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Formulation and characterizations of nanoenergetic compositions with improved safety

A. Wuillaume, A. Beaucamp, F. David-Quillot

Financially supported by DGA

IM/EM 2013, October 7 - 10, 2013

Abstract 16152

Context of the study

- Quest for safe matter for propulsion and explosives

- The properties of energetic material compounds are strongly affected by the microstructural properties of the main material (crystal size, shape, morphology, purity, defects, and the microstructure of inter crystalline voids)

Two ways to achieve less sensitive energetic materials

Optimize conventional crystallization conditions (RDX, HMX)

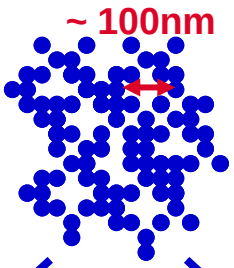
Significantly reduce the crystal size

Development of nanosized energetic materials

Context of the study - Concept

➢ **Key point:**

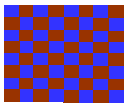
nanostructuring matrix (M)



✓ Three dimensional polymer
✓ Low-density mesoporous polymer
✓ Nanosized pores (open pores)

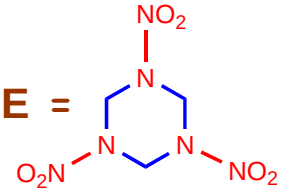
Explosive:

(M) ≤ 10wt%
+
explosive particles (E) ≥ 90wt%



= MEMEME EMEMEM MEMEME EMEMEM

E =

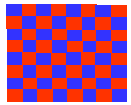


Objective: reduction of RDX particles size

Improve safety without degradation of performances

Propellant:

(M) = reductant
+
oxidizer particles (O)



= MOMOMO OMOMOM MOMOMO OMOMOM

Ex.: *O=AP*

Objective: increase of the oxidizer/reductant atoms interface

Improve combustion behavior without degradation of safety

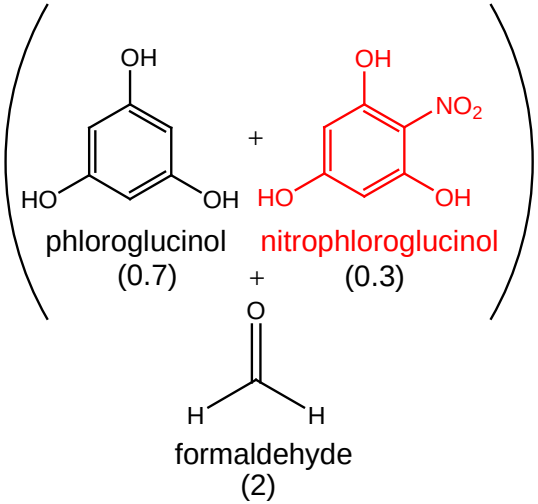
Prepared and tested materials

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

Conclusions and prospects

Synthesis and formulation

Synthesis of the nanostructuring matrix :



$Ca(OH)_2$

50°C

Water/EtOH 45/55

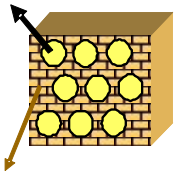
(P/NP7/3)F gels

to +1h

to +1day

Pores containing synthesis solvent

=

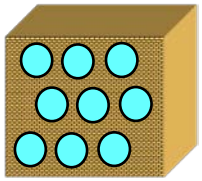


matrix

Gel washed with ethanol

Gel cut into pieces

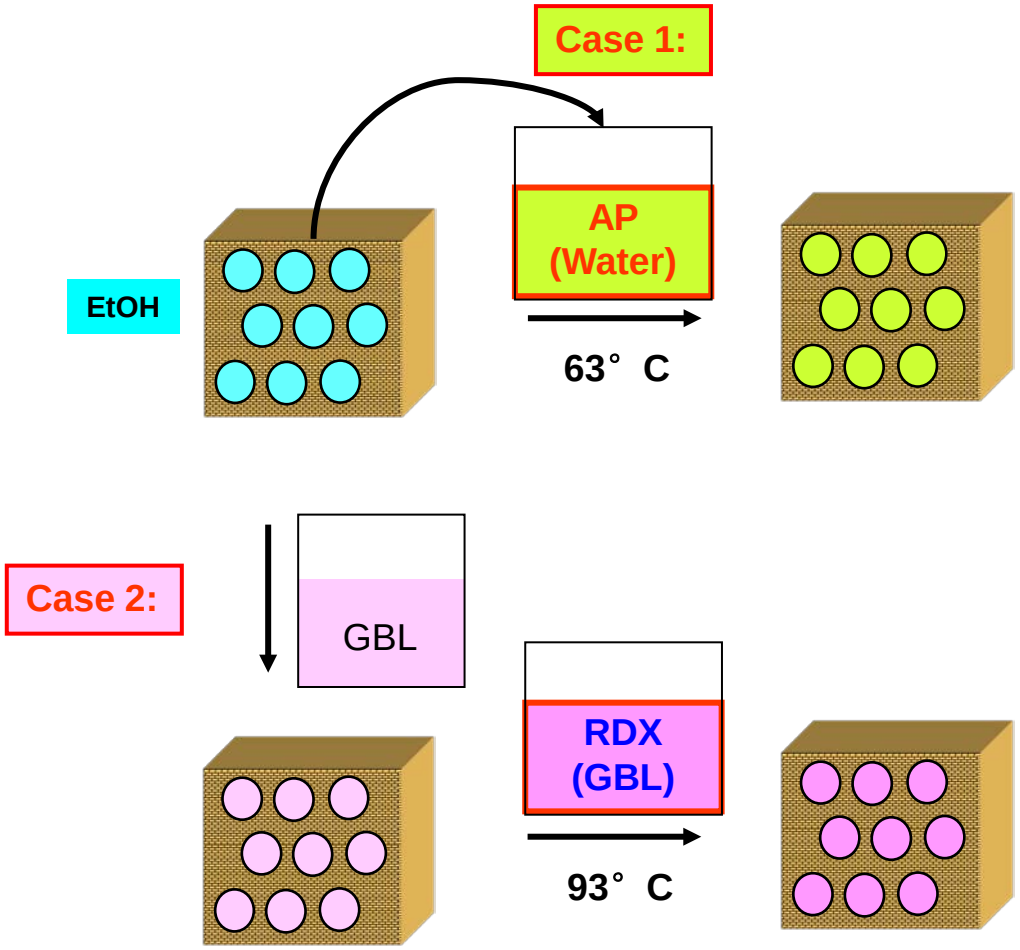
EtOH



Formulation of AP and RDX nanodispersions

Synthesis and formulation

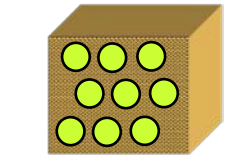
Impregnation of the nanostructuring matrix with AP or RDX :



Synthesis and formulation

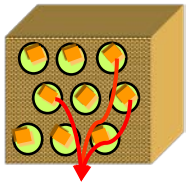
Charge crystallization and drying process:

Case 1: AP



AP saturated solution

Cryotransfer (liquid nitrogen)

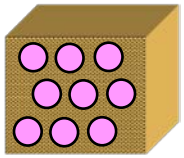


AP nuclei

Freeze drying + Dry crushing (vibratory ball mill)

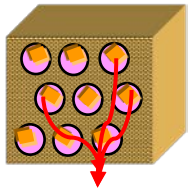
(P/NP7/3F)/AP

Case 2: RDX



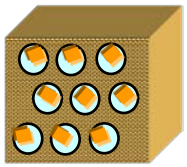
RDX saturated solution

Cryotransfer (liquid nitrogen)

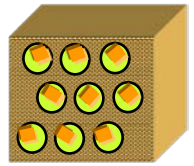


RDX nuclei

Exchange GBL → EtOH (-20 °C)



Exchange EtOH → Water ambient T



1- Cryotransfer (liquid nitrogen)

(P/NP7/3F)/RDX

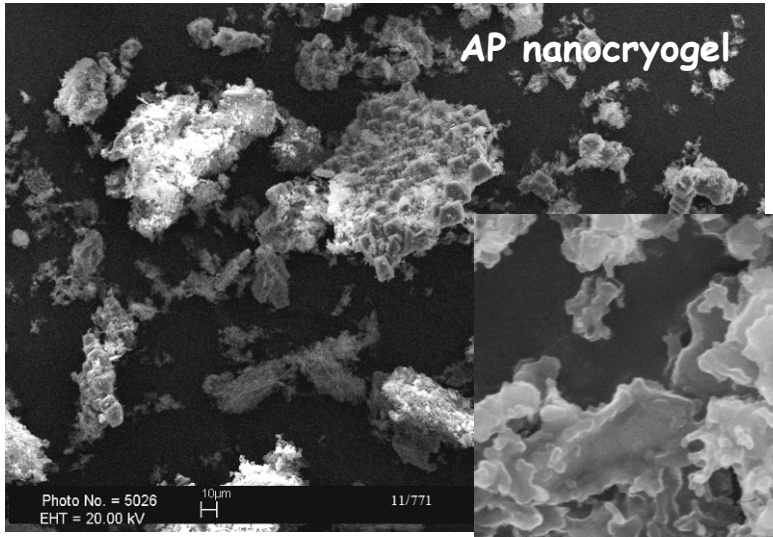
2- Freeze drying + Dry crushing (vibratory ball mill)

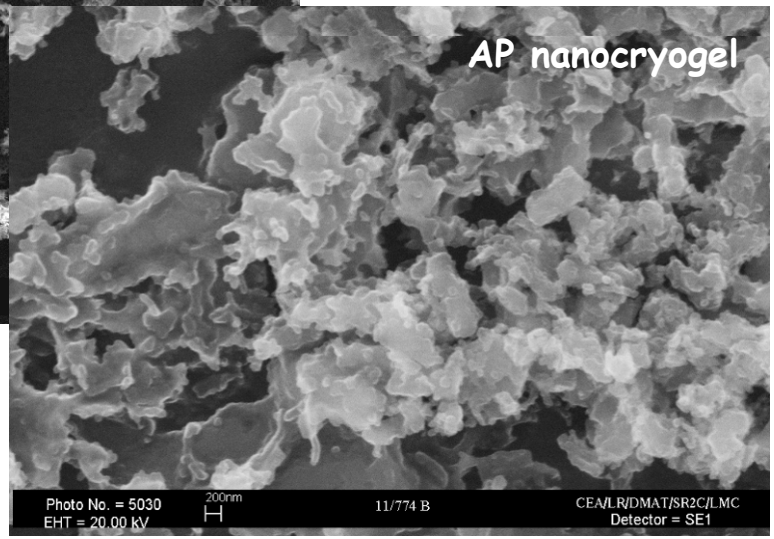
Physical characterizations

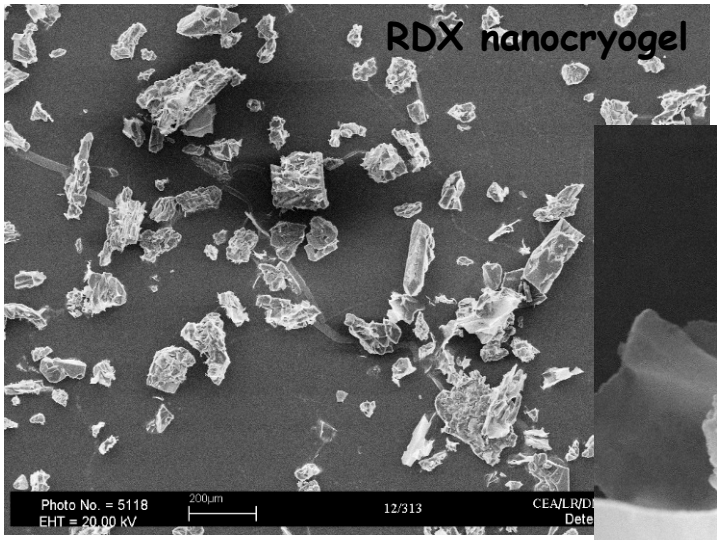
X-ray diffraction measurement:

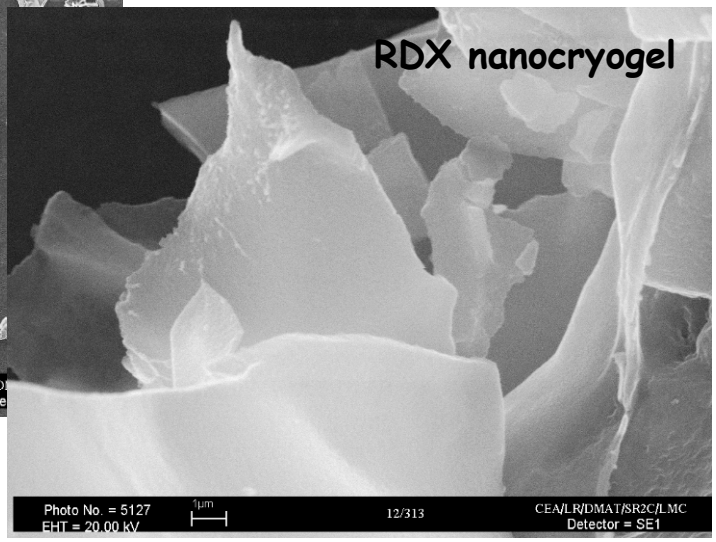
Sample	Average particle size
(P/NP7/3F)/PA 20/80	100-130nm
(P/NP7/3F)/RDX 10/90	100-150nm

SEM images :



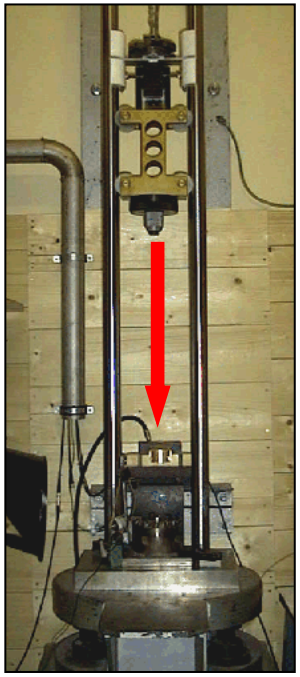






Energetic characterizations

Drop-weight results: impact behavior



	H_{50} (mm) / P_{MAX} (bars)	
	Macro	Nano
P/NP(7/3)F/AP 20/80	215/1.06	500-700/2-3.3
(P/NP 7/3))F/RDX 25/75	138 / 2.11	130 / 1.48
(P/NP 7/3))F/RDX 10/90	170 / 4.85	99 / 4.60
RDX Various crystal sizes	100-150 / 4.5-5	/

Nanosized AP formulations:
- better mix between oxidizer and reductant
- matrix protects AP towards aggression

RDX formulations:
- Sensitivity is controlled by intrinsic RDX sensitivity
- Strong effects of dispersion/dilution of RDX under 90 %wt

AP nanodispersions are less sensitive and more powerful than mixture of powders

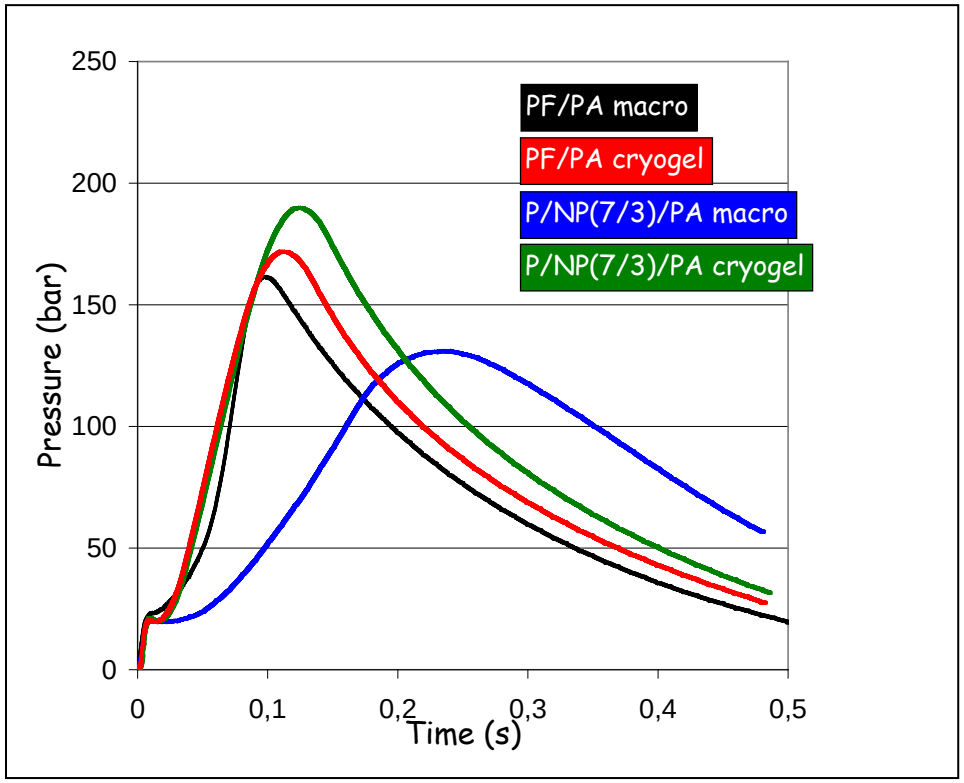
RDX nanodispersions are as sensitive as mixture of powders

Energetic characterizations on AP cryogels

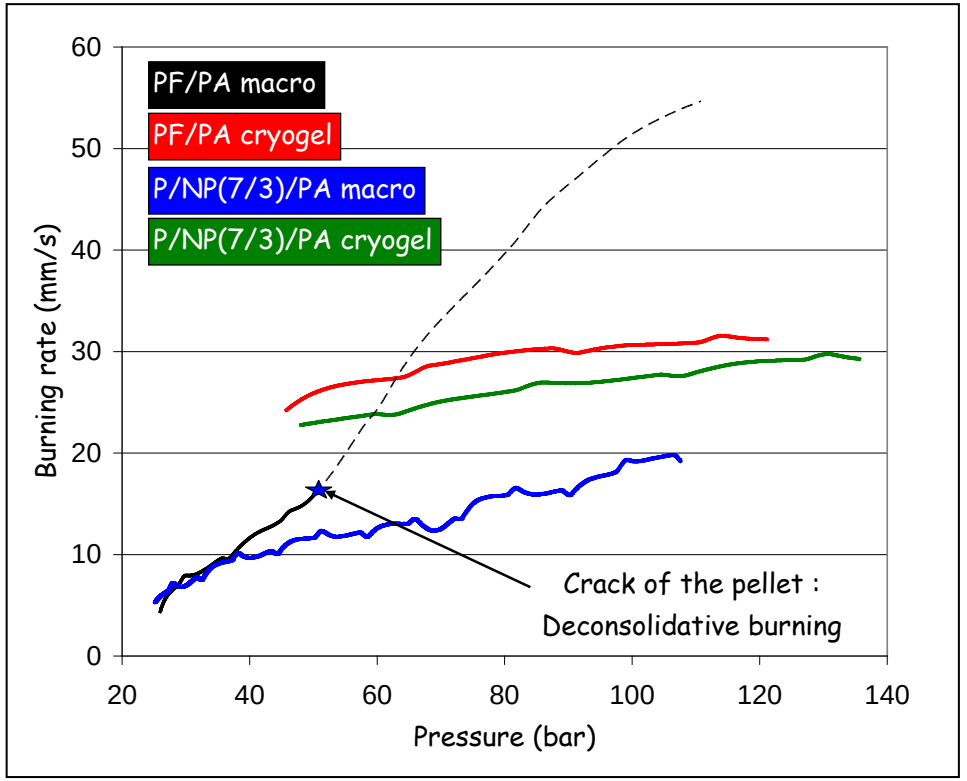
➢ Closed-chamber combustion : combustion behavior

2 g pellets in a 64 cm^3 chamber

Pressing sequence : 60° C + 3x1000 bar → ρ = 1.65 g/cm^3



Strong assumptions



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

Energetic characterizations on AP cryogels

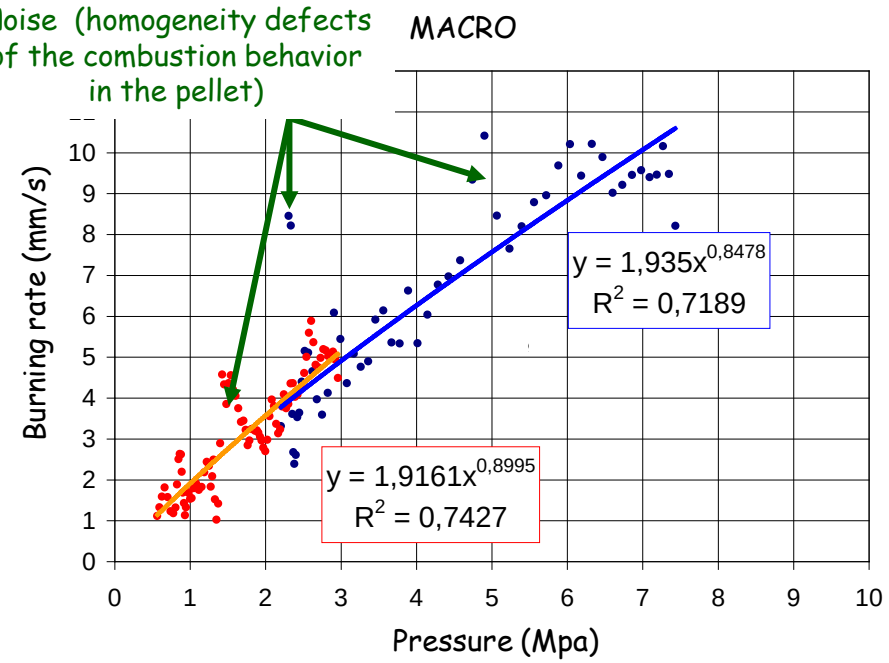
➢ Ultrasound measurement method (ONERA) : combustion behavior

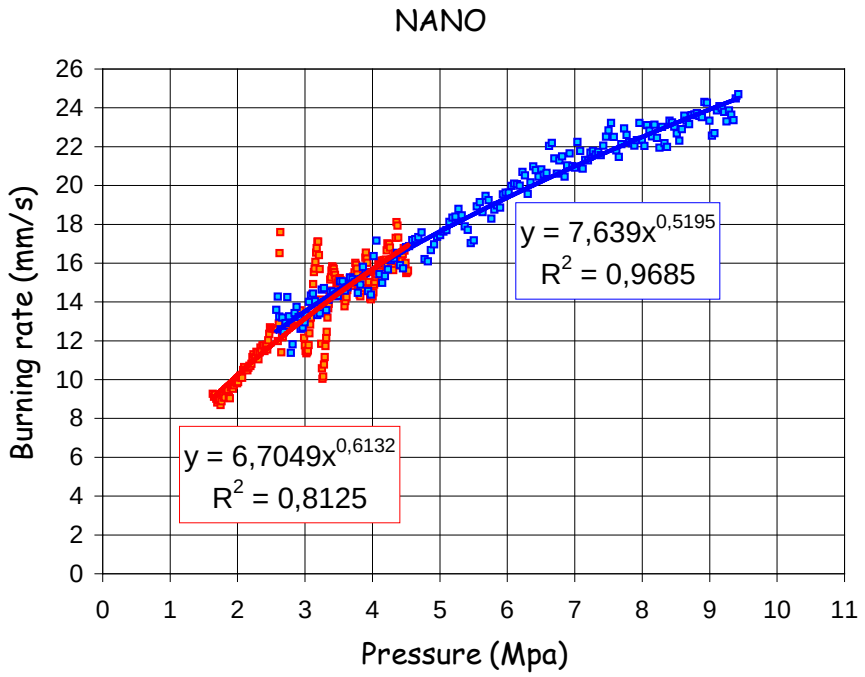
10 g pellets in a 0.6L chamber

Pressing sequence : nano = 60° C + 3x1100 bar
macro = 60° C + 3x1500 bar

→ ρ = 1.78 g/cm³

Noise (homogeneity defects of the combustion behavior in the pellet)



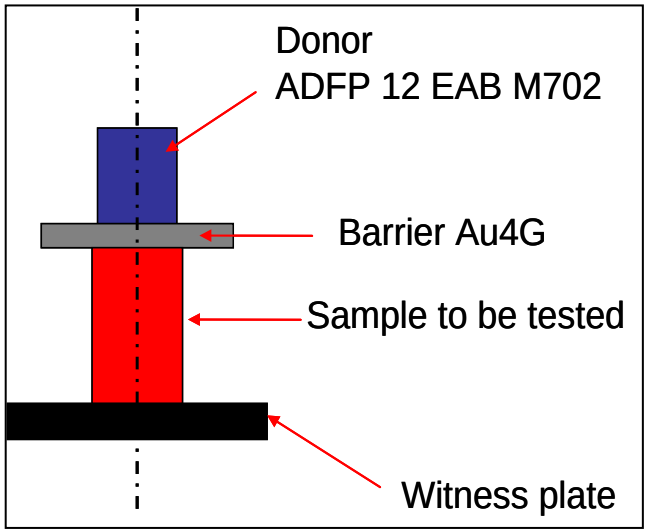


Confirm closed chamber combustion results

burning rate $_{nano}$ = 2 to 3 x burning rate $_{macro}$
pressure exponent $_{nano}$ < pressure exponent $_{macro}$

Energetic characterizations on RDX cryogels

➢ <u>Small-scale gap test:</u> detonation initiation behavior of RDX formulations



- Classical run: 30 to 50 tests (up-and-down method)
- Determination of the barrier thickness (e_{50}) driving to the sample initiation probability of 50%

Shock-sensitivity increases

Formulation	Reference HMX/TATB/phenoxy (45/52/3) 98 TMD%	Nano RDX/(P/NP7/3F) (90/10) 95 TMD%	HMX/TATB/technoflon (65/30/5) 98 TMD%	Macro RDX/(P/NP7/3F (90/10) 95 TMD%
e_{50} (mm)/ confidence limits	< 1	1.84 [1.52-2.09]	1.88 [1.78-2.00]	2.84 [2.50-3.10]

✓ Strong improvement of shock-sensitivity when nanostructuring,
✓ RDX nanoformulation is as insensitive as a formulation containing TATB despite more nitramine content, more porosity and lack of binder.
✓ Need to be validated with more shots (only 10 on each formulation until now)

Conclusions

- A formulation process able to produce nanodispersions of AP or RDX (up to 90wt%) in a nanostructuring matrix has been developed

- Propellant application: AP formulations
  - ✓ Nanodispersions are less sensitive than mixture of powders (impact sensitivity)
  - ✓ When they decompose, AP nanocryogels are more powerful than mixture of powders
  - ✓ Combustion of AP nanocryogels shows improved propulsion performances (burning rate and combustion stability) compared to mixture of powders

- Explosives application: RDX formulations
  - ✓ No effect of nanosizing on impact sensitivity (intrinsic to RDX)
  - ✓ Strong improvement of shock-sensitivity for nanostructured formulation

Propects

- Optimizations of the nanodispersion process (step simplification and duration, drying, get rid of the residual porosity)

- Propellant application: AP formulations
  - ✓ Classical propellant formulations are under way (SAFRAN partner)

- Explosives application: RDX formulations
  - ✓ Detonation characterizations to be completed
  - ✓ Direct use without further processing for high-energy detonators (exploding wire or slapper)
  - ✓ Development of formulations with binder for booster or loading explosive applications

Acknowledgements

- Contributors from the National Center of Aerospace Research (ONERA)
- Contributors from SAFRAN-HERAKLES
- Contributors from the CEA/DAM – Le Ripault

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