Formulation and characterizations of nanoenergetic compositions

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Energetic materials and chemistry

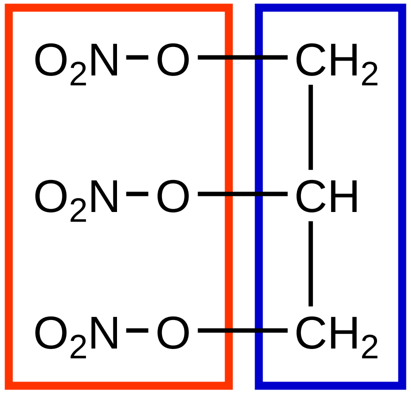
Energetic material: mixture between an oxidizer and a reductant (molecule or composition). The decomposition reaction can be written as follow

Oxidizer + Reductant ⟶ CO_2 + H_2O + O_2 + N_2 + …

Oxygen rich (↑ Oxidizer)

Carbone and hydrogen rich (↑ Reductant)

Energetic molecule: unimolecular reaction



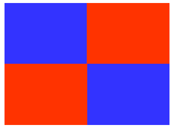
Oxidizer and reductant atoms are sufficiently close to one another for the decomposition reaction to take place ☺

☹ *Drawback: synthetic feasability*

Energetic materials and chemistry

<u>Energetic macrocomposition:</u> mixture of powders

Oxidizer powder (O) + **reductant powder (R)**

 =

RRROOO
RRROOO
OOORRR
OOORRR

Oxidizer and reductant atoms are distant to one another and the decomposition reaction kinetic may be too slow ☹

<u>Energetic nanocomposition:</u> mixture of particles

<u>Advantages</u>:

- homogeneity of the composition (sensitivity and performances)

☺ *- high contact area between O and R (performances)*

- kinetic of decomposition reaction comparable to unimolecular decomposition reaction

- no problem of synthetic feasability

- versatility of the composition (oxygen balance adjustment depending on the application)

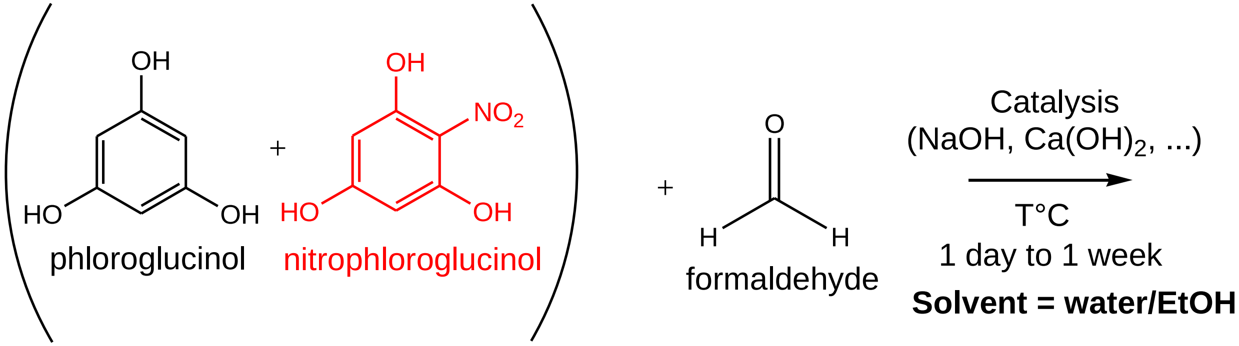
Prepared and tested materials

- ✓ Synthesis and formulation
- ✓ Physical characterizations
- ✓ Energetic results

Conclusion and Prospects

Synthesis and formulation

Synthesis of new functionalized organogels:



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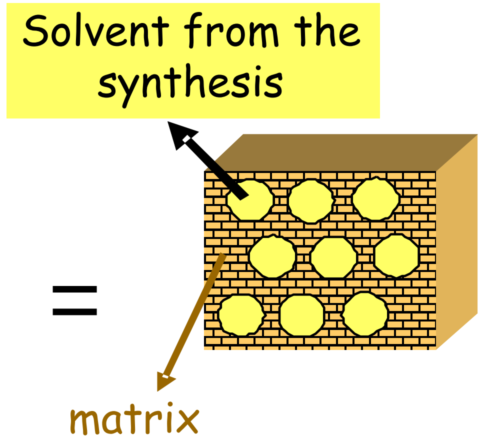
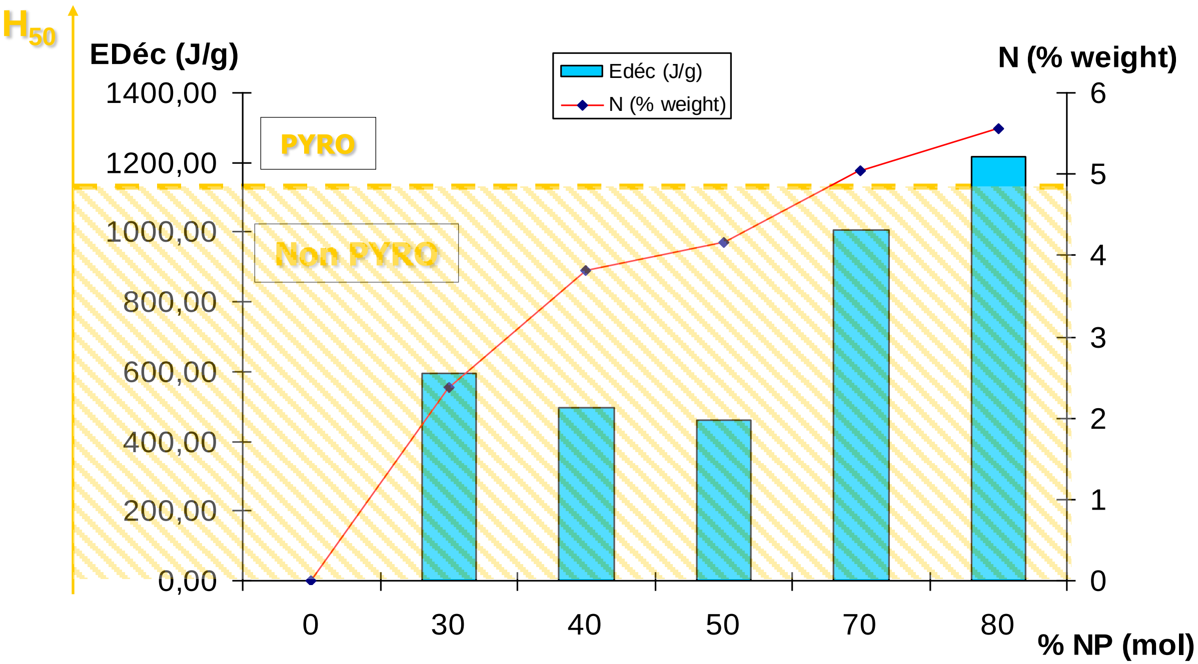
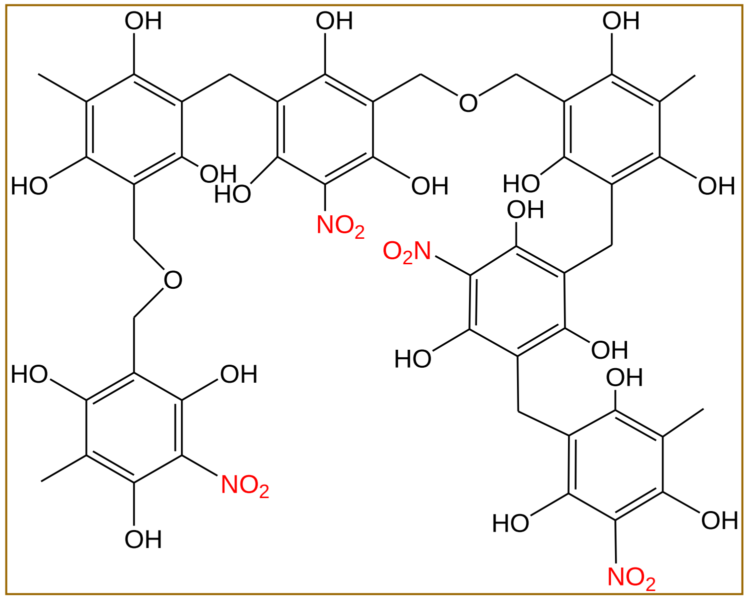




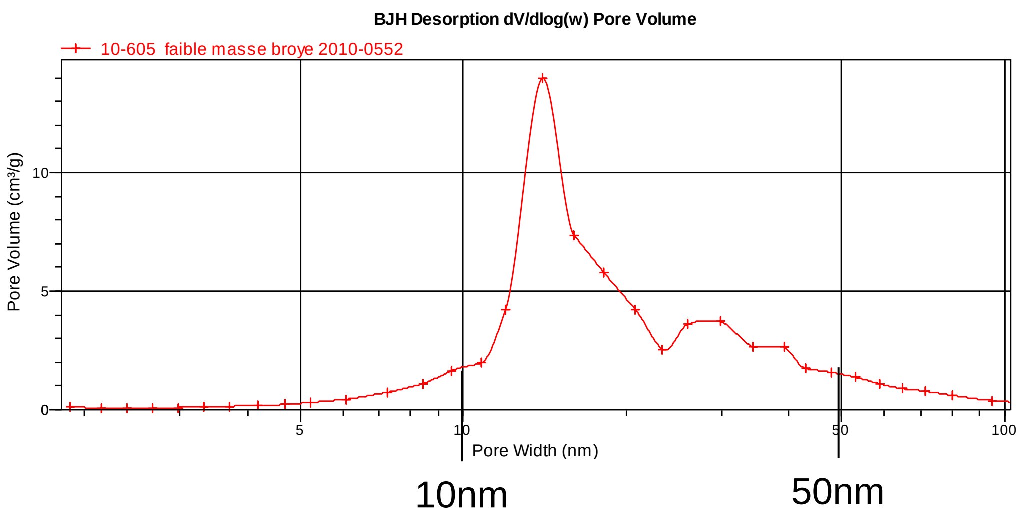


Synthesis and formulation

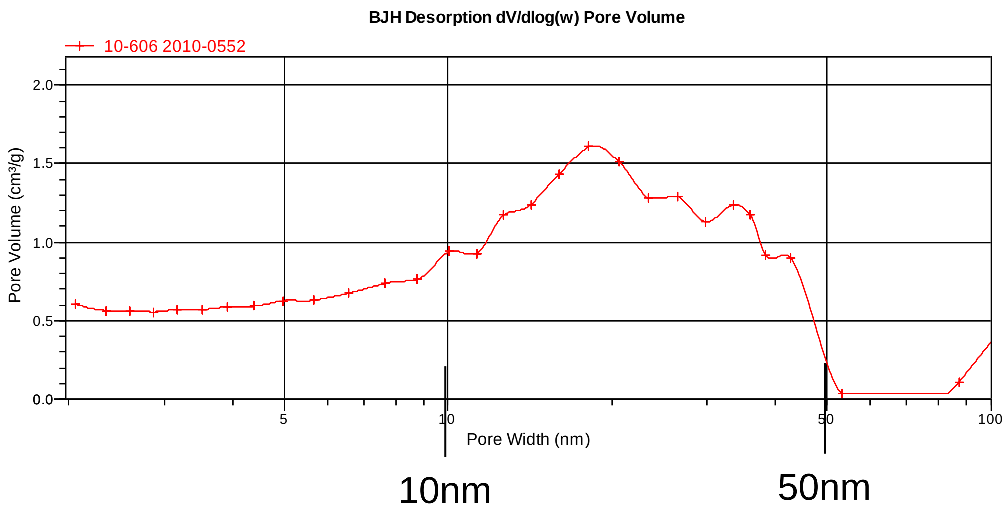
✓ BET analysis of PF and (P/NP7/3)F aerogels (supercritical CO_2 drying)

Sample	Specific area (m^2/g)
PF	795 ± 40
(P/NP7/3)F	688 ± 40

PF gel : Pore size distribution

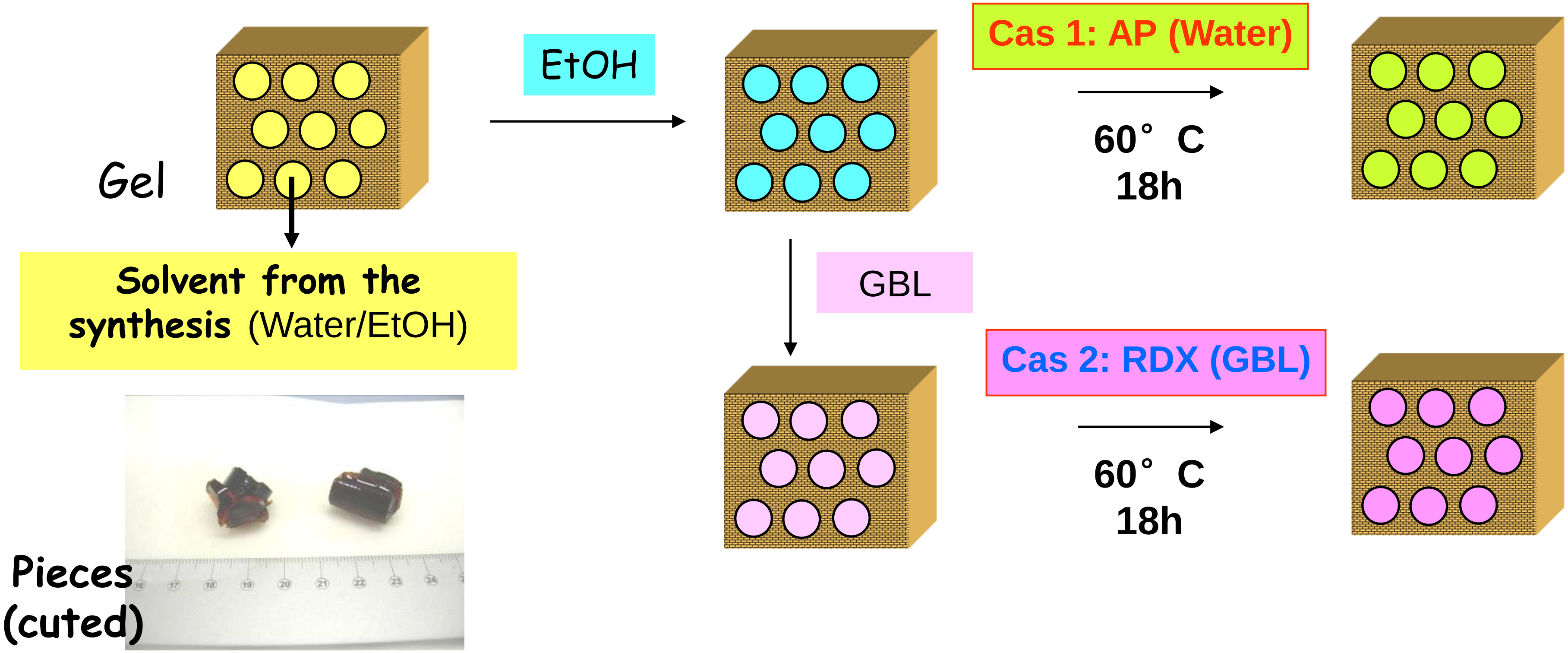


((P/NP7/3)F gel) : Pore size distribution



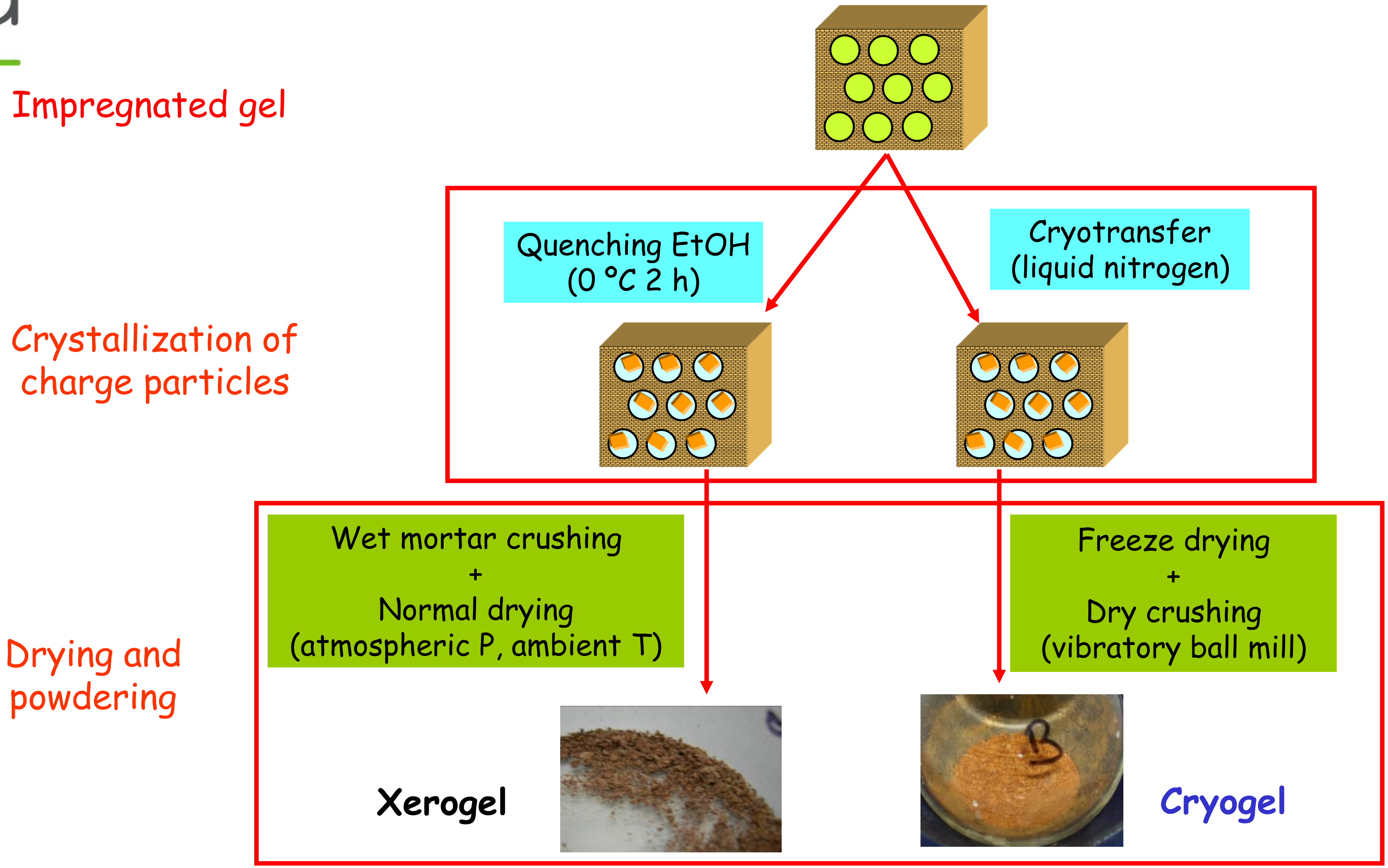
Synthesis and formulation

<u>Impregnation of an organogel with AP or RDX :</u>



Synthesis and formulation

From impregnated gel to powder :



Physical characterizations of prepared materials

X Ray powder Diffraction :

80 wt%. AP charge (BO_{CO2} = 0 %)	Average size of AP particles
PF/AP xerogel	> 120 nm (calculus : 480 nm) (repeatability : OK)
PF/AP cryogel	150 nm

Imaging :

- _Good microscopic homogeneity for xerogels and cryogels (SEM)
- Exocrystallization for xerogels

Before drying

After normal drying :

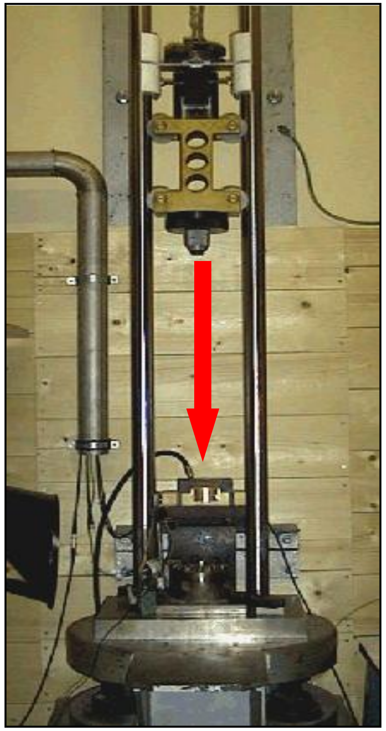
- White AP exocrystallites
- Partial destruction of the matrix

Example : xerogel balls

Energetic characterizations : RDX as a charge

➢ Instrumented drop-weight apparatus :

RDX charge
OB_{CO2} ~ -50 %
~ 70 to 75 wt%.



	Impact H_{50} (mm)/ P_{MAX} (bars)	
	Macro	Nano xerogel
RDX	100-150 / 5	/
PF/RDX	140 / 3,92	137 / 1,92 (- 51%)
P/NP(7/3)F/RDX	79 / 3,16	130 / 1,48 (- 53 %)
P/NP(3/7)F/RDX	95 / 3,63	/

Nanodispersions are slightly less sensitive and less powerful than mixture of powders

✓ Mixture of powders (macrosized) : matrix acts as a scraper
✓ Nanodispersions : matrix protects RDX towards aggression
✓ dispersion/dilution of RDX

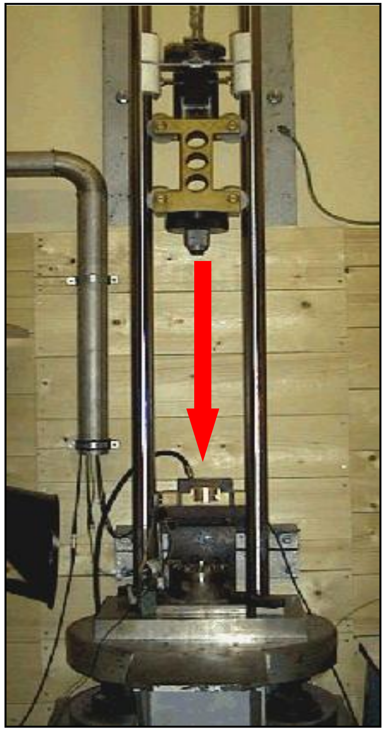
Future work : increase the wt%. of RDX beyond 90 % → nanostructured and powerful intrinsic explosive

Difficulties with the xerogel way because probable destruction of the matrix during drying phase

➡ Cryogel process

Energetic characterizations : AP as a charge

➢ Instrumented drop-weight apparatus :



AP charge :
OB_{CO2} = 0%
~ 80wt%.

	Impact H_{50} (mm) / P_{MAX} (bars)		
	Macro	Nano xerogel	Nano cryogel
PA	~ 500 / 0,75	/	/
PF/PA	350 / 1,48	367 / 1,92 (+30%)	503 / 3,03 (+104%)
P/NP(7/3)F/PA	231 / 1,06	580 / 2,47 (+133%)	500-700/2 to 3,3 (+100 to 200%)
P/NP(3/7)F/PA	189 / 1,60	203 / 1,64 (+2%)	257 / 2,41 (+50%)

nanodispersions are less sensitive and more powerful than mixture of powders

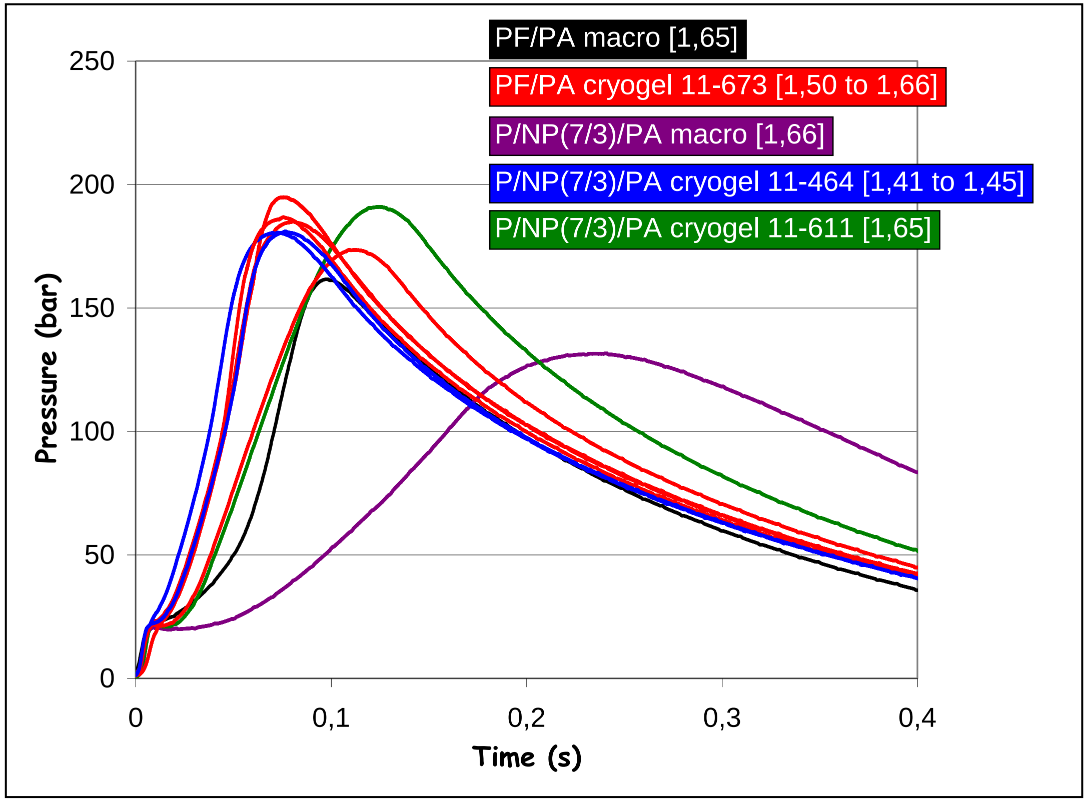
✓ Same mechanical influence of the matrix than for RDX compositions
✓ Better mix between oxydizer and reductant when nanodispersed
✓ Cryogel way better than xerogel way

➡ Cryogel process

Energetic characterizations on AP cryogels

➢ <u>Closed-chamber combustion :</u> 2 g pellets in a 64 cm^3 chamber

Pressing sequence : 60° C + 3x1000 bar) ➡ ρ = 1,65 g/cm^3



Scatter of pellets densities due to:

✓ Microscopic differences from batch to batch (freeze-drying, crushing conditions, …)

✓ Conservation conditions,

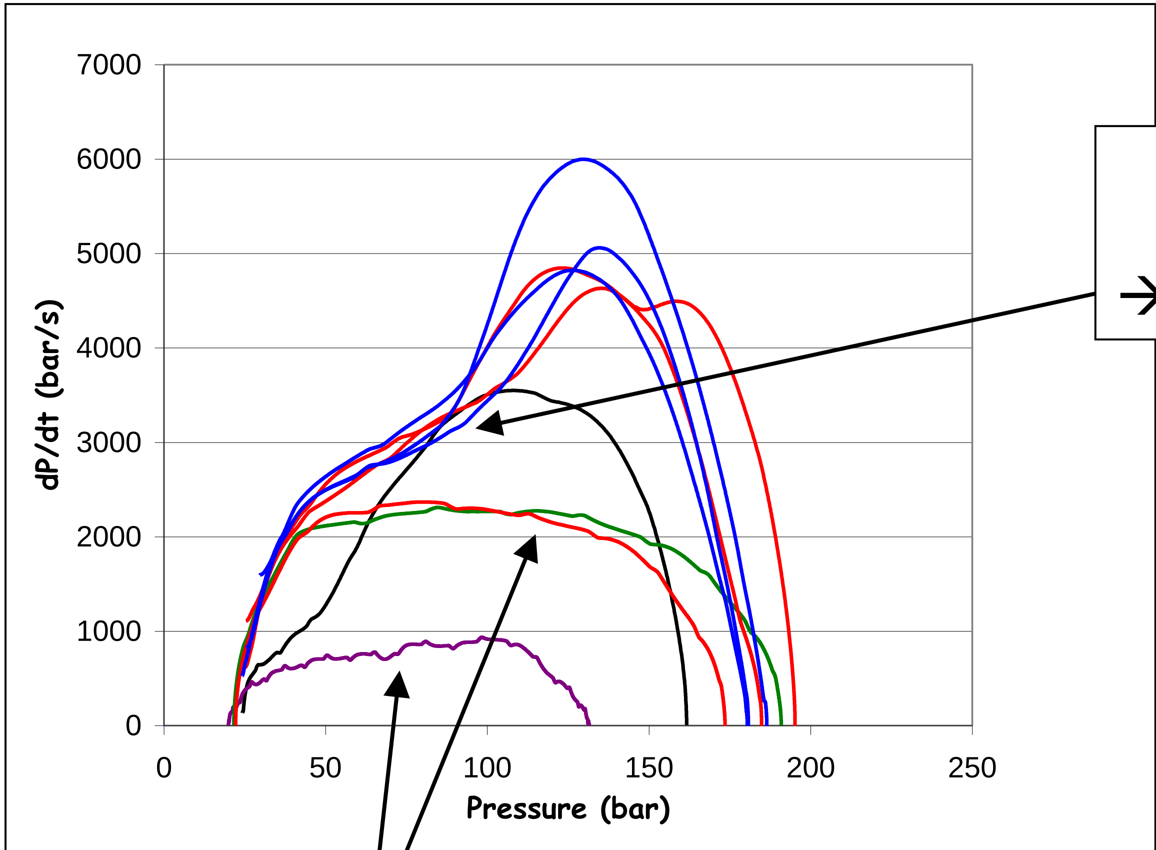
✓ …

Systematic deconsolitative burning for low density pellets

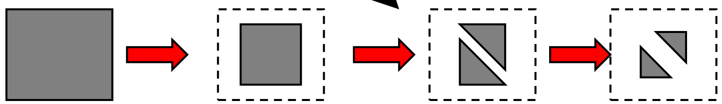
Difficulties to compare and to discriminate the different formulations

Energetic characterizations on AP cryogels

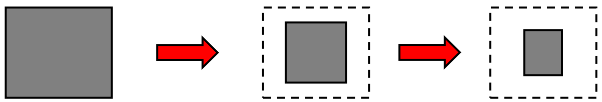
- Closed-chamber combustion :



Slope break-up of the pressurisation speed
→ Deconsolidative burning



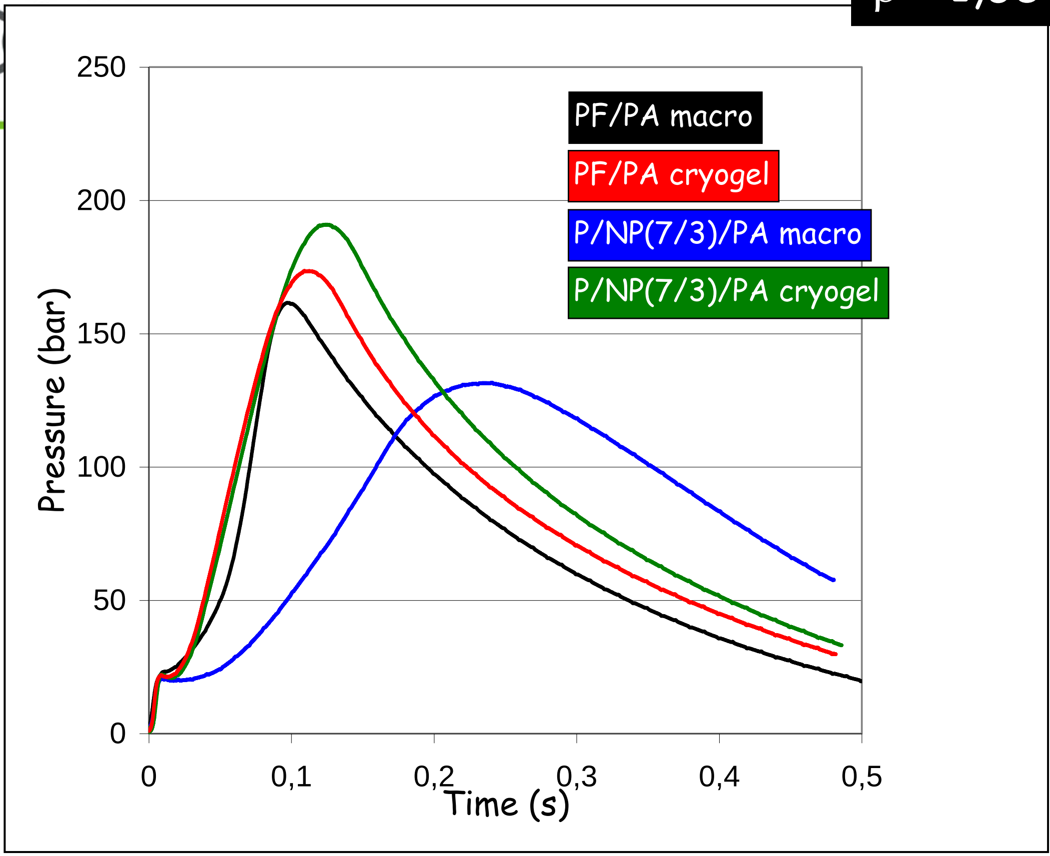
Bell-shaped curves → Regular burning

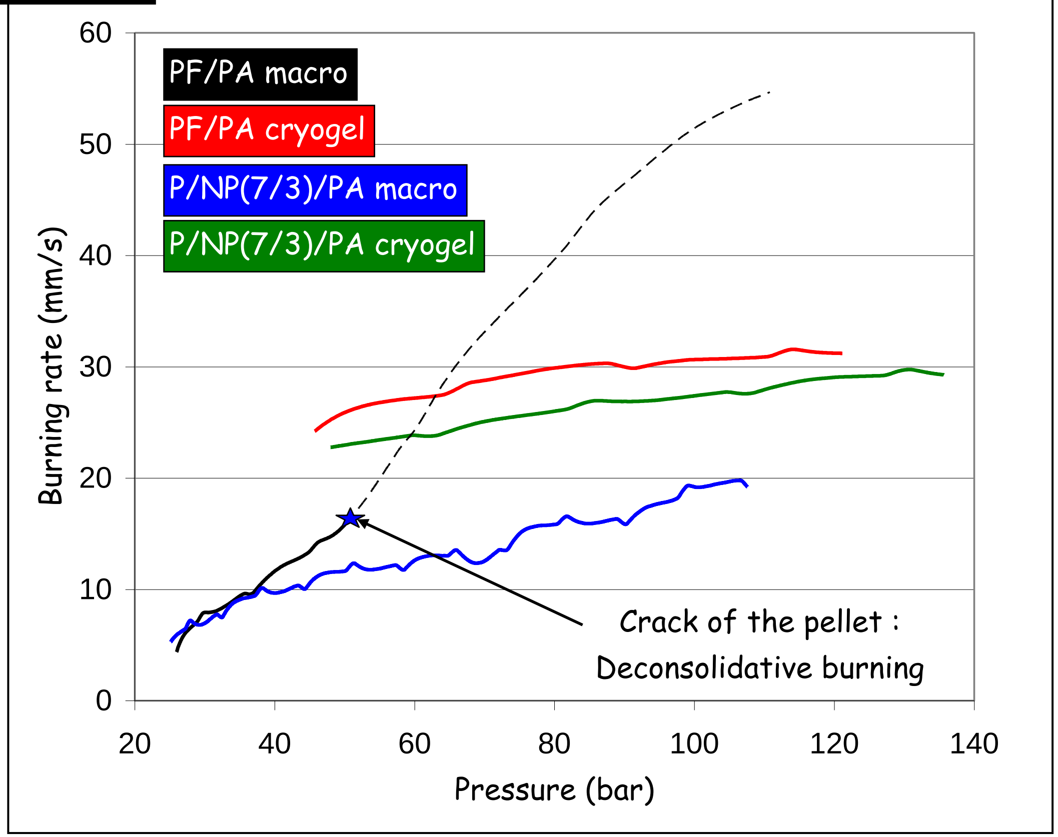


Combustion rate

Energetic characterizations on AP cryogels

ρ = 1,65 g/cm³





- ➢ Burning rate of the nanosized formulations is about two or three times higher than the one of the mixtures of powders
- ➢ Nanostructuration guarantees a stable combustion all over the explored pressure range (exponent pressure < 1)

Conclusion

➢ New energetic functionalized organogels have been synthesized and their ability to constrain the charge to nanostructure has been illustrated.

➢ Nanodispersions tend to be less sensitive than mixture of powders (Impact sensitivity).

➢ When they decompose, AP based nanomaterials are more powerful than mixture of powders.

➢ Combustion of nanodispersions shows improved propulsion performances (burning rate and combustion stability) compared to mixture of powders.

➢ A scale-up of the cryogel process has recently been done with success, allowing us to produce batches of 125 g of nanoformulations

→ Use in propellant formulation

Prospects

- Reproducibility of the cryogel process to nanostructure is demonstrated but improvements must be done to control and/or to tune the microstructure

- Ability of the cryogel process to nanostructure an intrinsic explosive (RDX) with charge ratio > 90 wt%. → nanostructured powerful intrinsic explosive.

THANK YOU FOR YOUR ATTENTION

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