



3D PRINTED ORIGINAL DESIGN TO CONCEIVE HIGHLY FLAME RETARDANT MULTI MATERIALS

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INTRODUCTION



Transportation fields ^I

I. <http://career.iresearchnet.com>

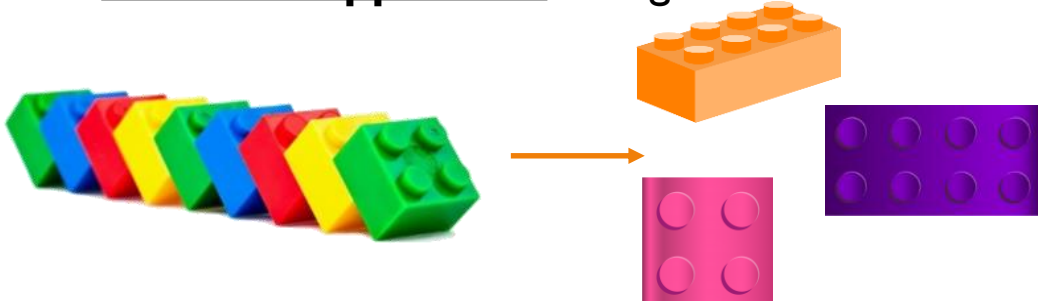


Building fields ^{II}

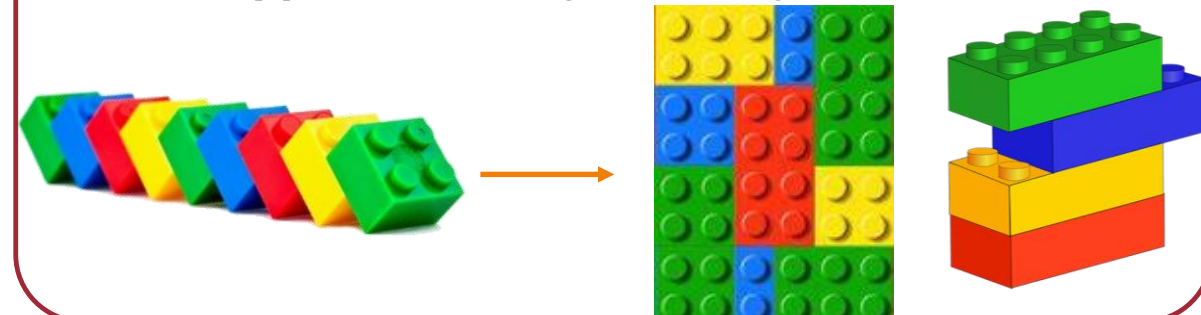
II. <https://www.soft-entreprise.com> & <https://www.letsbuild.com> & <https://www.groupe-legendre.com>



Standard approach: Change the formulation



Our approach: Change the design



Additive manufacturing



Additive manufacturing

Tooling

Prototyping

Mold making

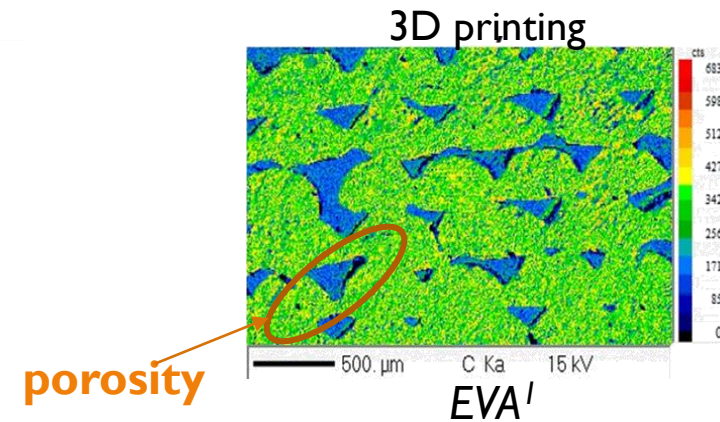
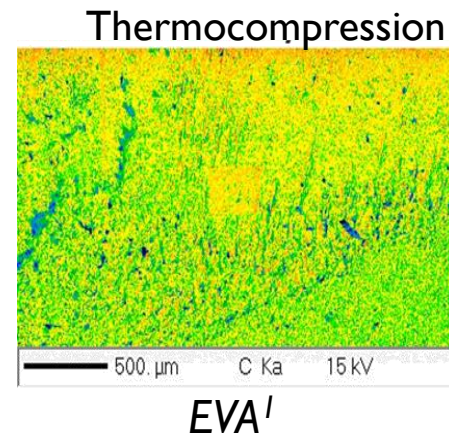
~~Mass production~~

Advantages

- Save materials
- Save money
- Freedom for designing objects

Disadvantages

- 3D part → lower mechanical properties
- Required specifications not respected



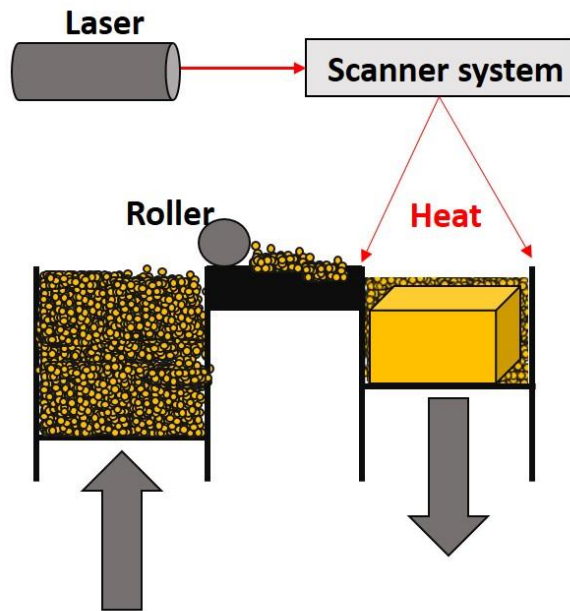
¹L. Geoffroy et al. / Polym Adv Technol. 2019;1-13, DOI: 10.1002/pat.4620

→ Very few study in terms of fire properties

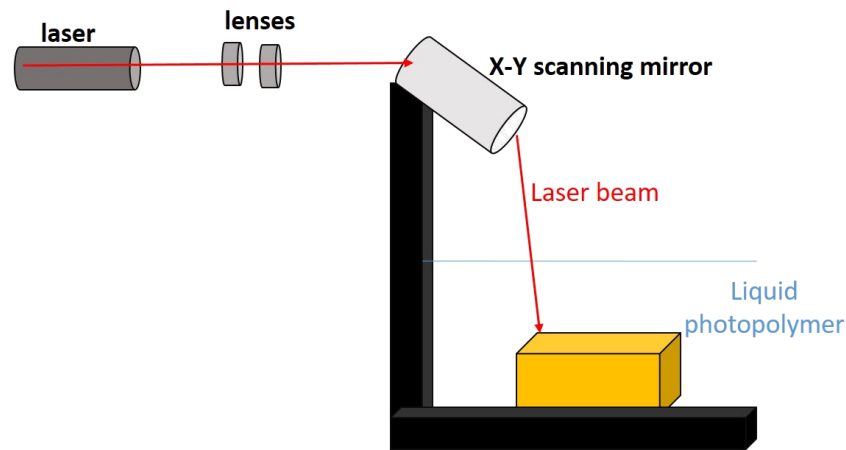
Several techniques

Many others ...

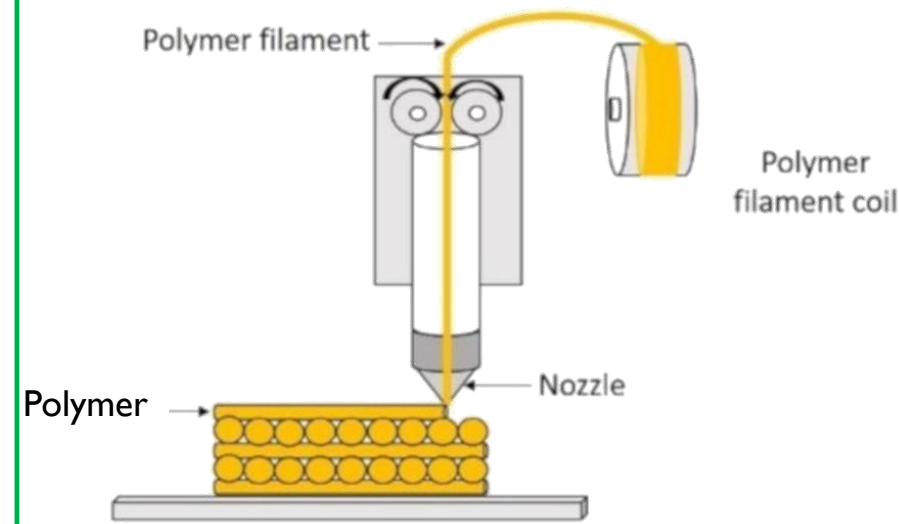
a) Selective Laser Sintering (SLS)



b) Stereolithography apparatus (SLA)



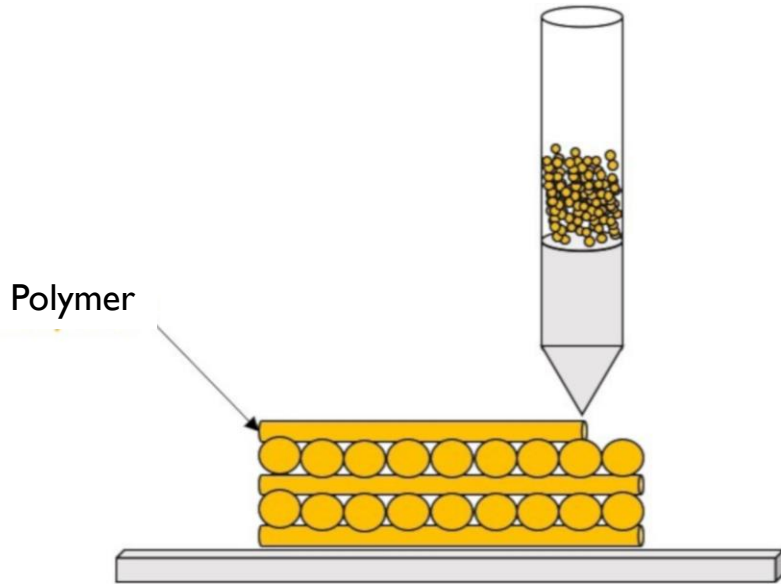
c) Fused Deposition Modeling (FDM)



👍 Best quality to cost ratio

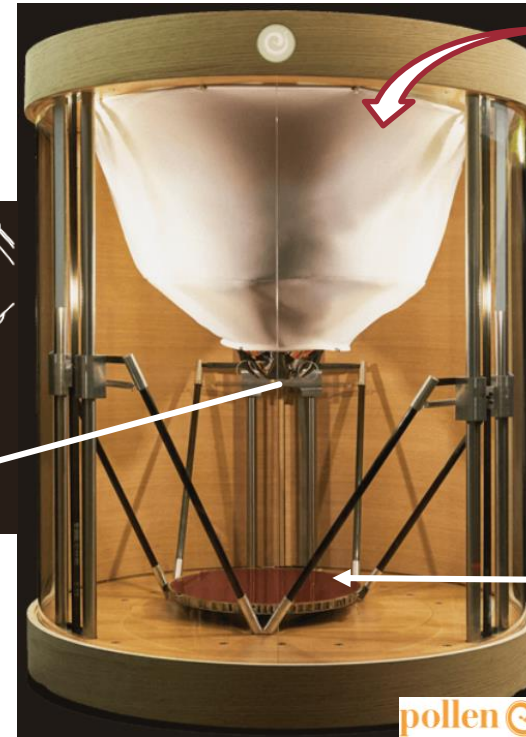
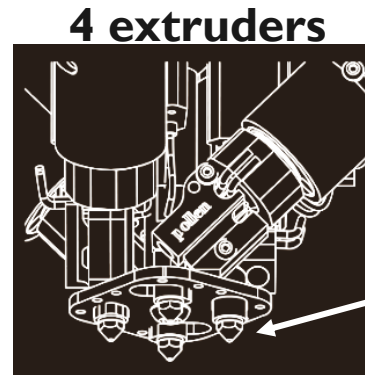
Fused Deposition Modeling (FDM)

👍 Best quality to cost ratio



FDM with pellets

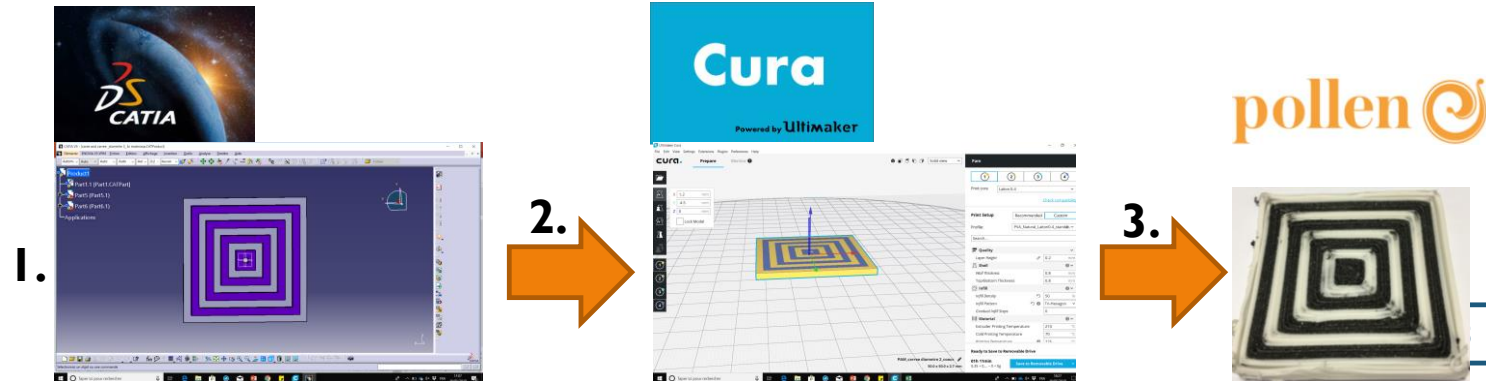
👍 No materials limitation
No winding step



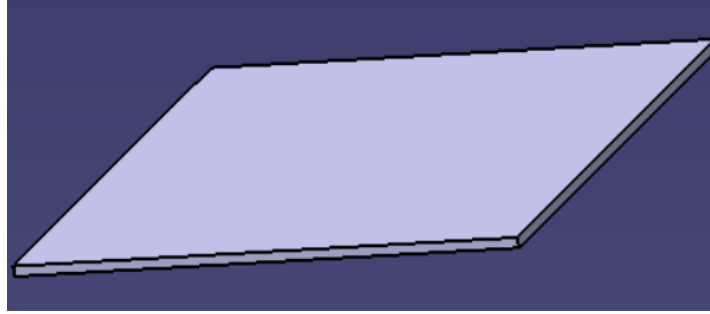
Printing Pellets polymer

Heating plate

3D printing process: 3 Steps



FR material with a simple design



New complex designs



Material

EVA/ATH (30%)

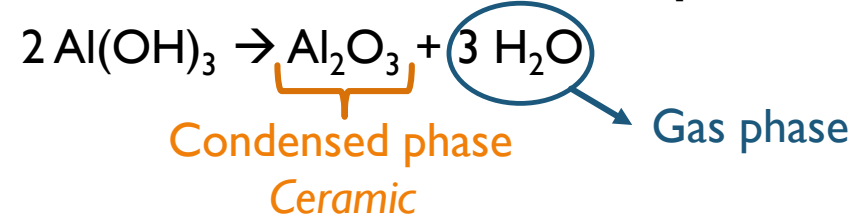


EVA/ATH (65%)

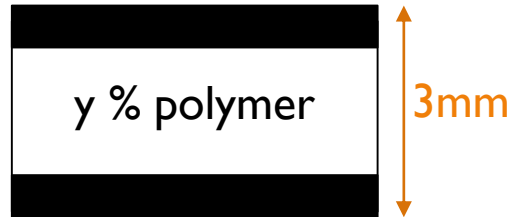


EVA: Ethylene Vinyl Acetate
 ATH: Aluminum Tri-Hydroxide _ Particle size: 1.5µm

Endothermic thermal decomposition

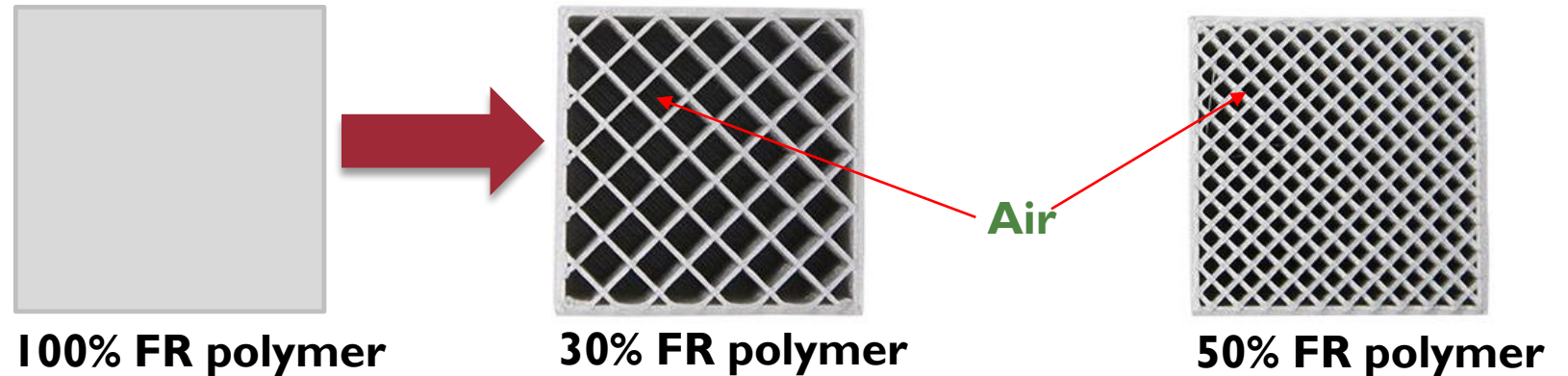


Structure

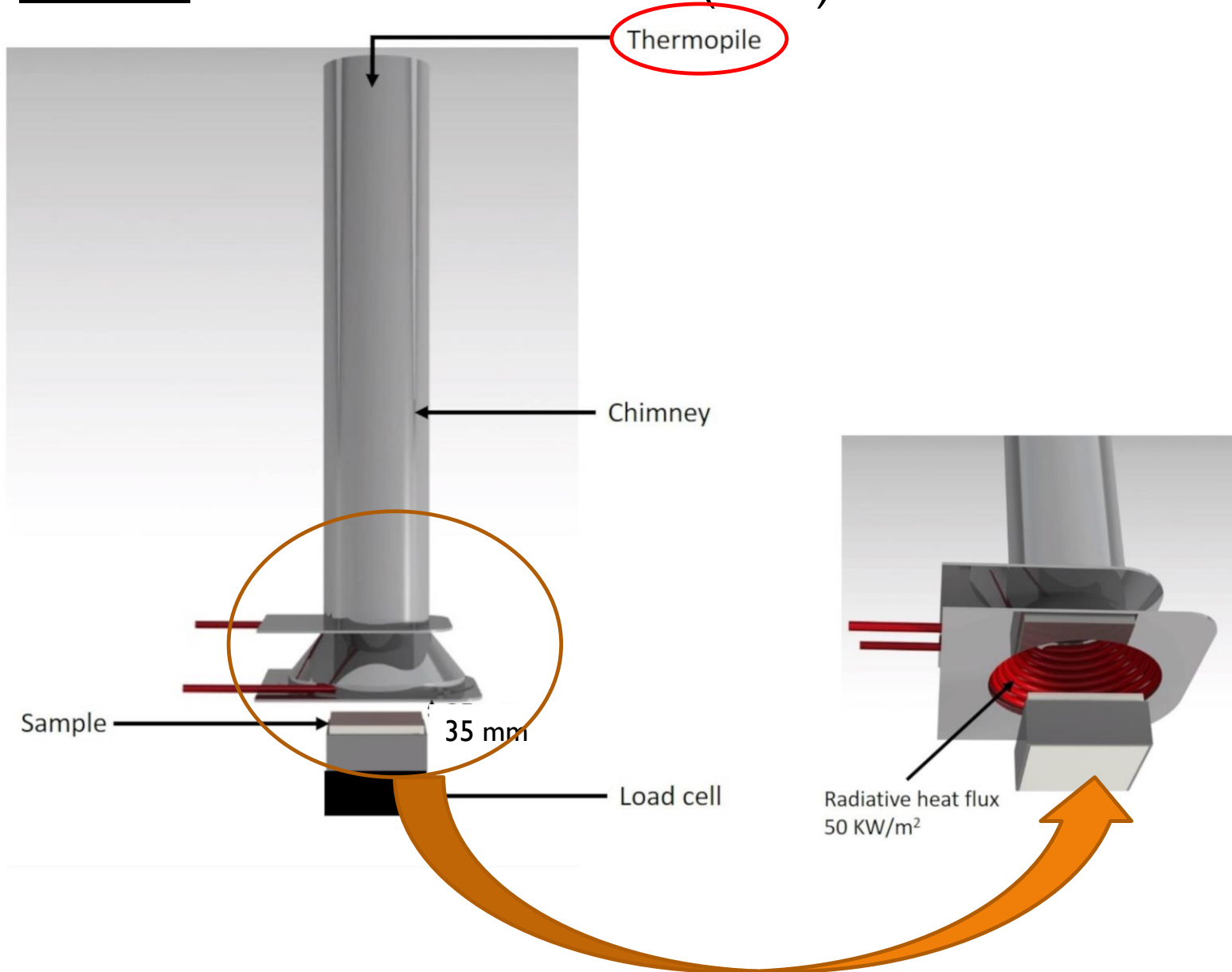


Sandwich materials

Core of the sandwiches



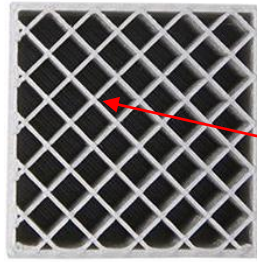
Fire test: Mass Loss Calorimeter (MLC)





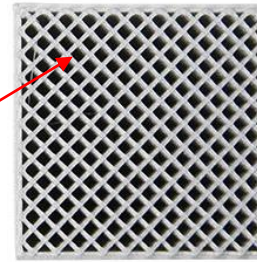
100% FR polymer

EVA/ATH (30%)



30% FR polymer

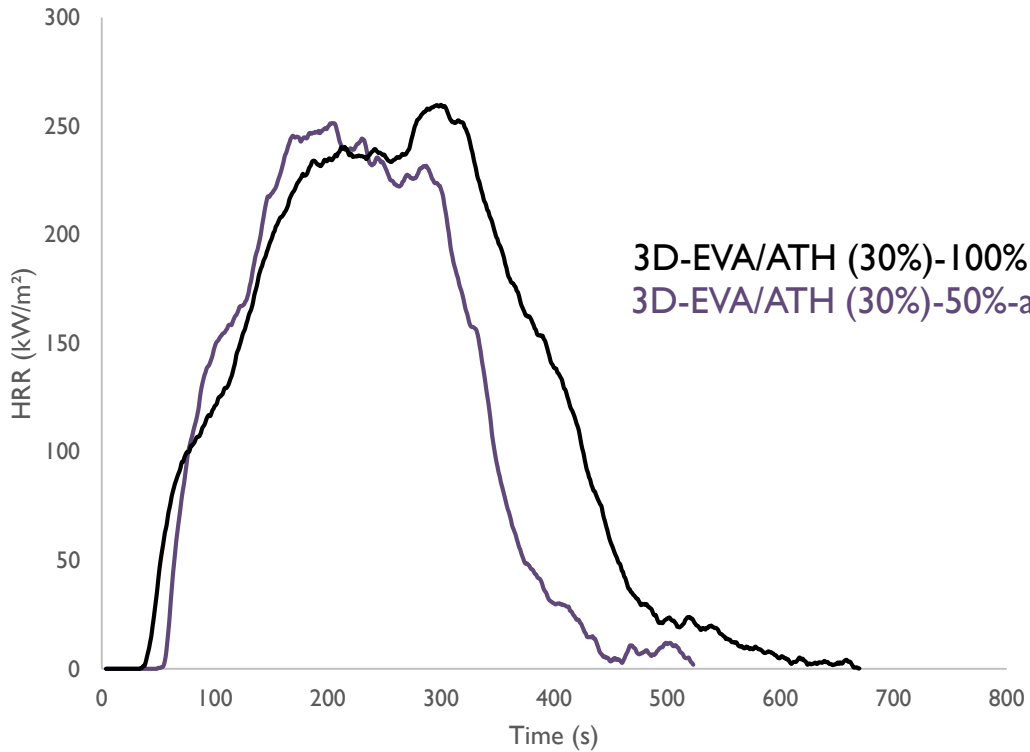
Air



50% FR polymer

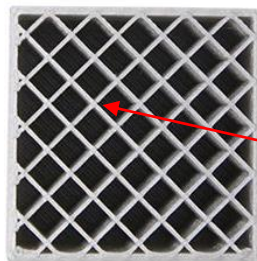


MLC condition
50 kW/m² at 35 mm



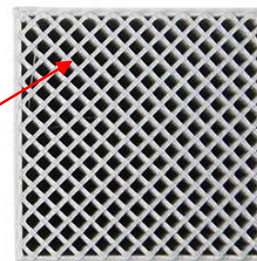


100% FR polymer



30% FR polymer

Air

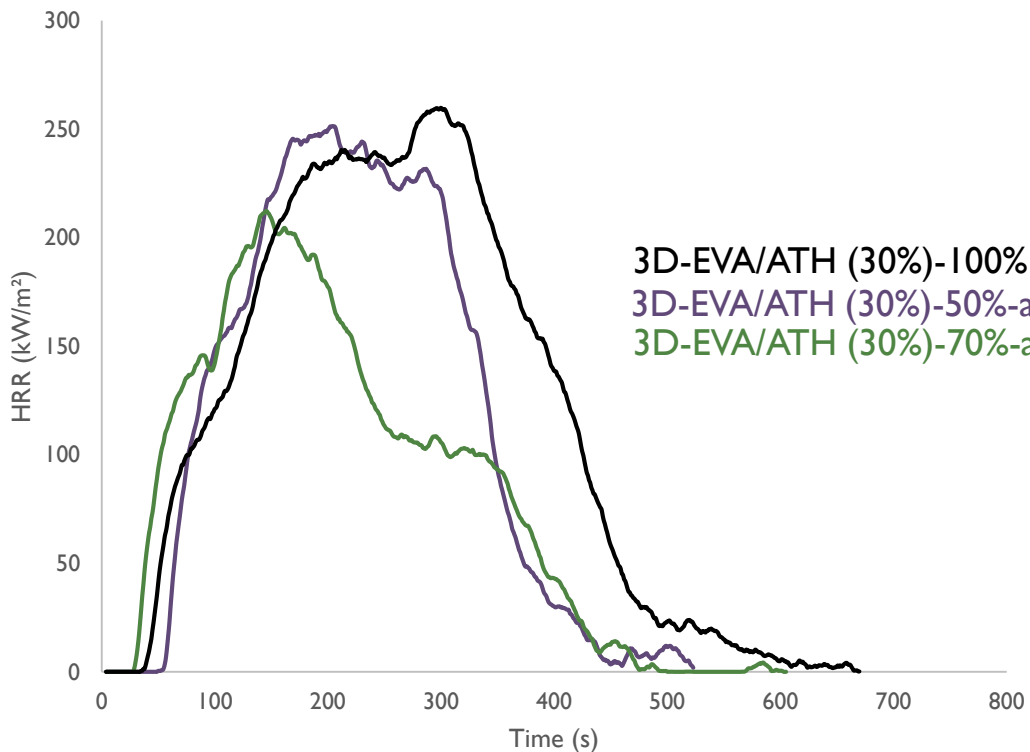


50% FR polymer



MLC condition
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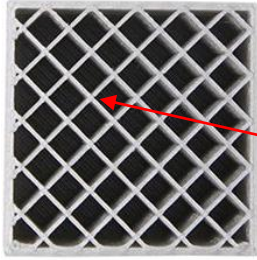
EVA/ATH (30%)



Less EVA → smaller THR and pHRR

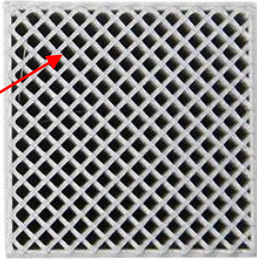


100% FR polymer



30% FR polymer

Air



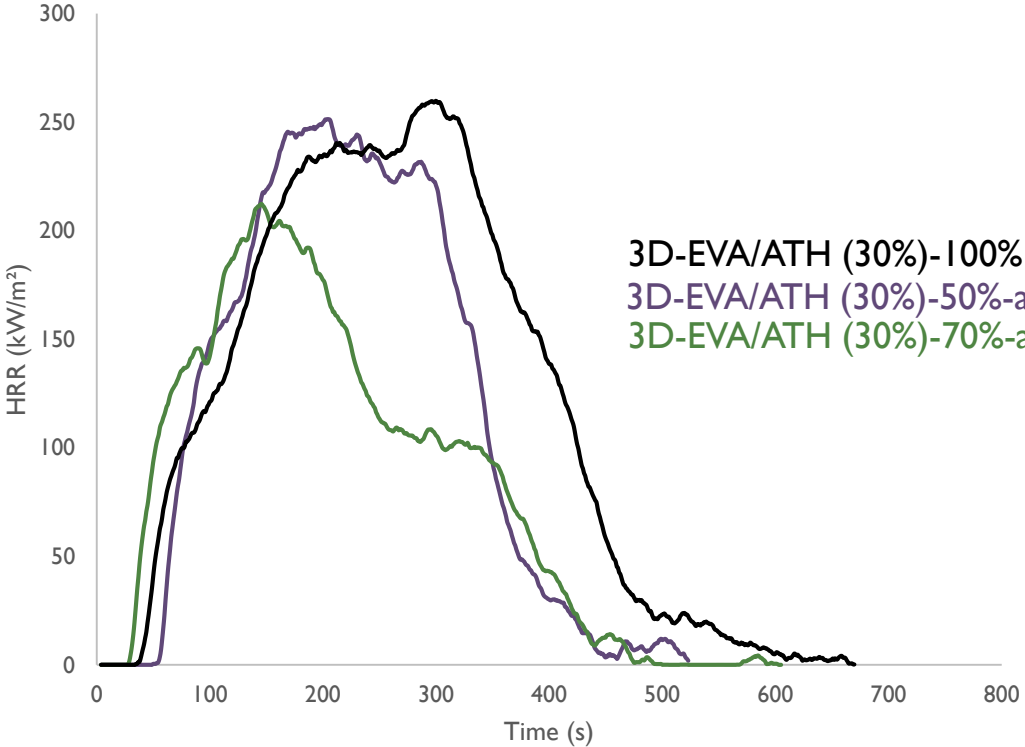
50% FR polymer



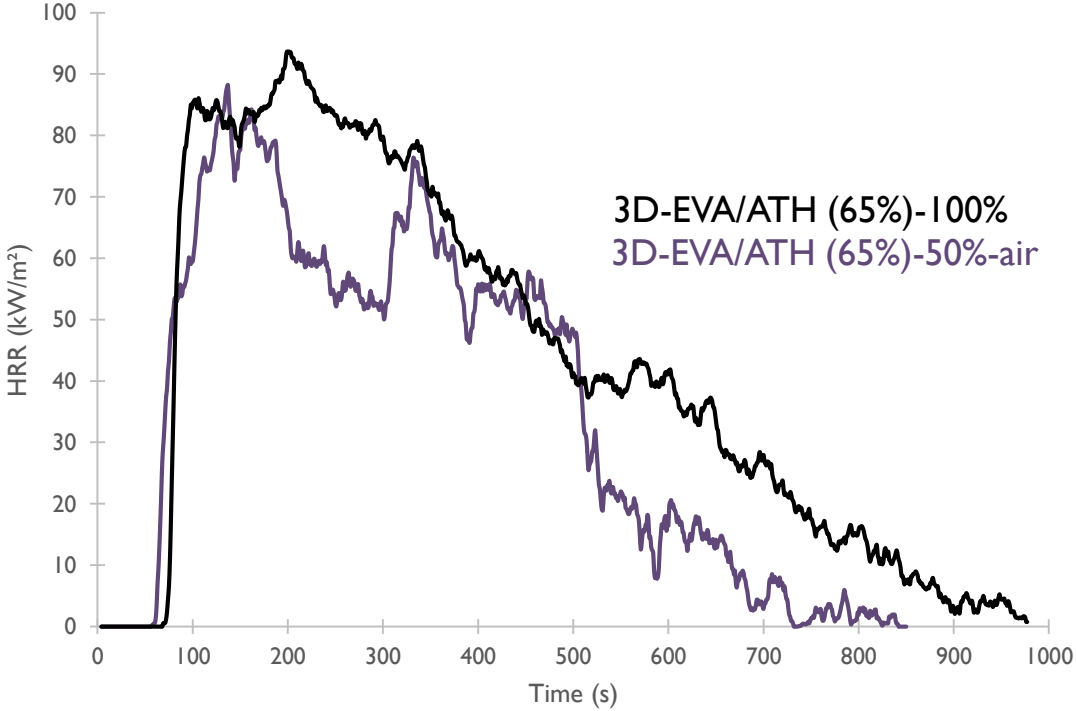
MLC condition

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EVA/ATH (30%)



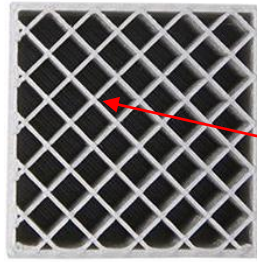
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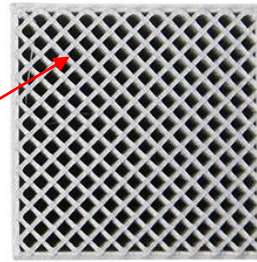


100% FR polymer



30% FR polymer

Air

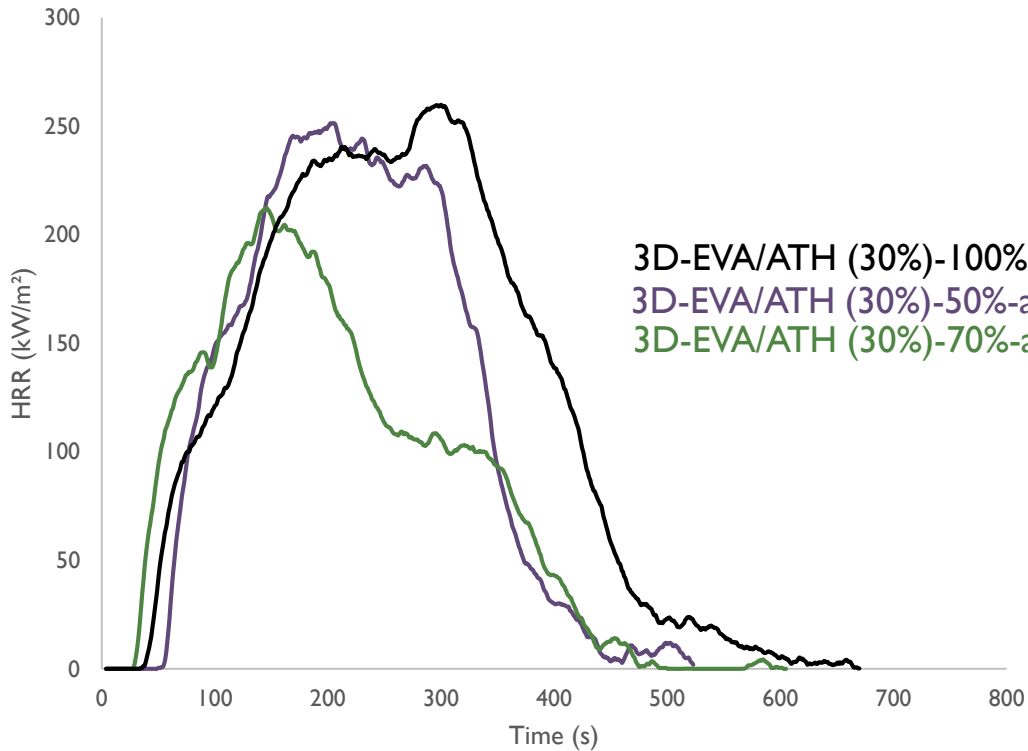


50% FR polymer

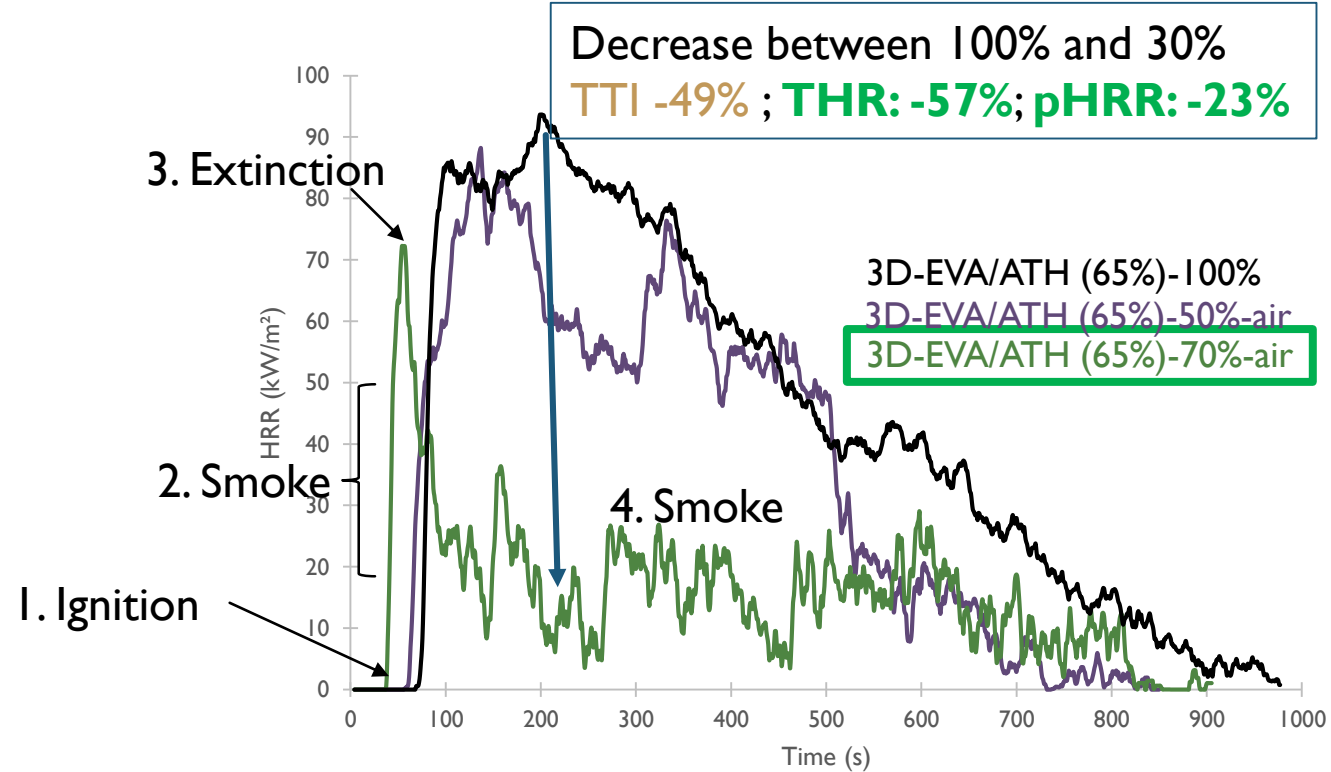


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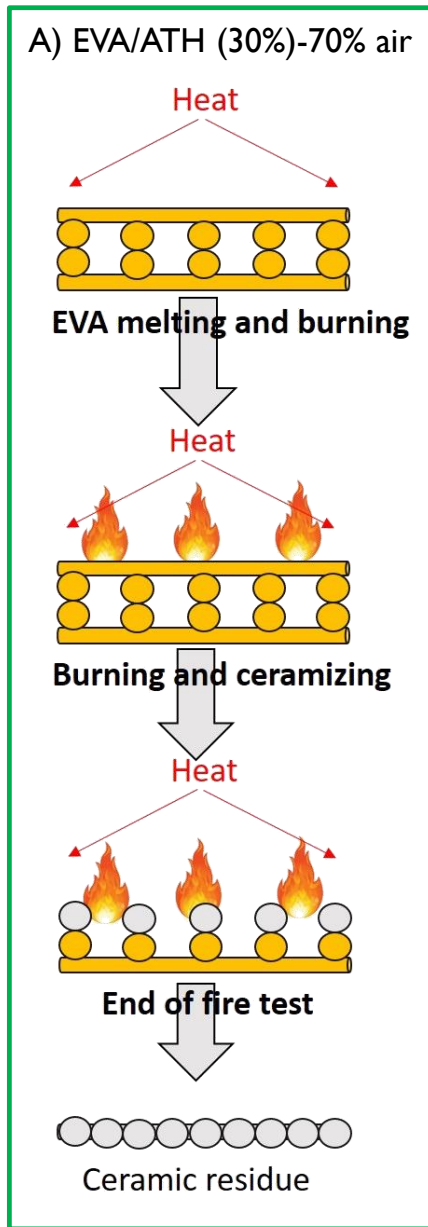
EVA/ATH (30%)



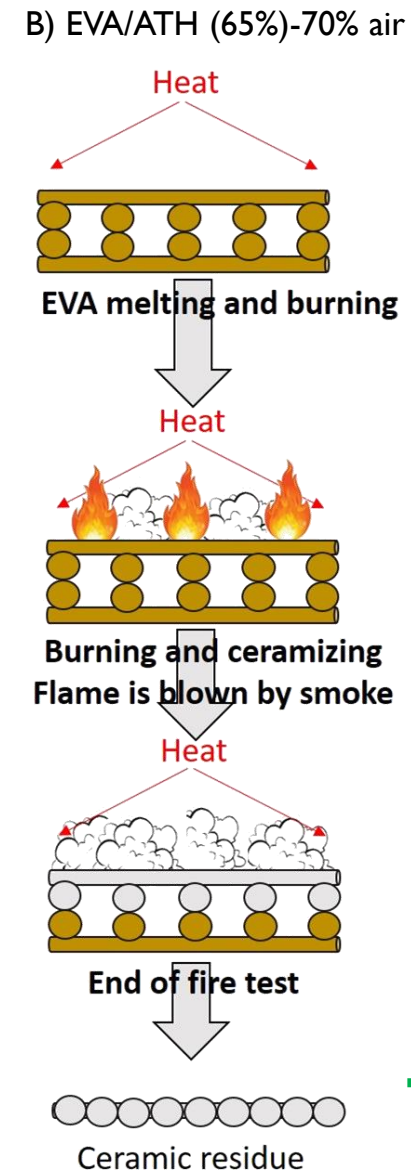
EVA/ATH (65%)



Less EVA → smaller THR and pHRR



→ Advantage of design lost



→ Advantage of design maintained

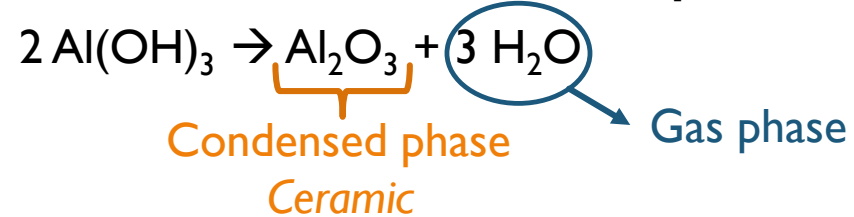
Material

EVA/ATH (30%)

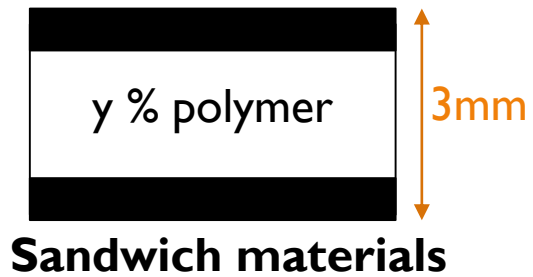


EVA: Ethylene Vinyl Acetate
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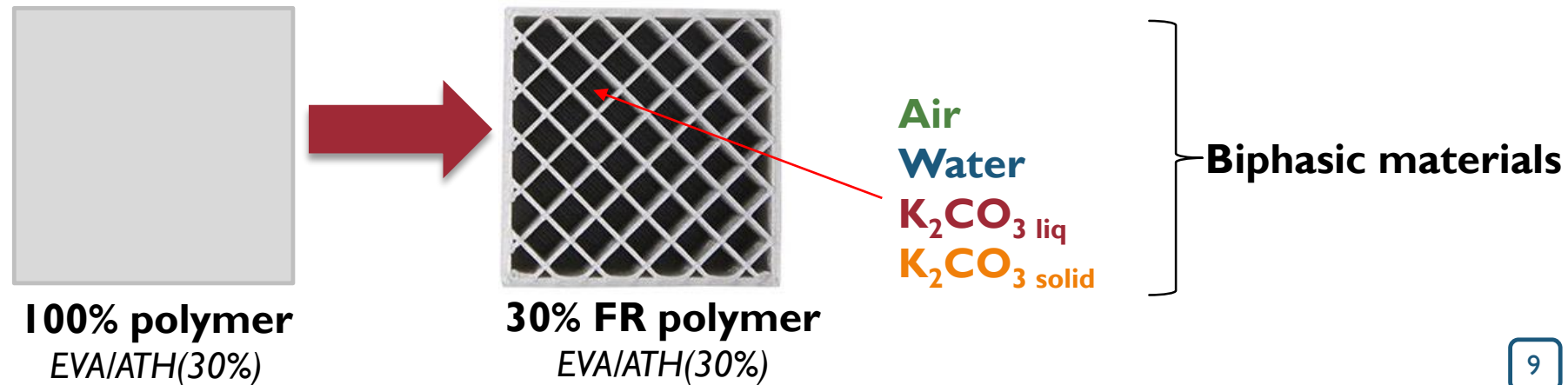
Endothermic thermal decomposition

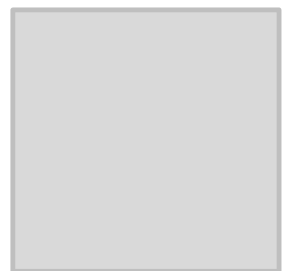


Structure

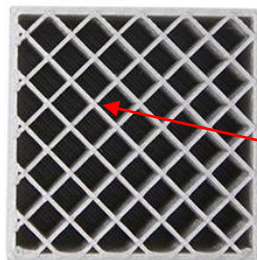


Core of the sandwiches





100% FR polymer



30% FR polymer

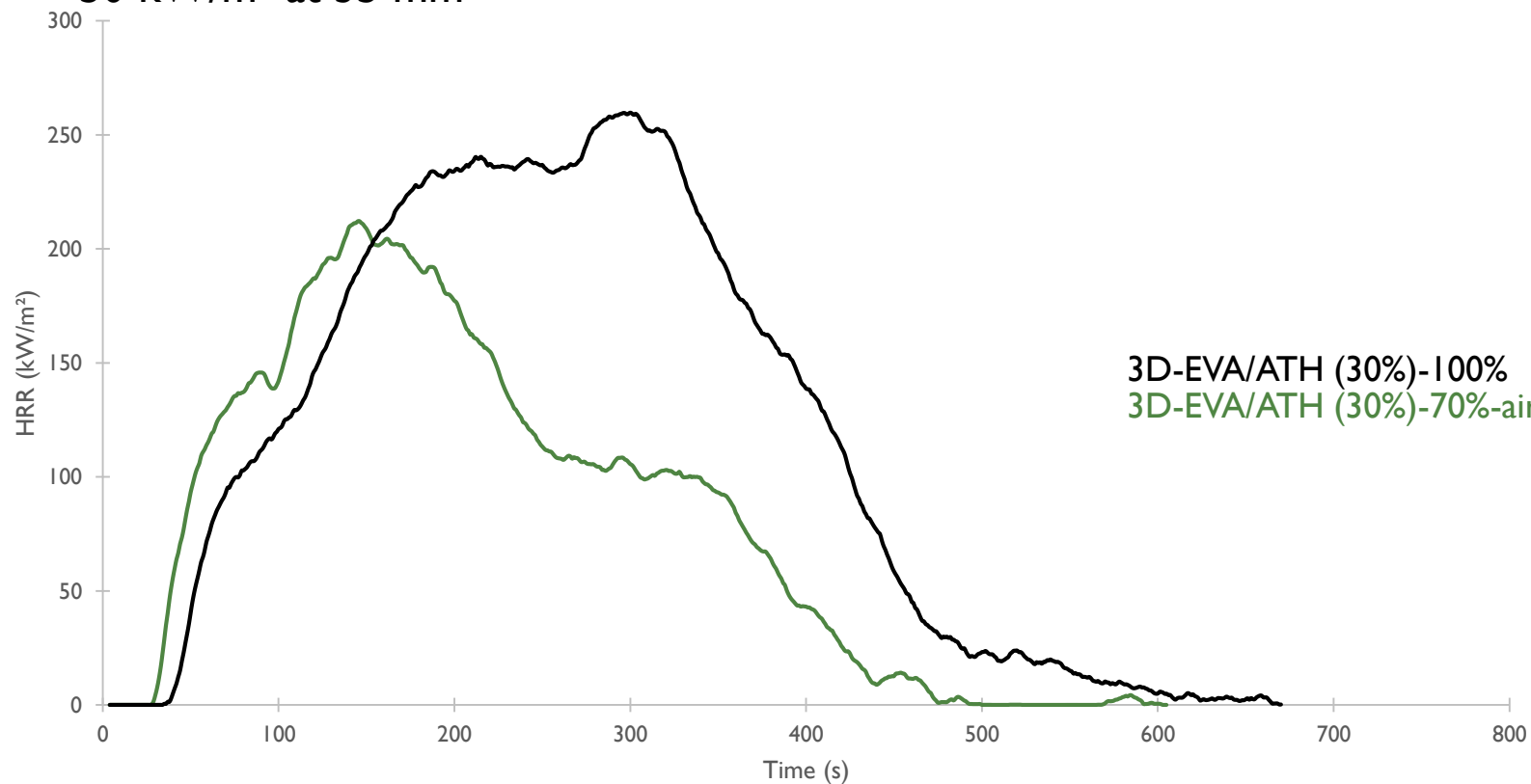
Air
Water
 K_2CO_3 liq
 K_2CO_3 solid

Biphasic materials



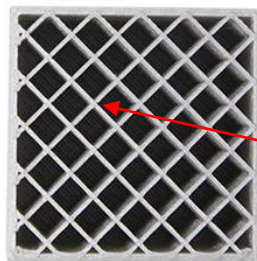
MLC condition
50 kW/m² at 35 mm

MLC condition:
50 kW/m² at 35 mm





100% FR polymer



30% FR polymer

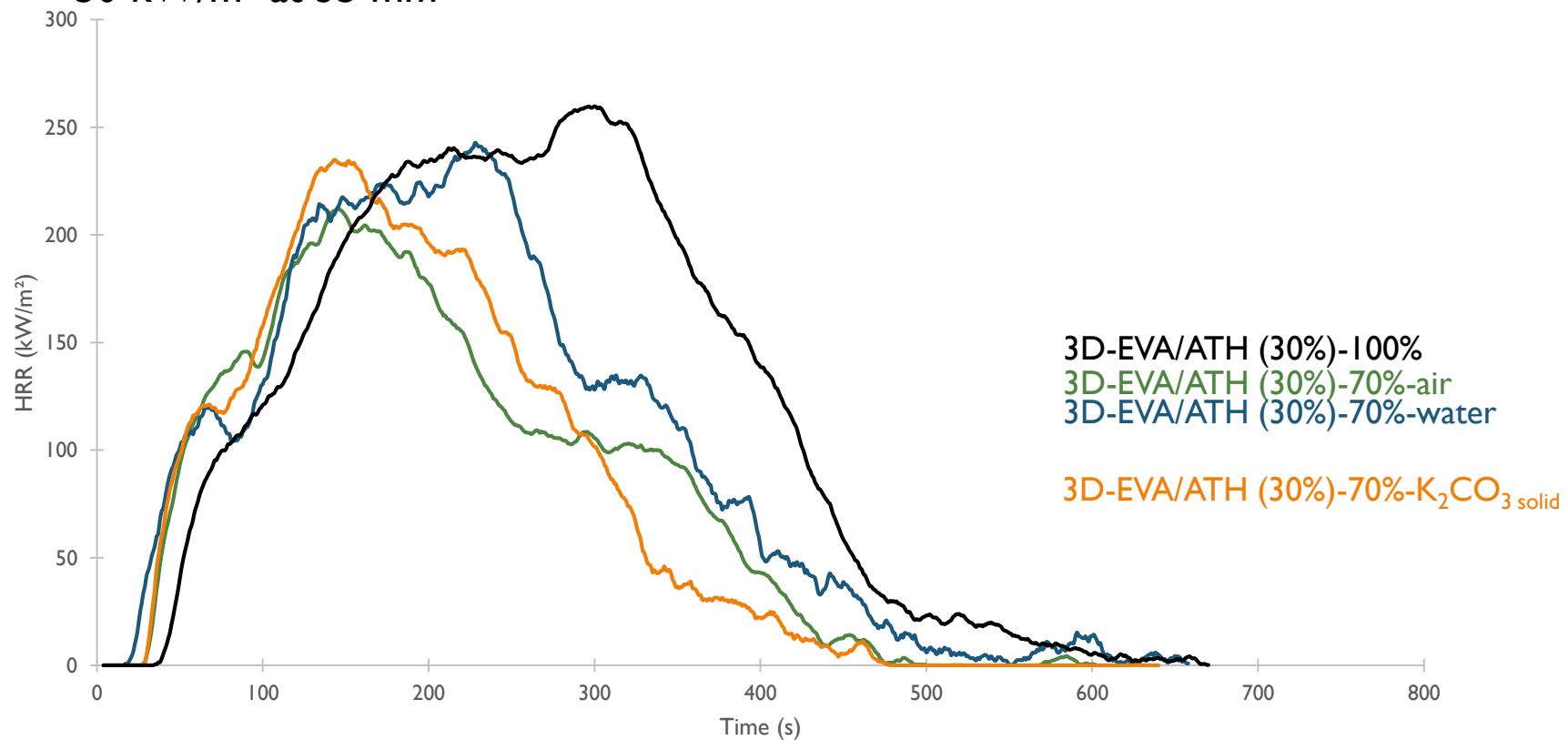
Air
Water
 K_2CO_3 liq
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Biphasic materials



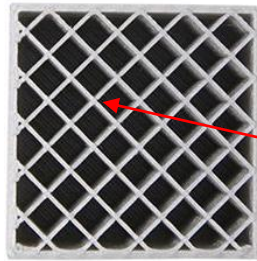
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Biphasic materials

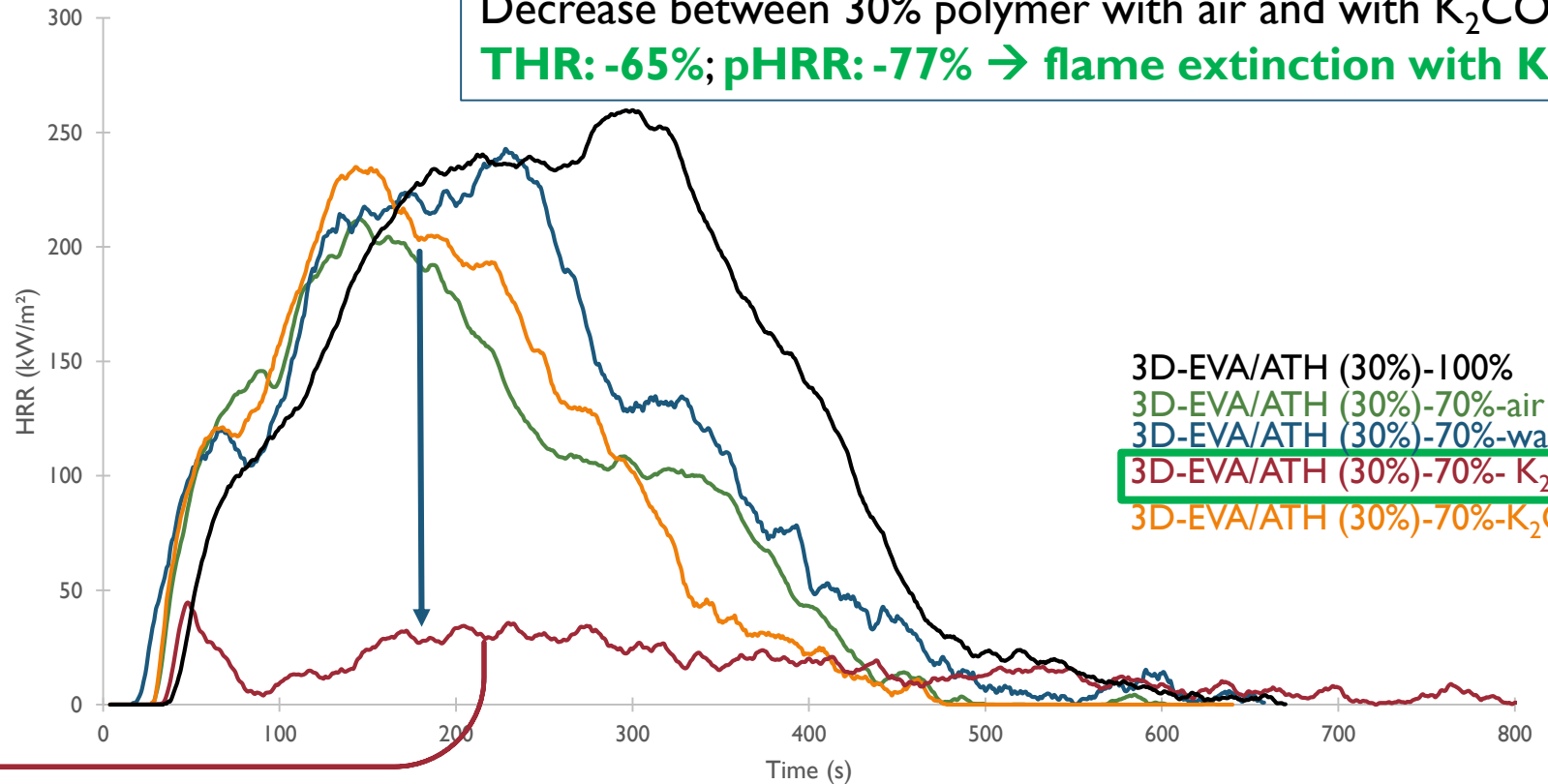


MLC condition
50 kW/m² at 35 mm

MLC condition:

50 kW/m² at 35 mm

Decrease between 30% polymer with air and with K_2CO_3 liq
THR: -65%; pHRR: -77% → flame extinction with K_2CO_3 liq



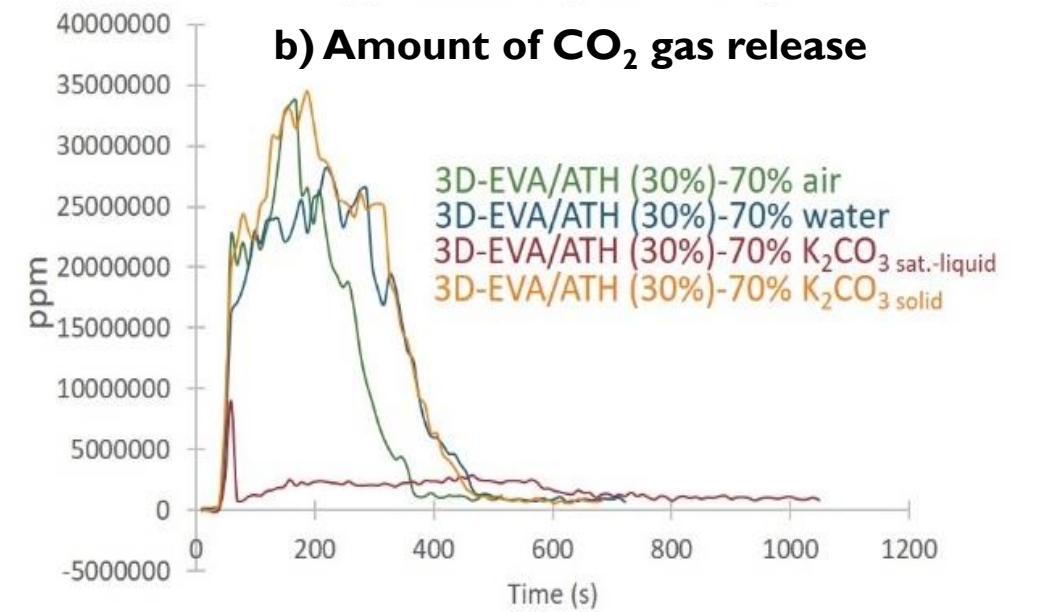
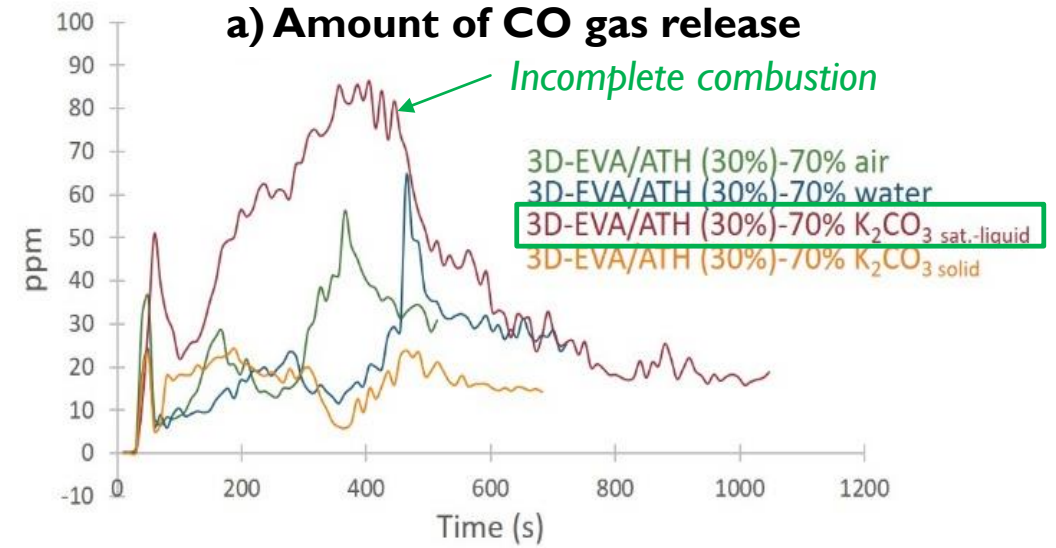
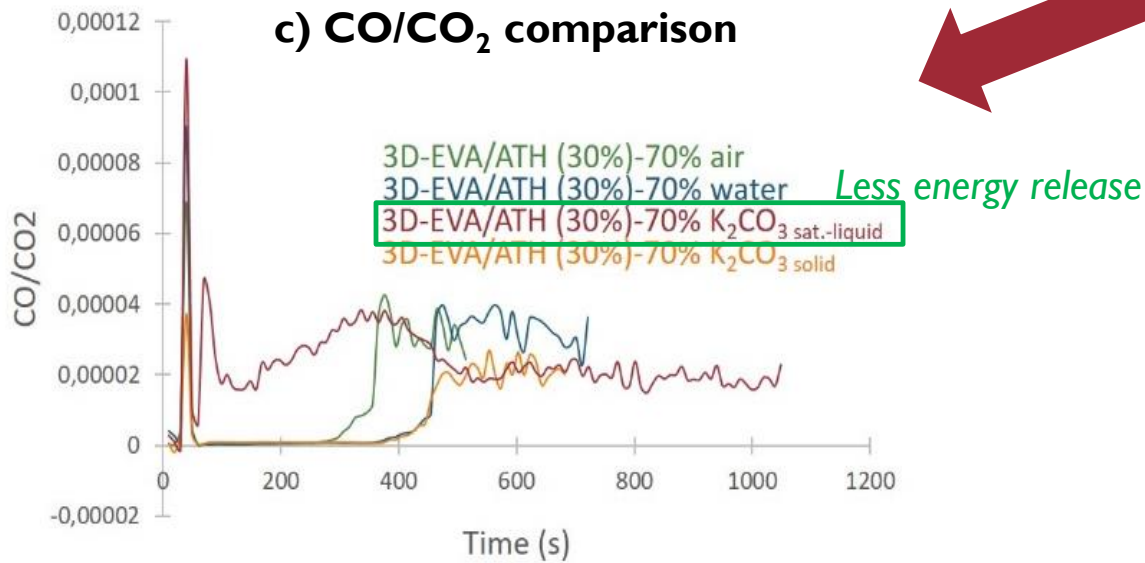
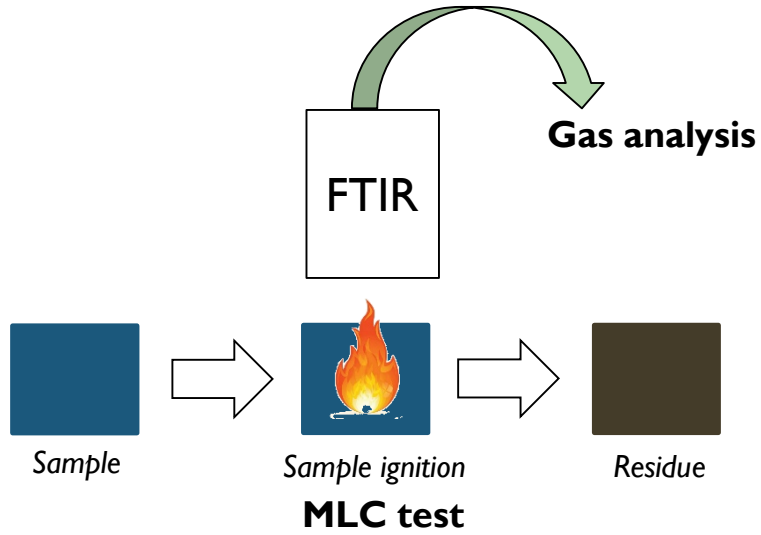
3D-EVA/ATH (30%)-100%
 3D-EVA/ATH (30%)-70%-air
 3D-EVA/ATH (30%)-70%-water
3D-EVA/ATH (30%)-70%- K_2CO_3 liq
 3D-EVA/ATH (30%)-70%- K_2CO_3 solid

Mechanism:

Gas phase ?
Condensed phase ?

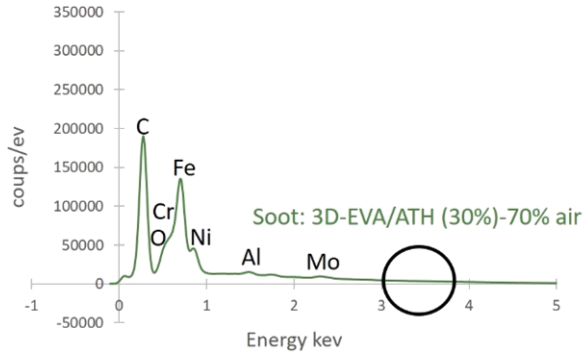


Mechanism in gas phase

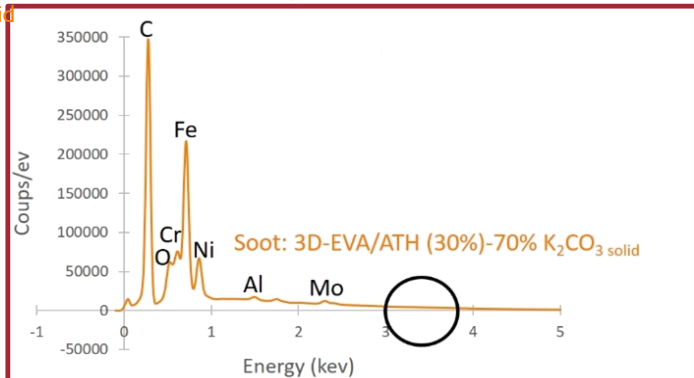


Mechanism in gas phase

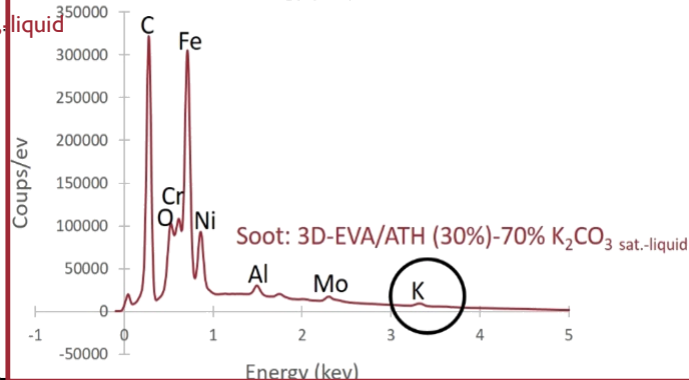
3D-EVA/ATH(30%)-70%-air



3D-EVA/ATH(30%)-70%-K₂CO₃ solid

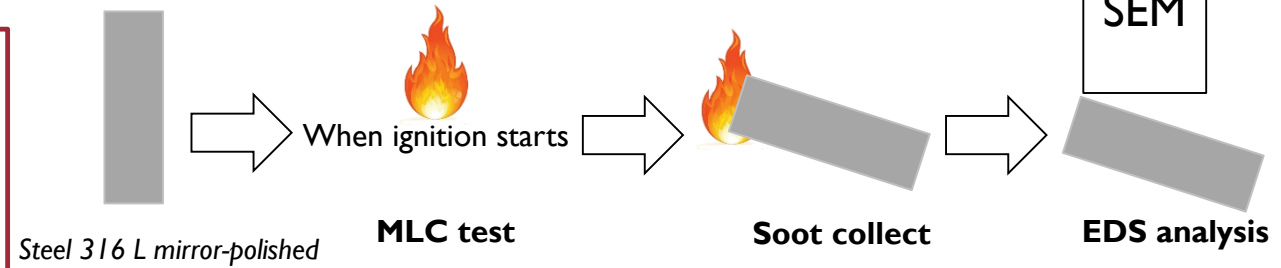


3D-EVA/ATH(30%)-70%-K₂CO₃ sat., liquid



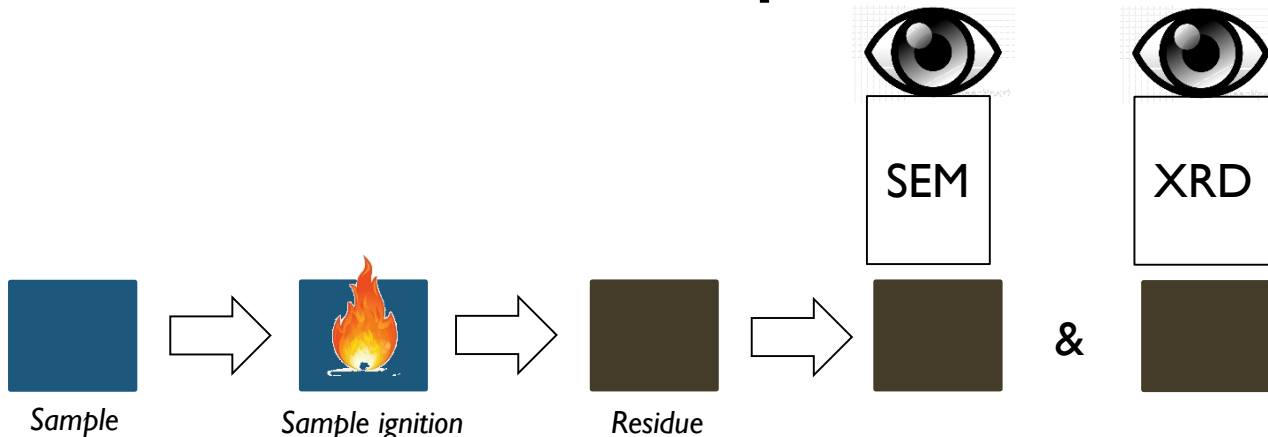
Purple flame → K⁺ is in flame

Soot analysis



L. Geoffroy et al. / Polymer Degradation and Stability 169 (2019) 1089922

Mechanism in condensed phase

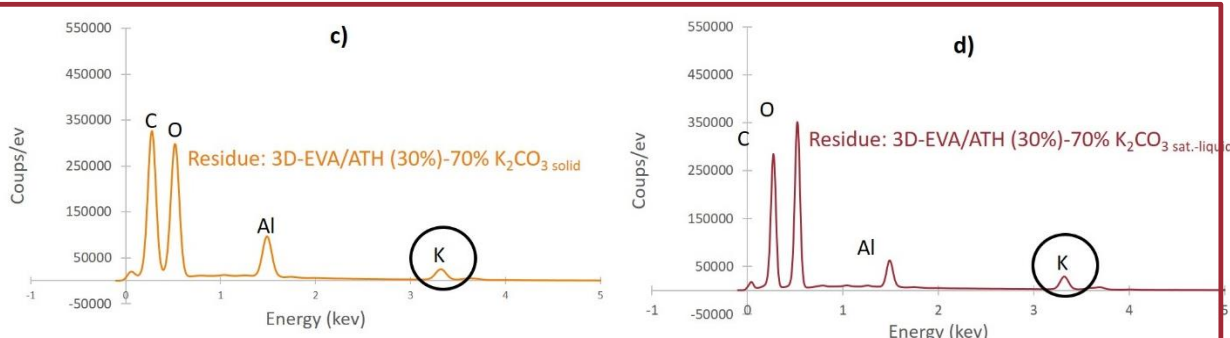
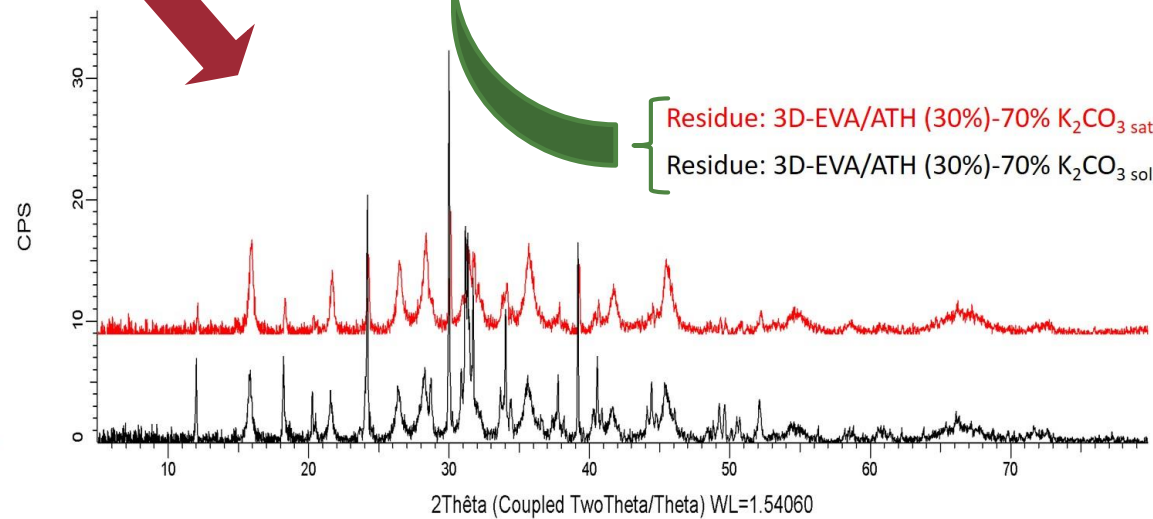
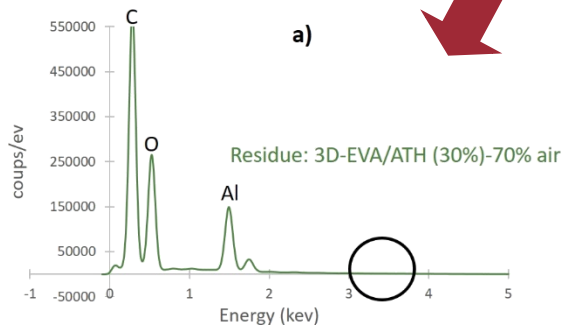


MLC test

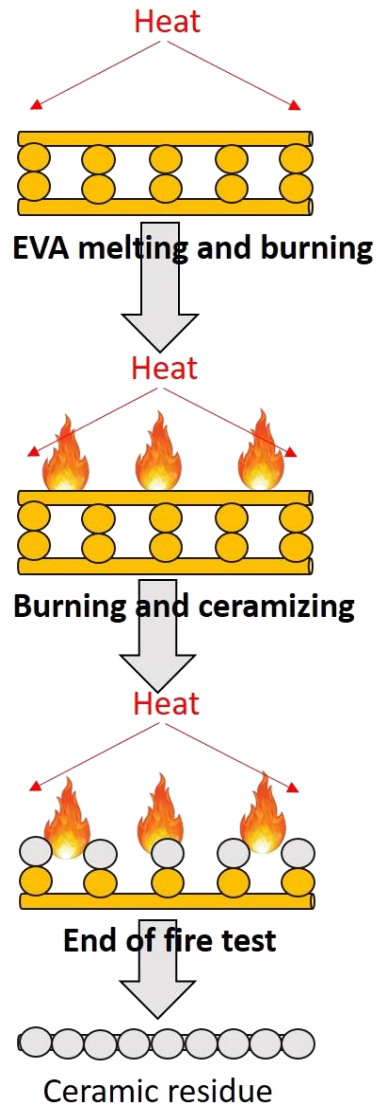
EDS analysis

XRD analysis

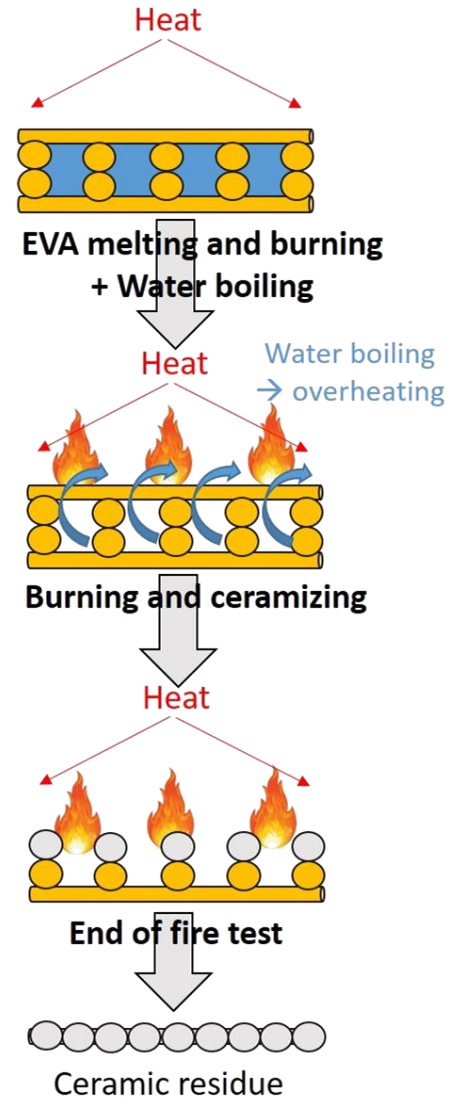
Crystalline phase:
 $KAl(CO_3)(OH)_2$: Orthorhombic
 $HK(CO_3)$, Monoclinic
 $Al(OH)_3$, Monoclinic



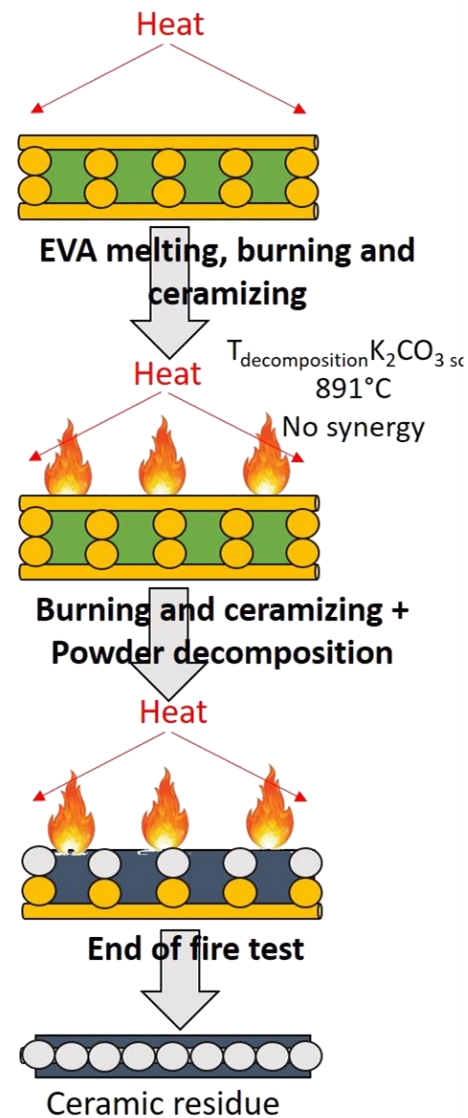
A) EVA/ATH (30%)-70% air



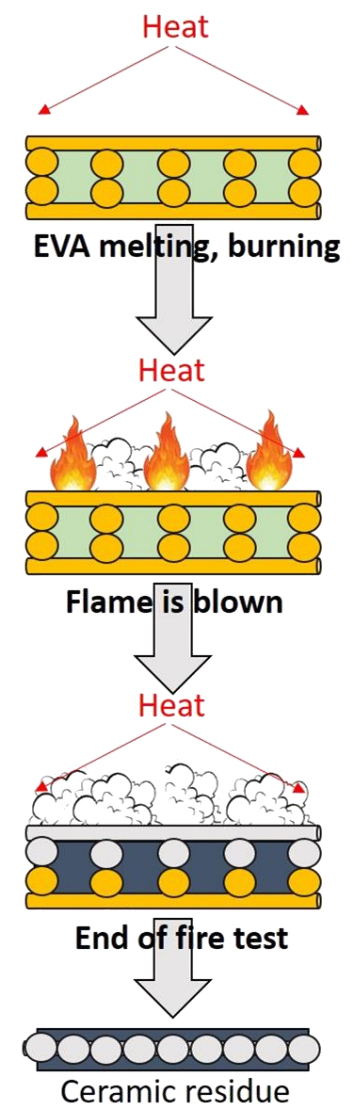
B) EVA/ATH (30%)-70% water

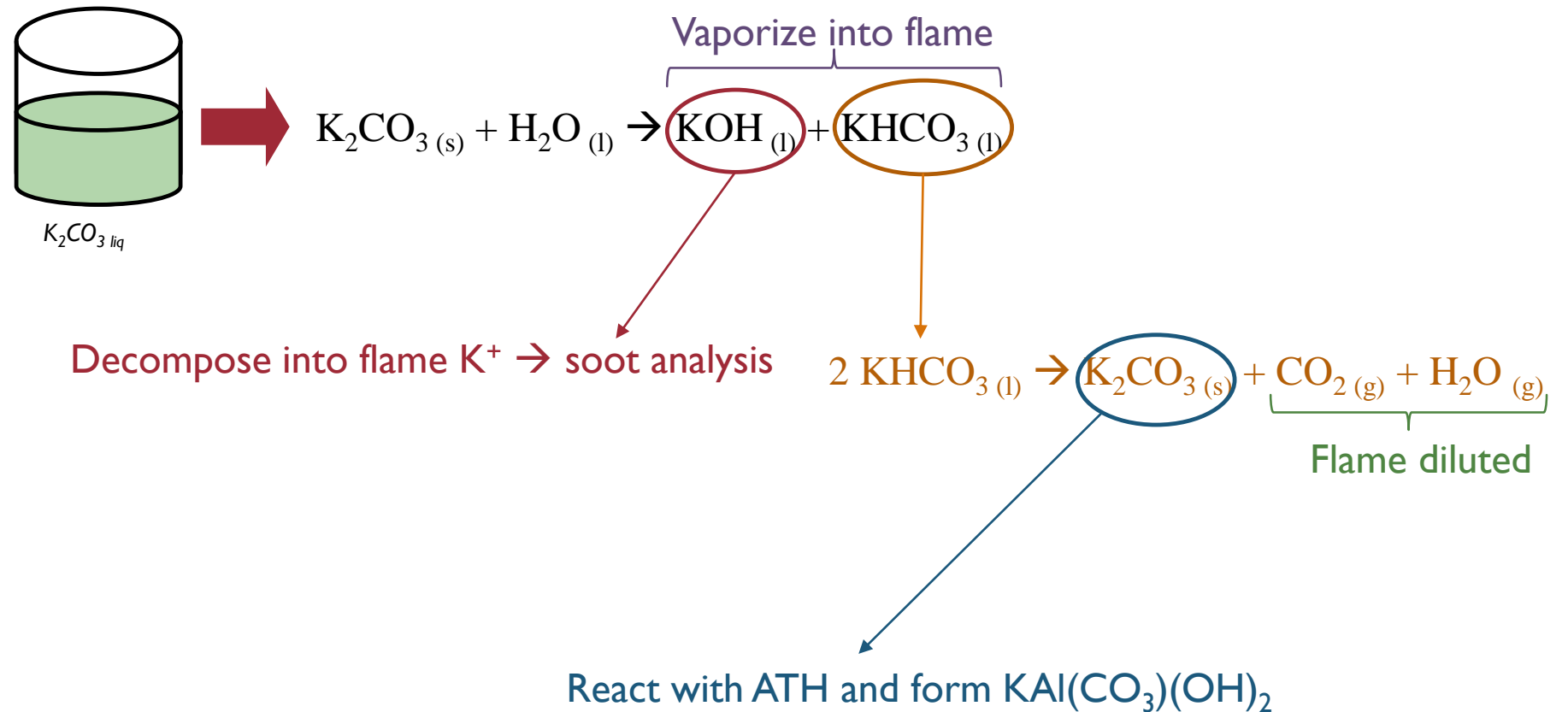
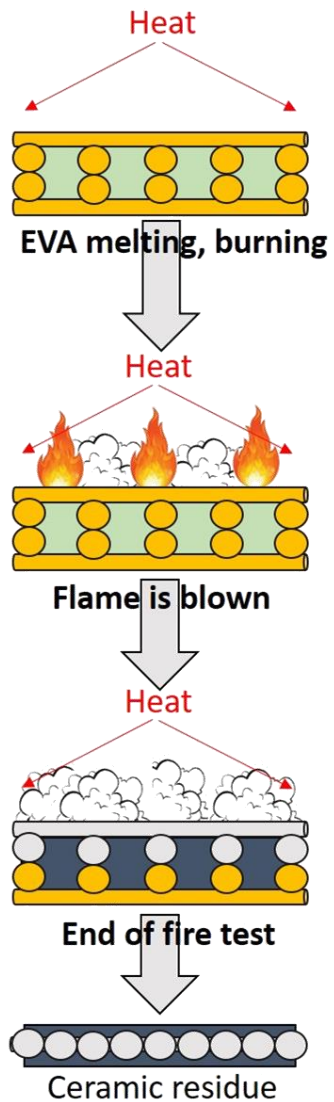


C) EVA/ATH (30%)-70% K_2CO_3 solid



D) EVA/ATH (30%)-70% K_2CO_3 liquid



D) EVA/ATH (30%)-70% K_2CO_3 liquid

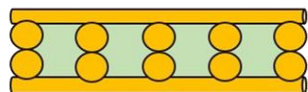
Conclusion



Eco-innovative process



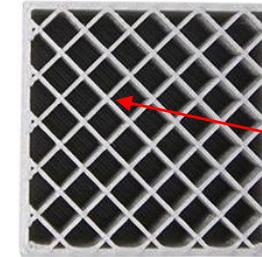
Original design and new way of thinking



New **fire protective** material elaborated which act in **gas and condensed** phase

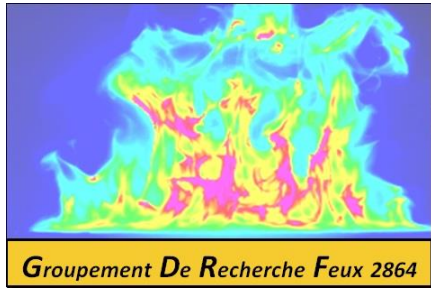
Outlook

- Work with another phase: Hydrogel



Hydrogel

GDR feux organization



Thank You For
Your Attention !

Any Questions ?

My PhD supervisors

S. BOURBIGOT



M. JIMENEZ



F. SAMYN



European Research Council



European
Commission

Horizon 2020
European Union funding
for Research & Innovation

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And all ERC team !