDP	

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POLY ETHYLEN TEREPHTALATE
POLY BUTYLEN TEREPHTALATE

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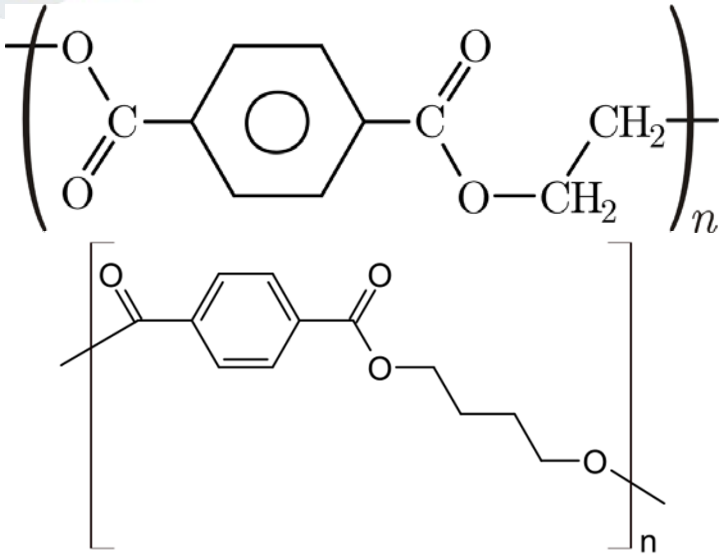

LOI	
PE	17
ABS	18
PET	25
PBT	23
PC	27
PTFE	95

% O < PET

HIGH LOI	BUONA RESISTENZA ALLA FIAMMA
HETEROATOMS IN CHAIN	SVILUPPA GAS MENO INFIAMMABILI
EXTRUSION T PET 260°C – 290°C PBT 230°C-270°C	Il FR DEVE ESSERE RESISTENTE ALLA T
PRESENCE OF HETEROATOMS	CHAR
POLY CONDENSATION	DRIPPING acidS
CURING ABILITY	CROSS-LINK

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PET PBT	TEST	+	-	GREENCHEMICALS PURE PRODUCT	GREENCHEMICALS BLENDS OR MASTERBATCHES
METAL HYDROXIDE	-	NO HEALTHY AND ENVIROMENTAL PROBLEMS	HIGH DOSAGE	GC Mg(OH)2	MB PE MGOH SETABOND
DECA-OXIDE/ Sb_2O_3 ($ZnBO_3$)	UL94 V0	LOW DOSAGE LOW COST	KILLED FOR HEALTHY AND ENVIROMENTAL PROBLEMS	GC DECA 83 Antimony trioxide,	MB PE DATO 41 MB EVA DATO 41 SETABOND
DECA ETHANE /Sb_2O_3 ($ZnBO_3$)	UL94 V0	LOW DOSAGE LOW COST GOOD COLOR	BROMINE ANTIMONY POOR THERMAL STABILITY	GC DPE 81 AntimonyTrioxide	MB EVA DETO 41 MB EMBA DETO 41 SETABOND
GC BPS /Sb_2O_3 ($ZnBO_3$)	UL94 V0	LOW DOSAGE LOW COST GOOD DISPERSION GOOD MECHANICAL PROPERTIES GOOD COLOR	COST BROMINE ANTIMONY	GC BPS 67 GC BPS 310 Antymomy trioxide GC Zinc Borate	EVA TRIX 80 and 90
P red	UL 94 V0	LOW COST HALOGEN FREE LOW DOSAGE	RED COLOR EXPLOSIVE	Acidity	MB PET P RED 50/60
PHOSPHINATE PHOSPHONATE MC $ZnBO_3$	UL94 V0	HALOGEN FREE WHITE COLOR	DISPERSION * HEAT STABILITY DOSAGE PROCESSABILITY MECHANICA PROPERTIES ACIDITY	GC MC25 GC HF 693 GC ZnBO3M ME PHOSPHINATE	MB HF EP 730 C GC HF 693

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POLYPROPYLENE

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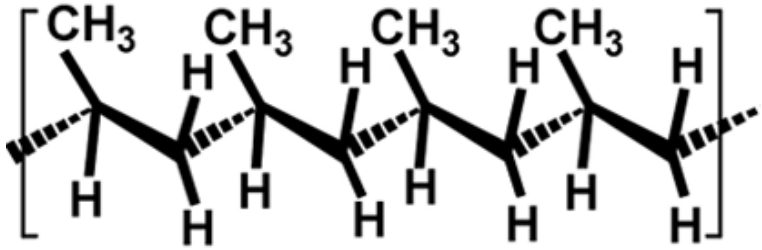

LOI	
PE	17
ABS	18
PA	24
PC	27
PP	17

HIGH LOI	BAD FLAME RETARDANT RESISTANCE
N AND O IN CHAIN	ALL FLAMABLE GASES
LOW PROC. TEMP. 200°C-280°C	WIDE RANGE OF FR
NO PRESENCE OF N AND O	BAD CHAR
RADICAL POLYMERIZATION / ZIEGLER NATTA	DRIPPING
CROSS-LINKING ABILITY	VERY BAD

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POLYPROPILENE	TEST	+	-	GREENCHEMICALS PURE PRODUCT	GREENCHEMICALS BLENDS OR MASTERBATCHES
METAL HYDROXIDE	-	NO HEALTHY AND ENVIROMENTAL PROBLEMS	HIGH DOSAGE	GC Mg(OH)2	MB PE MGOH Compatibilizer
DECA-OXIDE/ Sb_2O_3 ($ZnBO_3$)	UL94 V0	LOW DOSAGE LOW COST	KILLED FOR HEALTHY AND ENVIROMENTAL PROBLEMS	GC DECA 83 Antimony trioxide,	MB PE DATO 41 MB EVA DATO 41 Compatibilizers
DECA ETHANE /Sb_2O_3 ($ZnBO_3$)	UL94 V0	LOW DOSAGE LOW COST GOOD COLOR	BROMINE ANTIMONY POOR THERMAL STABILITY	GC DPE 81 AntimonyTrioxide	MB EVA DETO 41 MB EMBA DETO 41 Compatibilizers
GC BDDP 68/Sb_2O_3 ($ZnBO_3$)	UL94 V0	LOW DOSAGE LOW COST GOOD DISPERSION GOOD MECHANICAL PROPERTIES GOOD COLOR	COST BROMINE ANTIMONY	GC BDDP 68 GC BDMP 66 Antymomy trioxide GC Zinc Borate GC DICUMENE	PE TRIX 80 and 90 ISODRIPP BR 69 MB PE BDDP 68 AF
P red	UL 94 V0	LOW COST HALOGEN FREE LOW DOSAGE	RED COLOR EXPLOSIVE		MB PE P RED 50/60
APP PIPERAZINE PYROPHOSPHATE MC	UL94 V0	HALOGEN FREE WHITE COLOR	DISPERSION * HEAT STABILITY DOSAGE PROCESSABILITY MECHANICA PROPERTIES	GC MC25 GC APP GC PIPER compatibilizer	GC HF 2000 GC FLAM V0
ME PHOSPHINATE M-Br-Hydrate	UL94 V2 (V0)	LOW COST LOW DOSAGE HALOGEN FREE	VERY SENSITIVE TO POISONS. ONLY VERGIN PP	GC DRIPP HF 70	MB PP DRIPP HF 70

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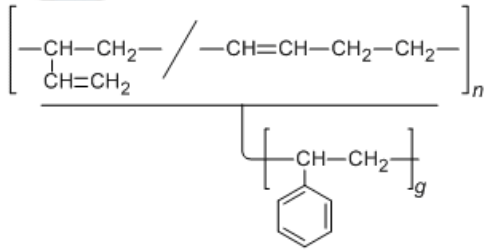
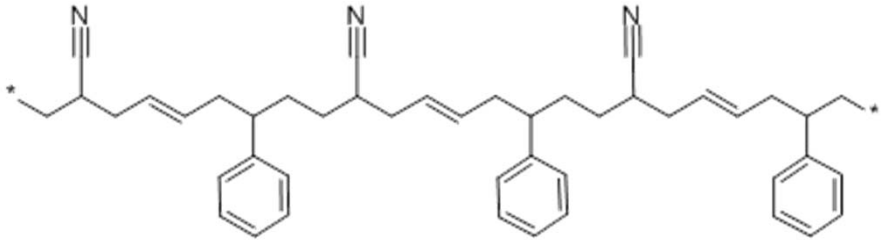
ABS / HIPS





LOI	
HIPS	17
ABS	18
PET	25
PBT	23
PC	27
PTFE	95

LOI BASSO	SCARSA RESISTENZA ALLA FIAMMA
NON HA ETEROATOMI	SVILUPPANO GAS INFIAMMABILI
T DI LAVORAZIONE > 200°C	RESISTE QUASI TUTTI GLI FR
NON HANNO ETEROATOMI IN CATENA	SCARSO CHAR
POLIMERIZZAZIONE RADICALICA	DRIPPING attenzione alle temperature di processo
NON RETICOLANO	NO CROSS-LINK

Smart PLASTICS VII edition

POLYSTRYRENE

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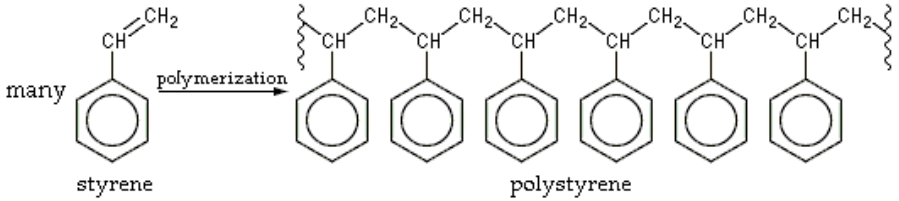


	LOI
PE	17
ABS	18
PA	24
PC	27
PS	18

HIGH LOI	BAD FLAME RETARDANT RESISTANCE
N AND O IN CHAIN	ALL FLAMABLE GASES
LOW PROC. TEMP. 180°C-280°C	WIDE RANGE OF FR
NO PRESENCE OF N AND O	BAD CHAR
RADICAL POLYMERIZATION	HARD DRIPPING
CROSS-LINKING ABILITY	VERY BAD

plast PLAST:DESIGN

GC GreenChemicals IMPROVE YOUR PERFORMANCE

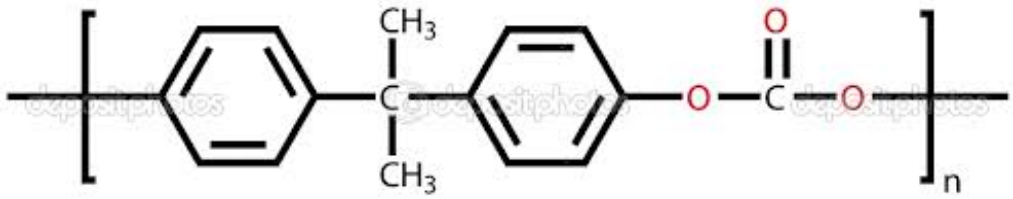
ABS, HIPS	TEST	+	-	GREENCHEMICALS PURE PRODUCT	GREENCHEMICALS BLENDS OR MASTERBATCHES
METAL HYDROXIDE	-	NO HEALTHY AND ENVIROMENTAL PROBLEMS	HIGH DOSAGE	GC Mg(OH)2	MB PE MGOH SETABOND
DECA-OXIDE/ Sb_2O_3 ($ZnBO_3$)	UL94 V0	LOW DOSAGE LOW COST	KILLED FOR HEALTHY AND ENVIROMENTAL PROBLEMS	GC DECA 83 Antimony trioxide,	MB PE DATO 41 MB EVA DATO 41 SETABOND
DECA ETHANE FR 245 /Sb_2O_3 ($ZnBO_3$)	UL94 V0	LOW DOSAGE LOW COST GOOD COLOR	BROMINE ANTIMONY POOR THERMAL STABILITY	GC DPE 81 AntimonyTrioxide GC FR 245 66	MB EVA DETO 41 MB PE DETO 41 SETABOND GC FR 245 compacted
GC BDDP 68/Sb_2O_3 ($ZnBO_3$) Even without Sb_2O_3	UL94 V0,V2	LOW DOSAGE LOW COST GOOD DISPERSION GOOD MECHANICAL PROPERTIES GOOD COLOR	COST BROMINE ANTIMONY	GC BDDP 68 GC BDMP 66 Antymomy trioxide GC Zinc Borate GC DICUMENE	PE TRIX 80 and 90 ISODRIPP BR 69 MB PS SAM series MB PS DRIPP 69
GC HF 693 GC ME PHOSPHINATE	UL 94 V0	LOW COST HALOGEN FREE LOW DOSAGE	RED COLOR EXPLOSIVE	GC HF 693 GC ME PHOSPHINATE GC Zinc Borate	GC EP HF 730
MODIFIED POLYMER CEPPA/DOPO GC HF 693	UL94 V0	HALOGEN FREE WHITE COLOR	DISPERSION * HEAT STABILITY DOSAGE PROCESSABILITY MECHANICA PROPERTIES	GC HF 693 GC ME PHOSPHINATE GC Zinc Borate GC CEPPA, GC DOPO	GC HF40 series

GC GreenChemicals
IMPROVE YOUR PERFORMANCE

Smart PLASTICS VII edition

POLYCARBONATE

15·16 MAY 2019 MUSEO ALFA ROMEO, ARESE MI



LOI	
PE	17
ABS	18
PET	25
PBT	23
PC	27
PTFE	95

VERY HIGH LOI	GOOD FLAME RESISTANCE
HETEROATOMS	LESS FLAMABLE GASES
PROCESSING T 240°C – 280°C	FR MUST HAVE HIGH FR RESISTANCE
HETEROATOMS	CHAR
POLYCONDENSATION	DRIPPING ACIDS
CURING ABILITY	CROSS-LINK

plast PLAST:DESIGN

GC GreenChemicals IMPROVE YOUR PERFORMANCE

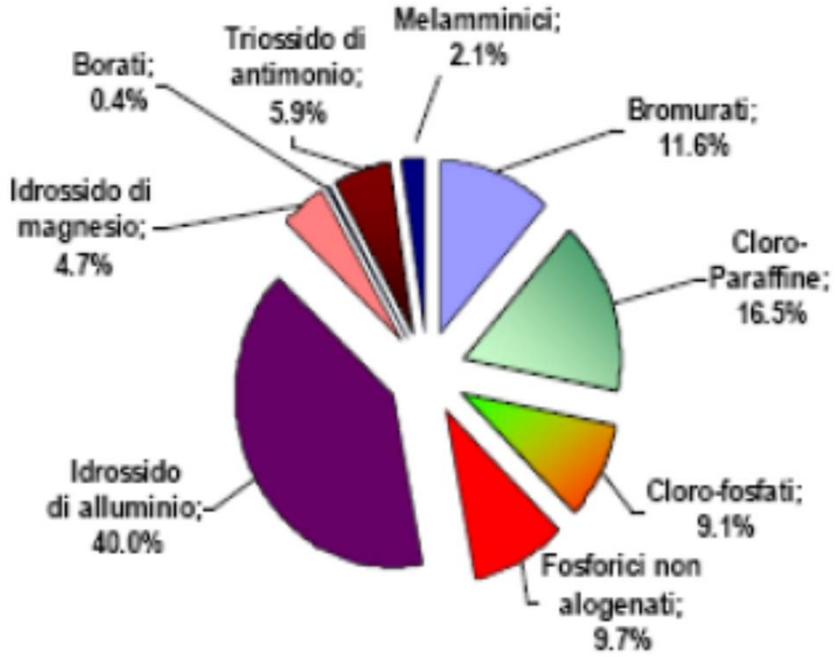
PC	TEST	+	-	GREENCHEMICALS PURE PRODUCT	GREENCHEMICALS BLENDS OR MASTERBATCHES
DECA ETHANE /Sb_2O_3 ($ZnBO_3$)	UL94 V0	**LOW DOSAGE LOW COST GOOD COLOR**	**BROMINE ANTIMONY POOR THERMAL STABILITY**	**GC DPE 81 Antimony sin GC BC58 GC FR3100**	
Br-PC oligomeri/Sb_2O_3, Na antimoniato (BEO, BT_{93}, BPS)	UL94 V0	**LOW DOSAGE LOW COST GOOD COLOR**	**BROMINE ANTIMONY POOR THERMAL STABILITY**	**GC BC58 GC FR3100 GC BT67 GC BPS67**	
RDP BDP FH_{693}	UL94 V0	**HALOGEN FREE OPALESCENT**	**HIGH DOSAGE DIFFICULT FOR LOW THICKENSS**	**GC BDP GC RDP GC 693 GC PTFE**	
KSS PBSK HF_{693} PTFE	UL 94 V0	**HALOGEN FREE TRASPARENT LOW DOSAGE**		**GC KSS GC PBSK GC 693 GC PTFE**	**NACHFLAME PC-HF**

PC/ABS					
RDP BDP FH_{693} PTFE	UL 94 V0	**HALOGEN FREE TRASPARENT LOW DOSAGE**	**RELATIVELY HIGH DOSAGE**	**GC BDP GC RDP GC 693 GC PTFE**	

COMMERCIAL NAME	PRODUCT DESCRIPTION
GC HF V0 PAP1	It'a a mixture which can be powder or compacted, for white polyamide GF reinforced.
GC HF V0 PAP6	It's a mixture, which can be powder or compacted, for white GF polyamide compound. Particularlòy suitable with high GF level.
GC HF EP 730 c	It's a mixture (powder or compacted), with low acidity, which is particularly suitable for PET/PBT compounds. White color.
NACHFLAM PC HF	It's a mixture, ideal for transparect PC low thickness.
GC HF 2000	Intumescent mixture, in powder/compacted with compatibilizer, ideal for low loading needs.
GC DRIPP HF 70	< 900 ppm bromine blend, ideal for PPV2
GC HF40	Powder or compacted blend, ideal for GPPS/HIPS V2 or classE application
GC ABS P169	Powder orcompacted blend for ABS, V1 and V0.

CRITERI DI SCELTA DEGLI FR

- TOSSICITÁ
- BIODEGRADABILITÁ E BIOACCUMULAZIONE
- STABILITÁ ALLA TEMPERATURA DI TRASFORMAZIONE
- COMPATIBILITA' CON IL POLIMERO
- COSTO/ATTIVITA'



Mercato dei ritardanti di fiamma

CONCLUSIONI

- SI CERCANO FR HALOGEN FREE O A BASSO IMPATTO PER LA SALUTE E AMBIENTALE
- CHIMICA DEL P E' QUELLA CHE SI STA SVILUPPANDO
- ETP SI PRESTANO A FR INNOVATIVI
- ANTIFIAMMA REATTIVI
- POLIMERI SUPER FR PER LEGHE