The 2019 IMEMTS

Desensitization of nitramine explosives with reserved high energy

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Oct 22nd, 2019, Sevilla

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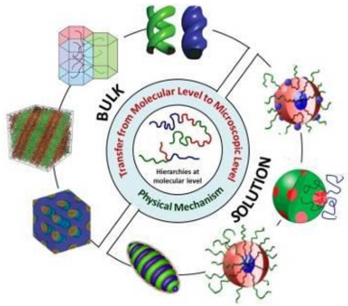

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I. Introduction

I. Introduction

1.1 Energetic materials in modern weapons

Effective destructibility
&
High safety

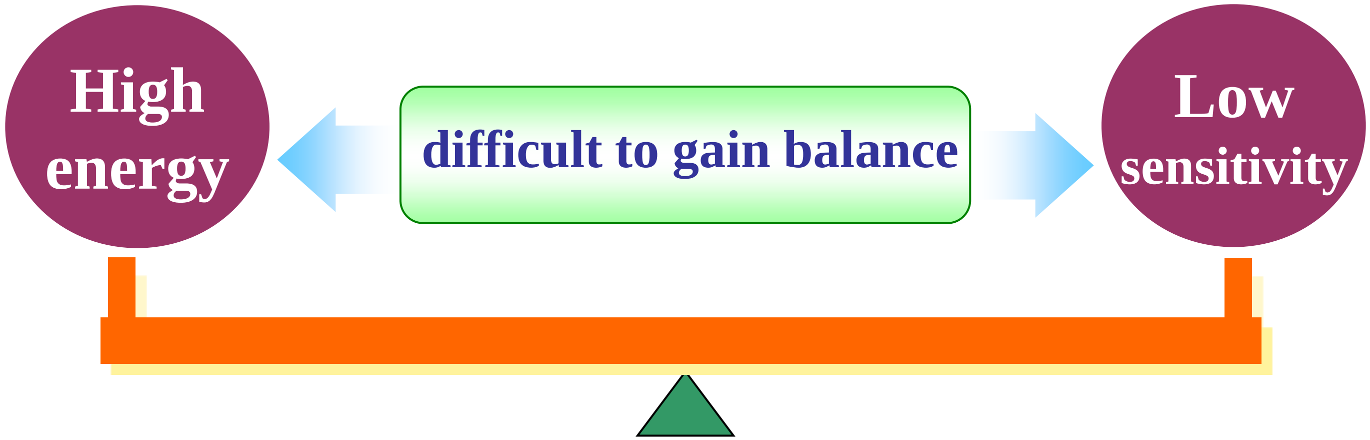
CHE → **IHE**
replacement




Defence Sci. J. 60 (2010) 137-151
J. Am. Chem. Soc. 135 (2013) 9931-9938

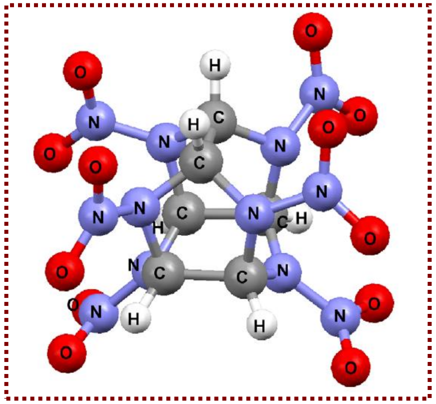
I. Introduction

1.1 Energetic materials in modern weapons



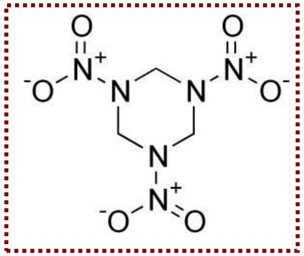
I. Introduction

1.2 The research object: CL-20, HMX, RDX



- First synthesized in 1987
- Most powerful EM in practical use
- Restriction for application: high sensitivity

HMX

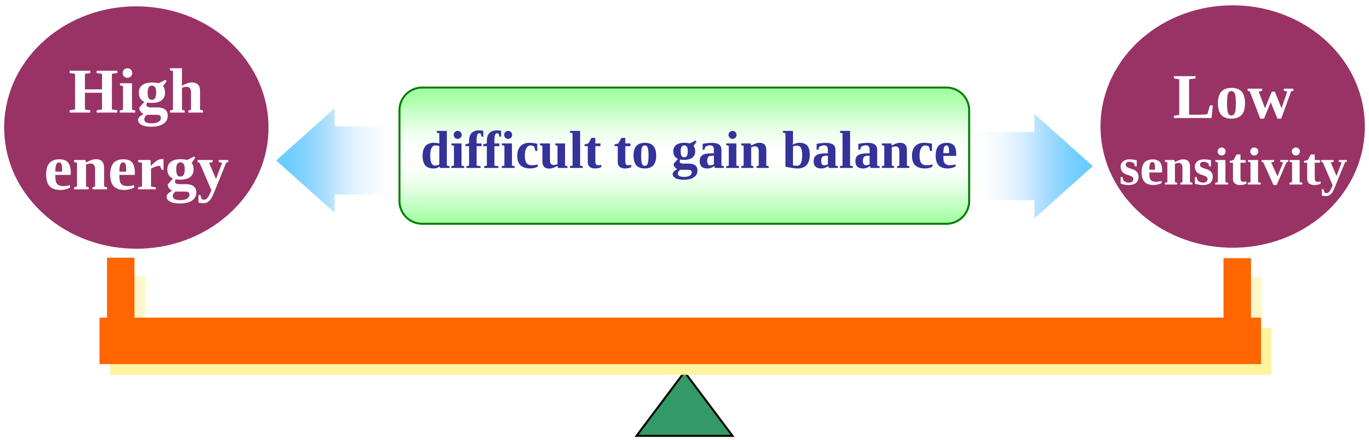


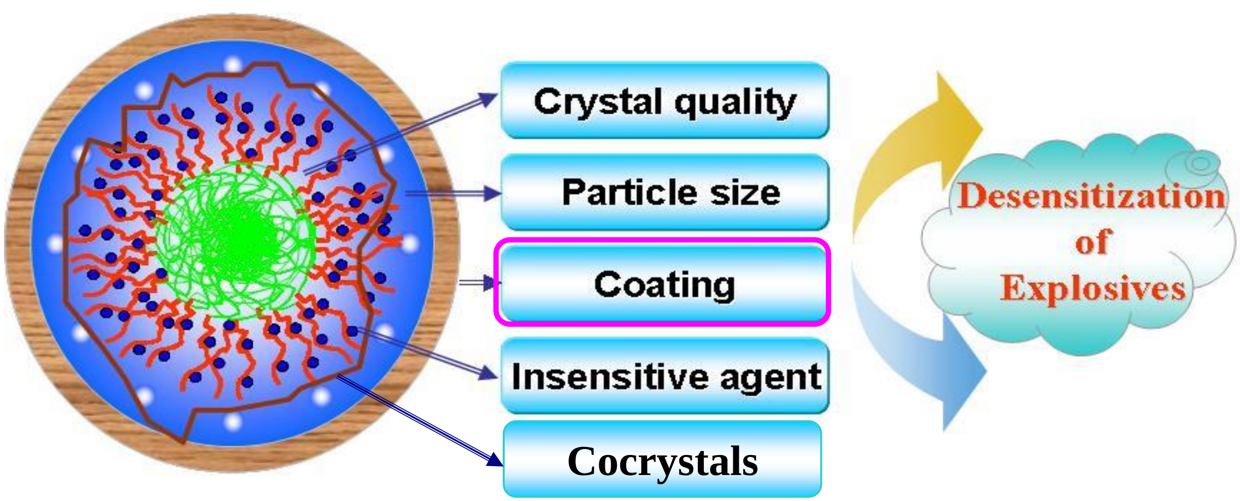
RDX

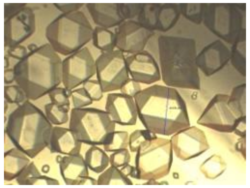
Propellants Explos. Pyrotech., 2014, 39, 51-58

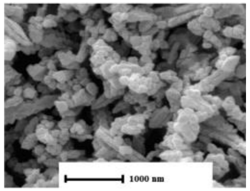
I. Introduction

1.3 Reduce the sensitivity of high explosives

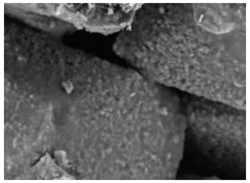


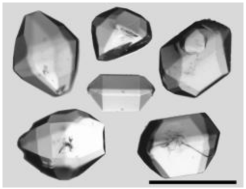



Recrystallization



nano


Coating

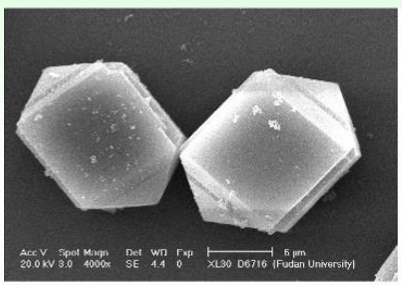

cocrystal

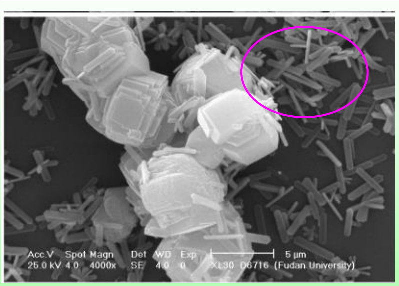
I. Introduction

1.3 Reduce the sensitivity of high explosives

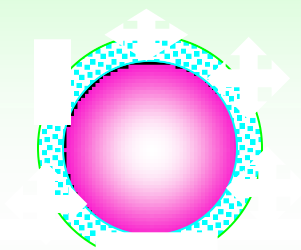
Key points for explosive coating techniques

Shell Self-nucleation

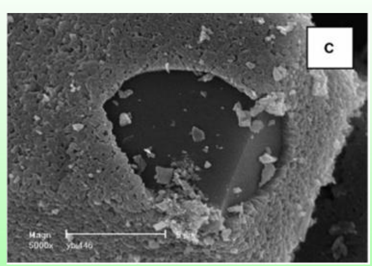




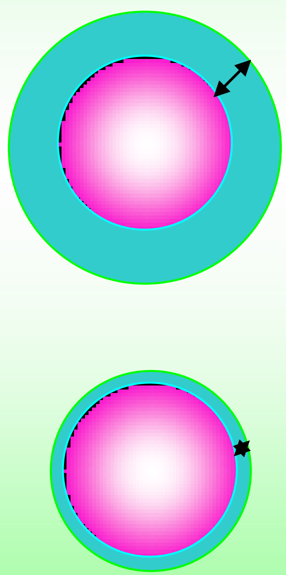
Degree of coverage



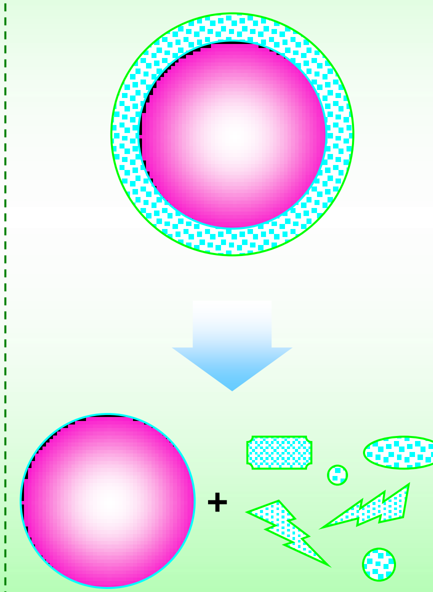
60 % coating



Control of thickness



High shell Strength



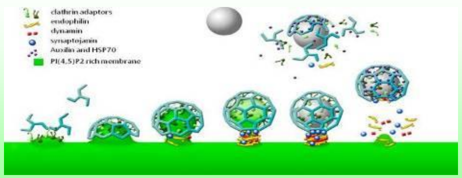
Nat. Mater. 20 (2015), 143
Angew. Chem. Int. Ed. 47 (2013), 522

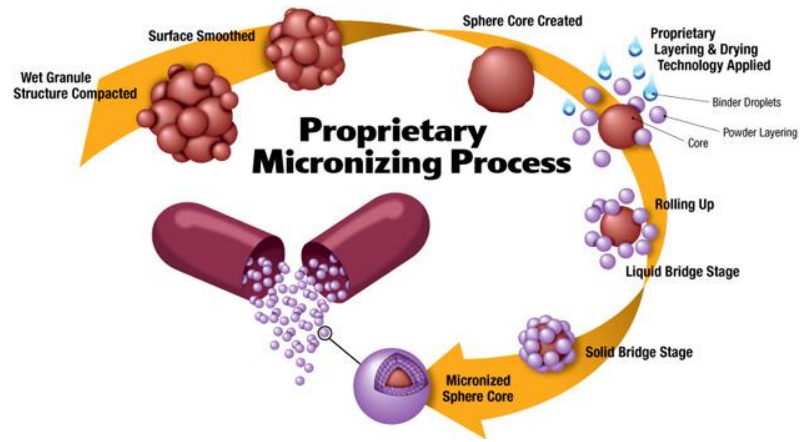
I. Introduction

1.4 Microencapsulation via *in-situ* polymerization

Microencapsulation

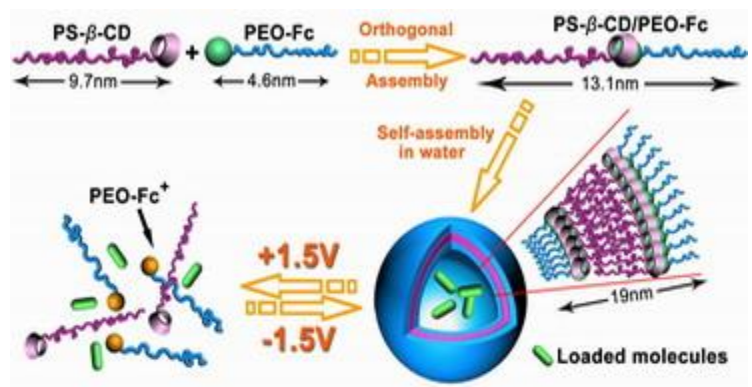
- protect active substance
- controlled release





In-situ polymerization

- monomer intercalation
- chemical polymerization
- extraordinarily high coverage
- high shell strength



Adv. Colloid Interfac. 207 (2014) 65-80.
Polym. Rev. 52 (2012) 142-188.

I. Introduction

1.4 Microencapsulation via *in-situ* polymerization

Candidate: MF resins

- **melamine + formaldehyde**
- **widely applicable**
- **facilely prepared**
- **economical, adjustable**

MF resins performances

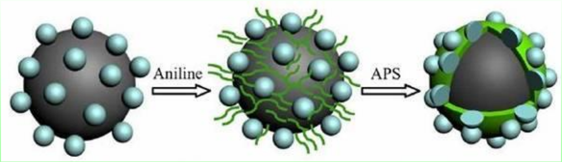
- **outstanding thermal stability**
- **mechanical strength**
- **relatively high density**
- **water and aging resistance**

Extensive application

- **phase change materials**
- **self-healing composites**
- **flame retardants**
- **dyes**

Great potential

- **reduce impact sensitivity**
- **improve thermal stability**



Chem. Eng. J. 249 (2014) 27-33.

II. CL-20/TATB core-shell coating

core

high explosives

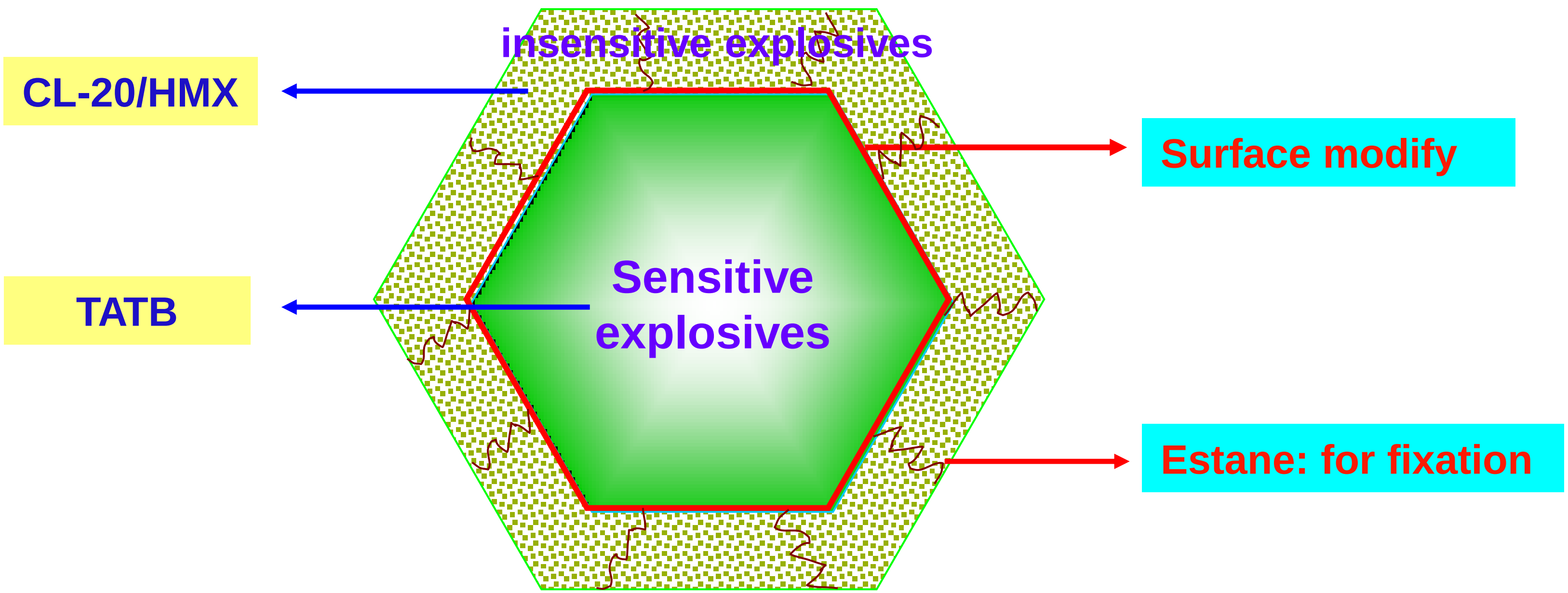
- CL-20
- HMX
- RDX

Energetic coating

shell

insensitive explosives

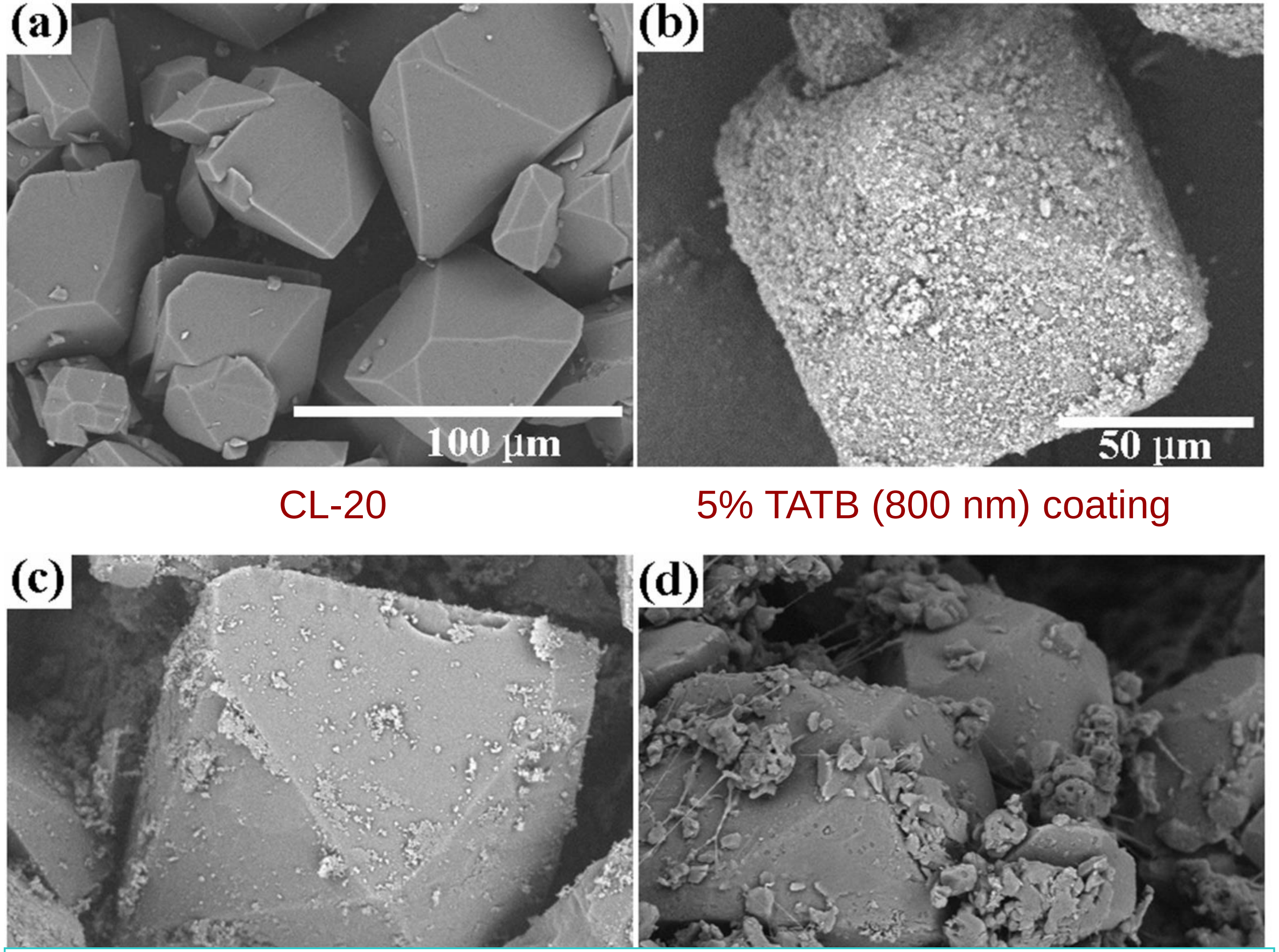
- TATB
- NTO
- LLM-105
- FOX-7
- TNT
- HNS



High energy & Low sensitivity

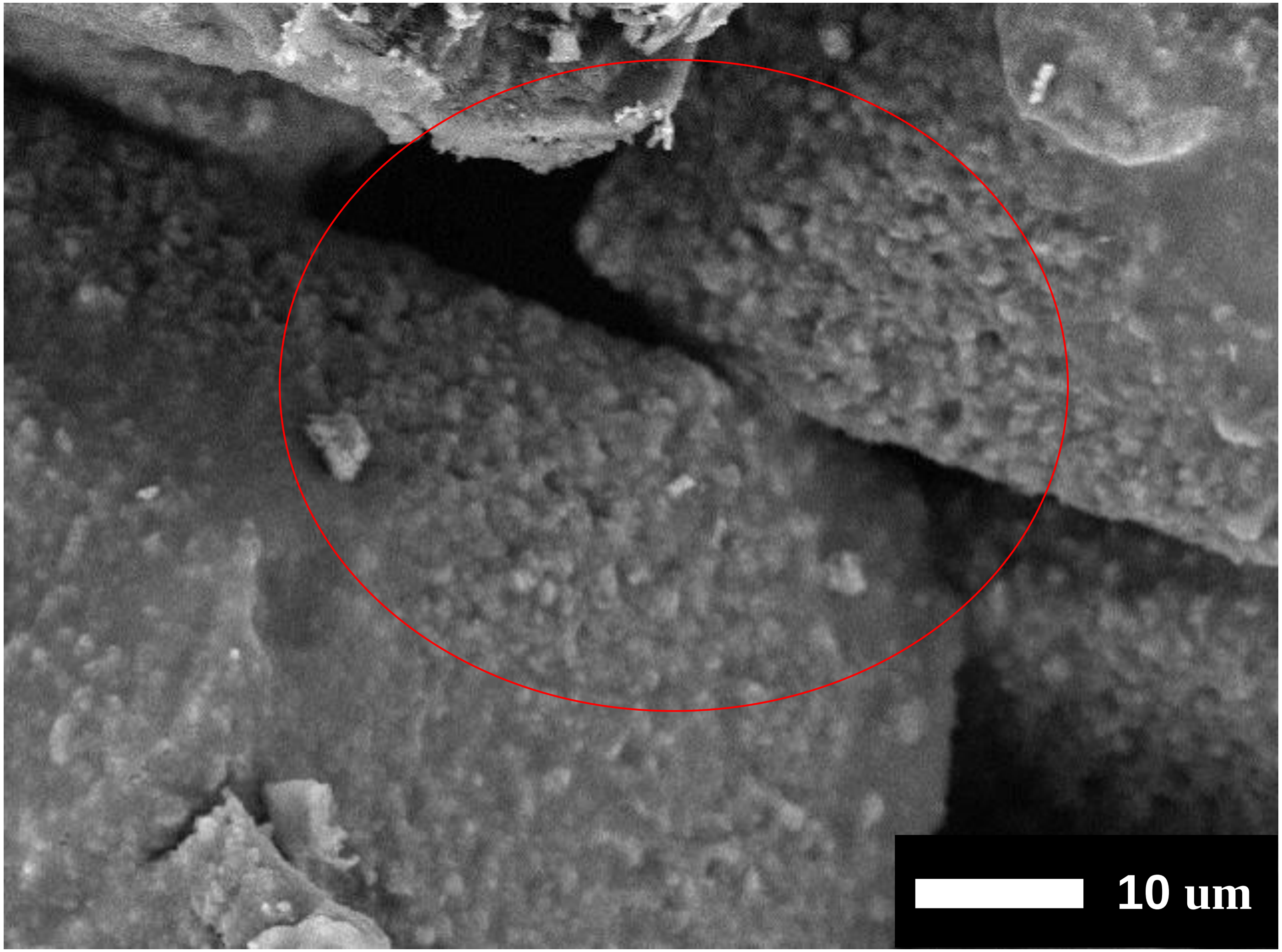
II. CL-20/TATB core-shell coating

CL-20/TATB

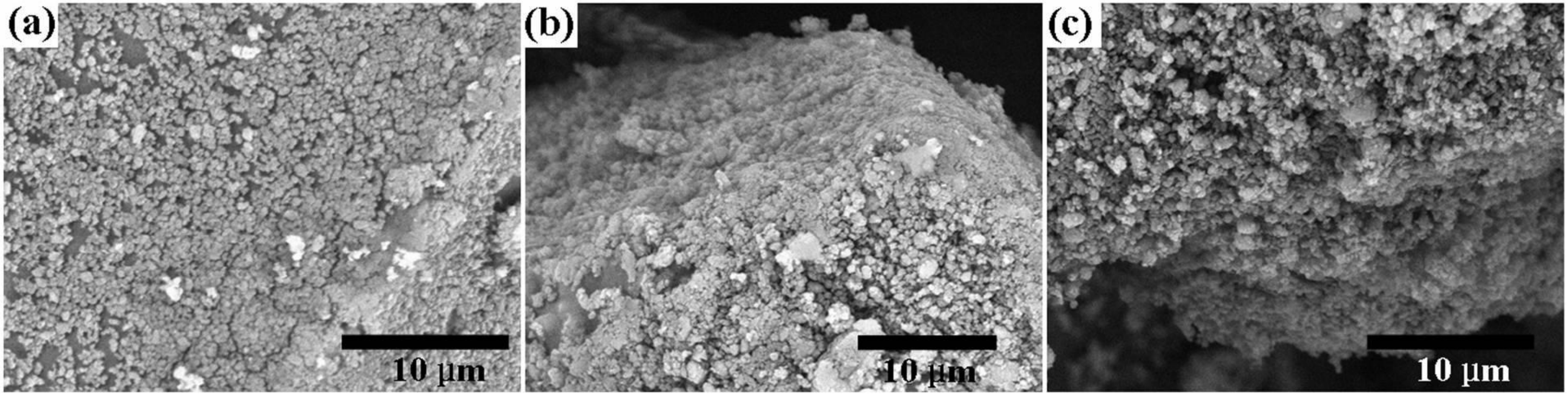


- Using submicron TATB as raw material;
- Tween-20 or PVA surface modification;
- Compact coating TATB on CL-20 surface was obtained.

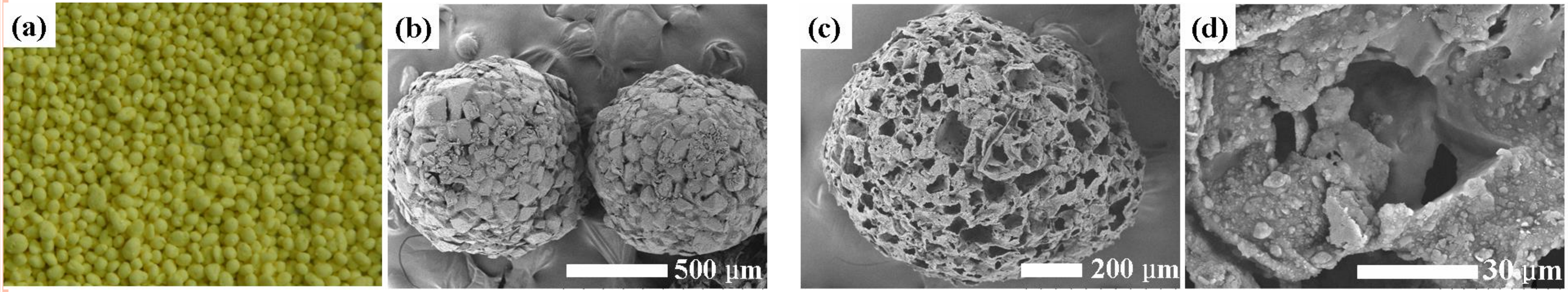
II. CL-20/TATB core-shell coating



2.1 Surface of the composites with TATB increased



TATB: 5% TATB: 15% TATB: 25%

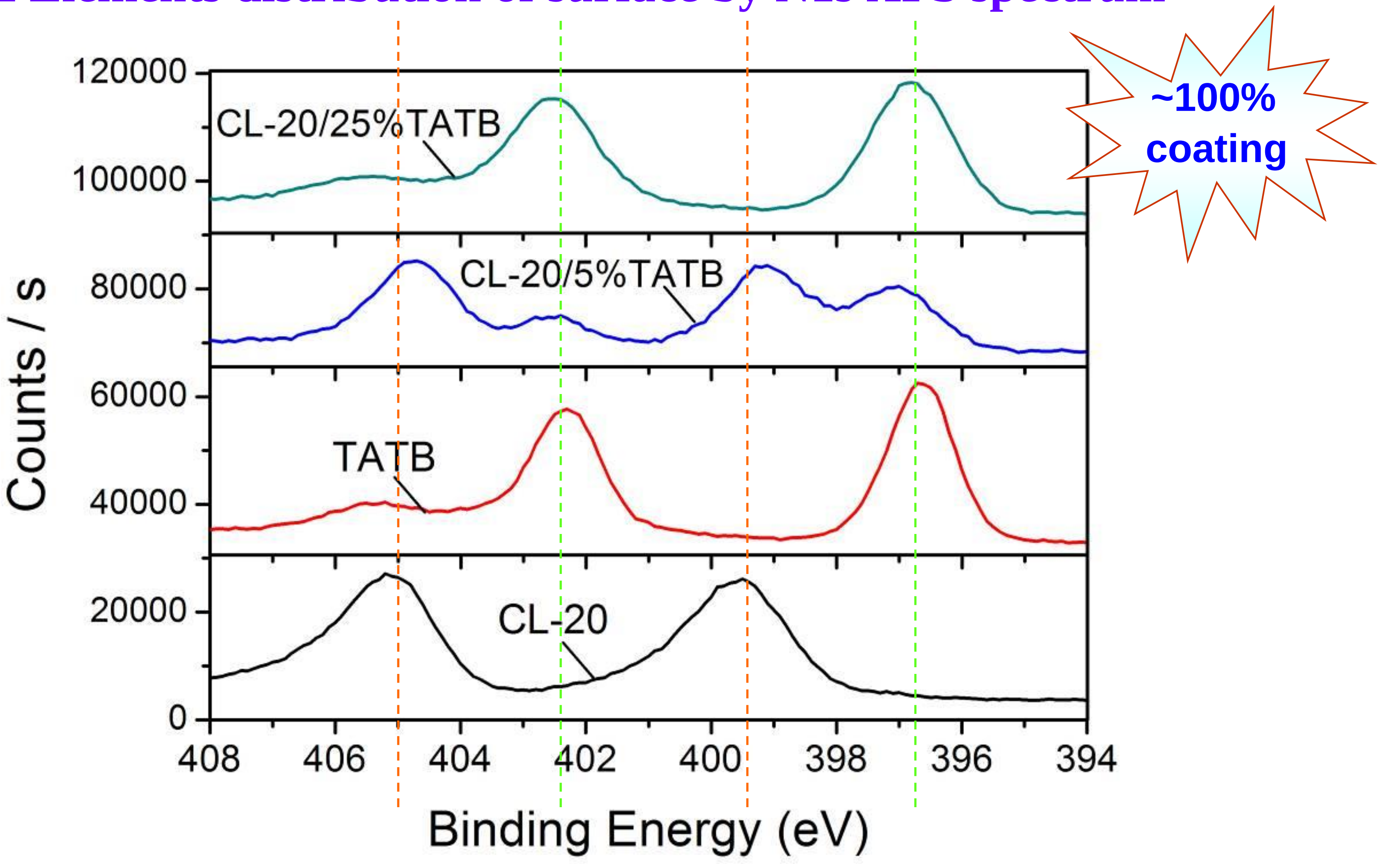


Products of molding powder Hollow shell after etching

Zhijian Yang, et al. *Propellants, Explos. Pyrotech*., 2014, 39(1): 51-58.

II. CL-20/TATB core-shell coating

2.2 Elements distribution of surface by N1s XPS spectrum



II. CL-20/TATB core-shell coating

2.3 Sensitivity studies

Table 1: Impact and friction sensitivity of CL-20/TATB composites

Sample	TATB [%]	Size of TATB [μm]	TATB introduced	H_{50}* [cm]	Friction sensit. [%]
CL-20	0	/	/	16.0	100
CL-20/TATB-1	5	0.8	physical mixing	23.7	100
CL-20/TATB-2	5	0.8	core-shell coating	49.6	68
CL-20/TATB-3	5	20	core-shell coating	30.5	92
CL-20/TATB-4	25	0.8	core-shell coating	56.7	0

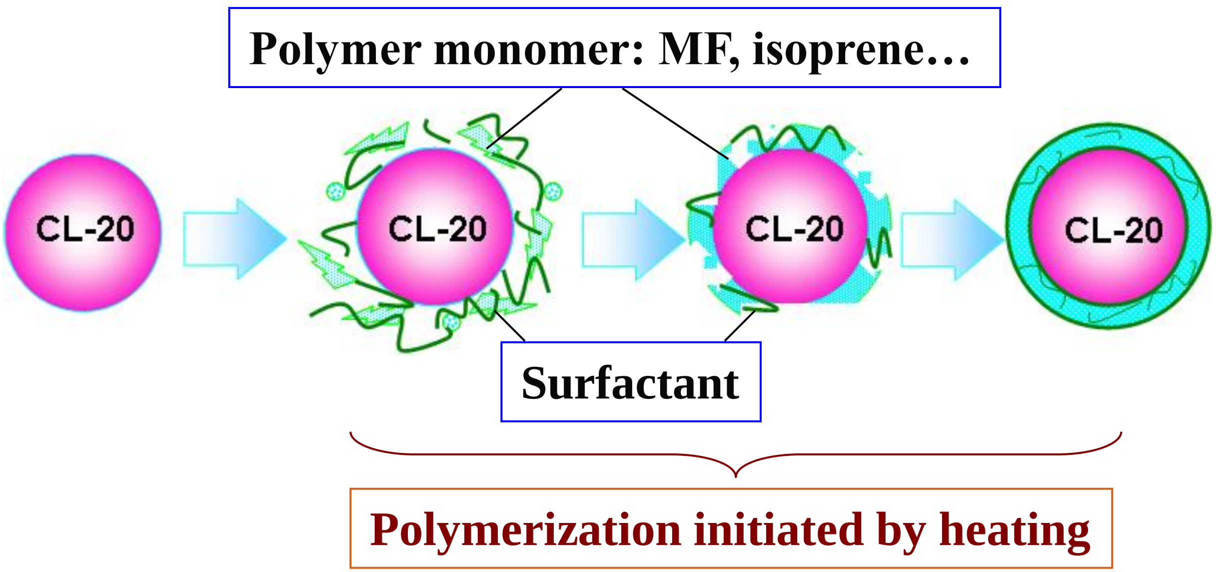
* 2 kg drop weight for H_{50}

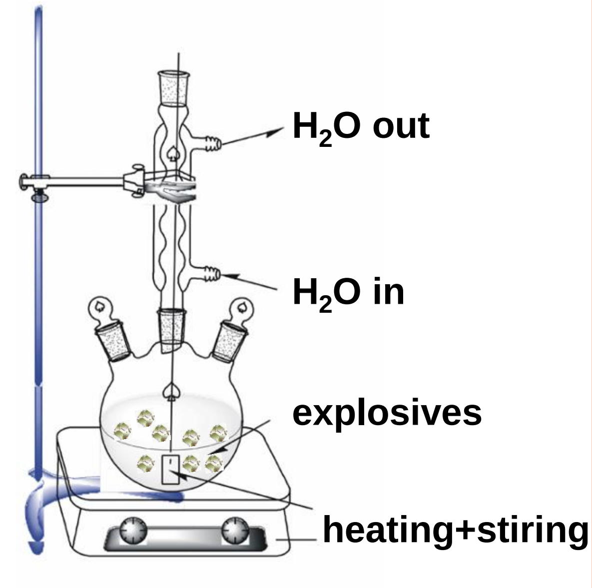
Zhijian Yang, et al. *Propellants, Explos. Pyrotech*., 2014, 39(1): 51-58.

III. Microencapsulation via in situ polymerization

III. Microencapsulation via in situ polymeriza

3.1 Research approach





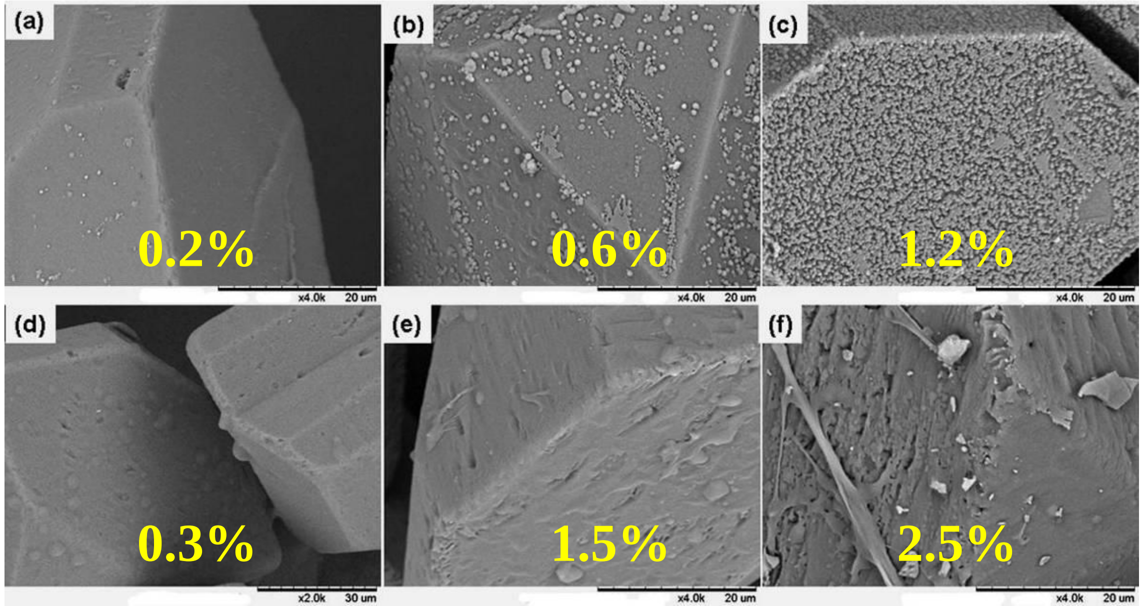
Surface *in-situ* polymerization process

III. Microencapsulation via in situ polymeriza

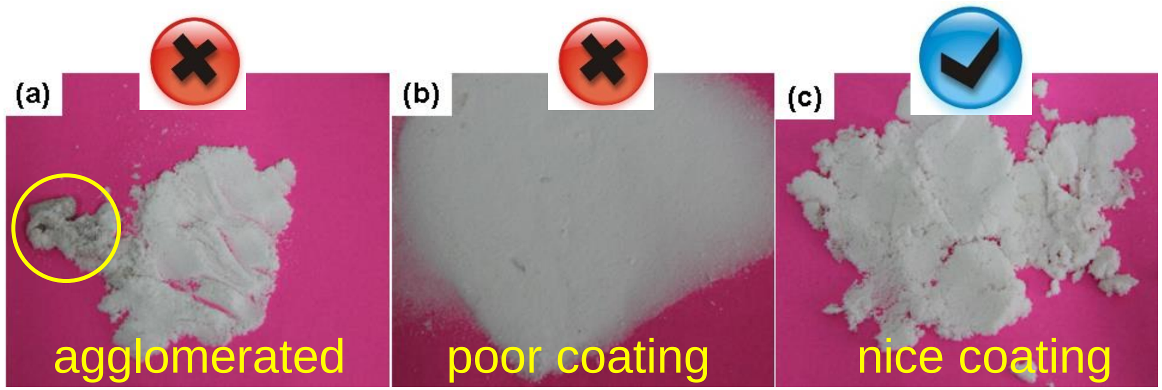
3.2 Appearance & structure of coated explosives

MF resins

polyisoprene

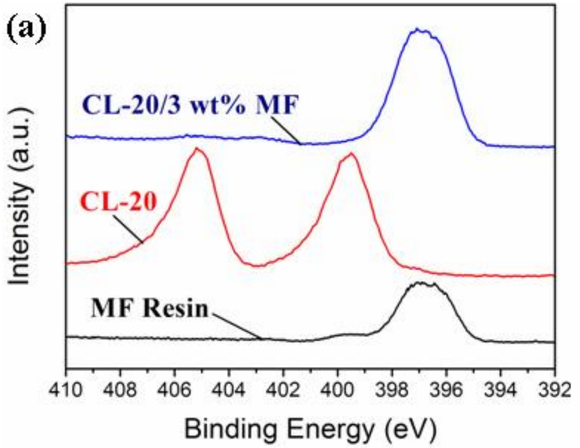


Process Optimization

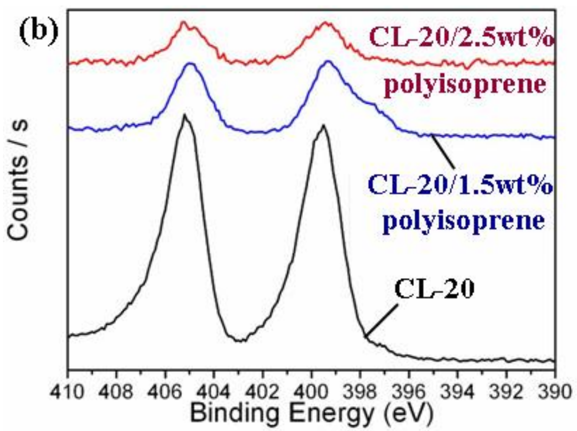


III. Microencapsulation via in situ polymeriza

3.2 Appearance & structure of coated explosives



（XPS）



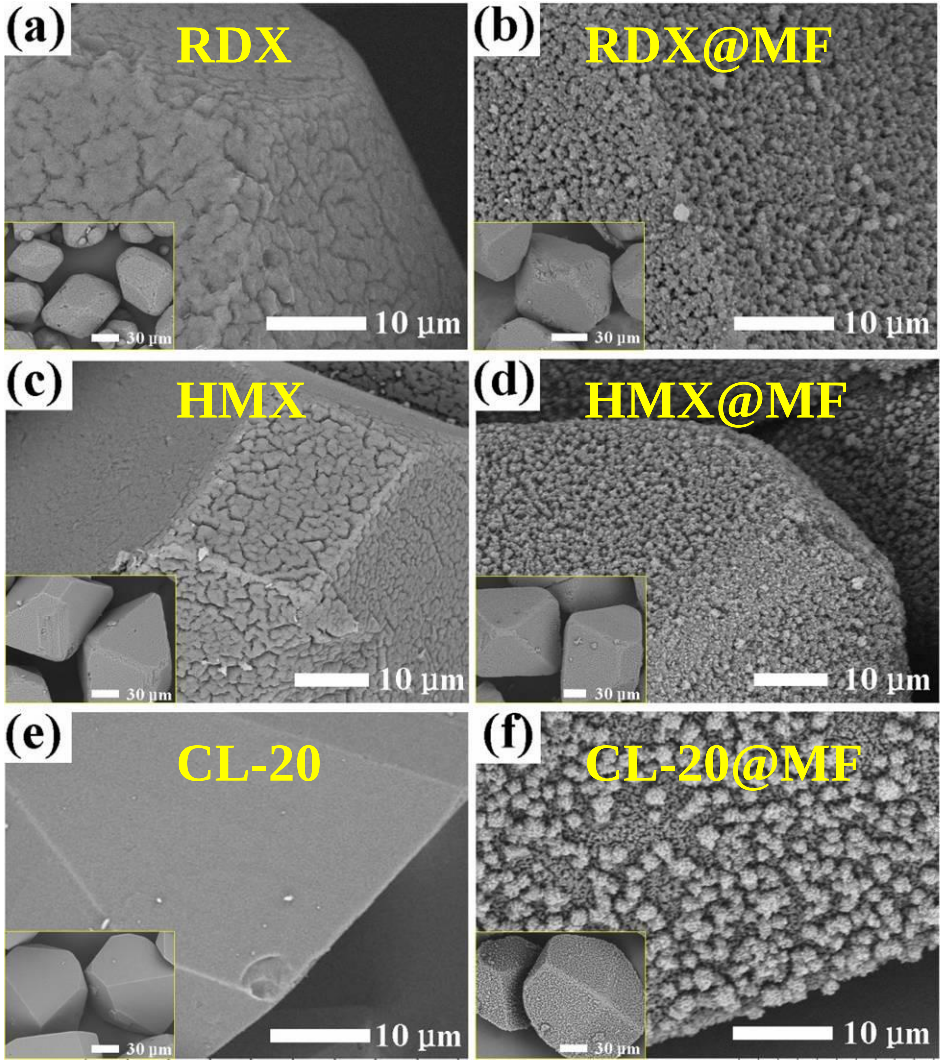
Samples	Polymer/wt%	Polymer introduced	H_{50}*/cm
CL-20	0	/	16.3
CL-20/MF	0.6	core-shell coating	19.6
CL-20/MF	1.2	core-shell coating	23.2
CL-20/MF	3.0	core-shell coating	42.8
CL-20+MF	3.0	physical mixing	18.7
CL-20/polyisoprene	1.5	core-shell coating	25.7
CL-20/polyisoprene	2.5	core-shell coating	33.4
CL-20+polyisoprene	2.5	physical mixing	15.9

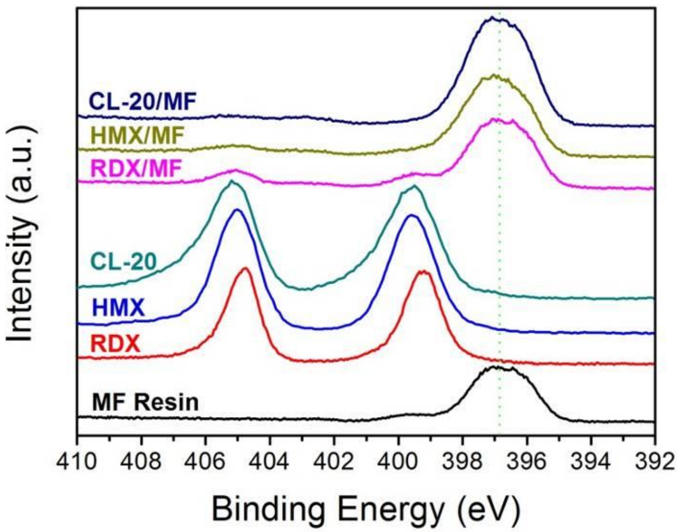
* 5 kg drop weight, 25cm, 50mg samples

More controllable system: MF resins!

III. Microencapsulation via in situ polymeriza

3.2 Appearance & structure of coated explosives

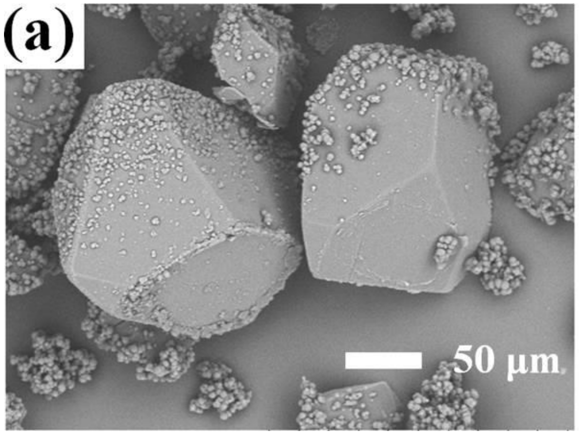




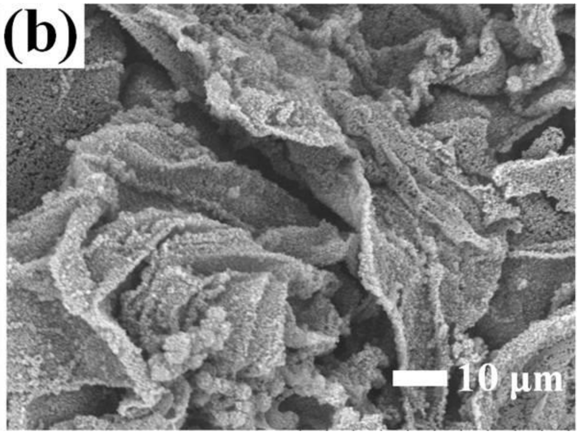
Coating structure

- Surface: uniform, compact;
- Coverage: ~ 100%;
- Polymer: all coated;
- Strength test: fairly high.

3.2 Appearance & structure of coated explosives

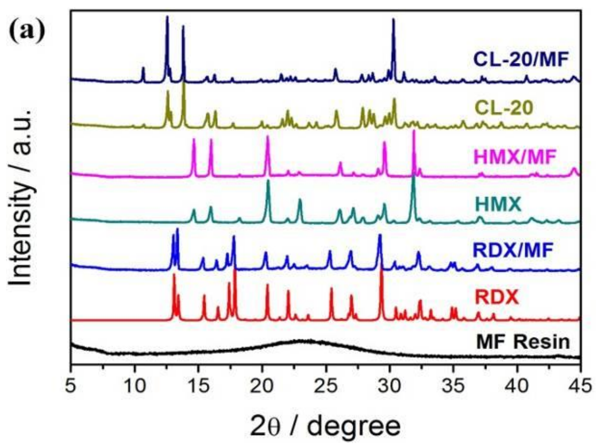


(Physical mixed sample)

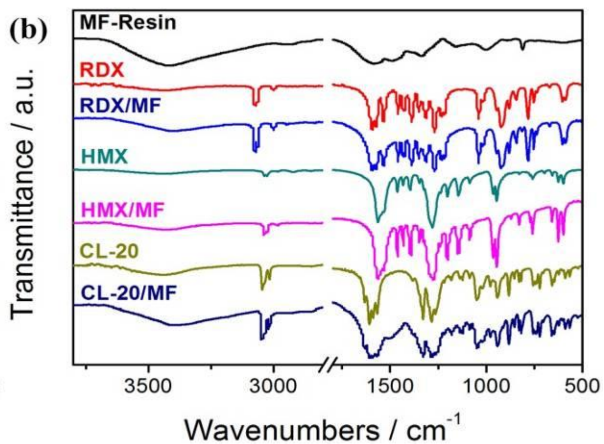


(Shell after CL-20 etching)

- Mixed: negligible coating
- Etching: ethyl acetate
- Shell thickness: 1~2µm



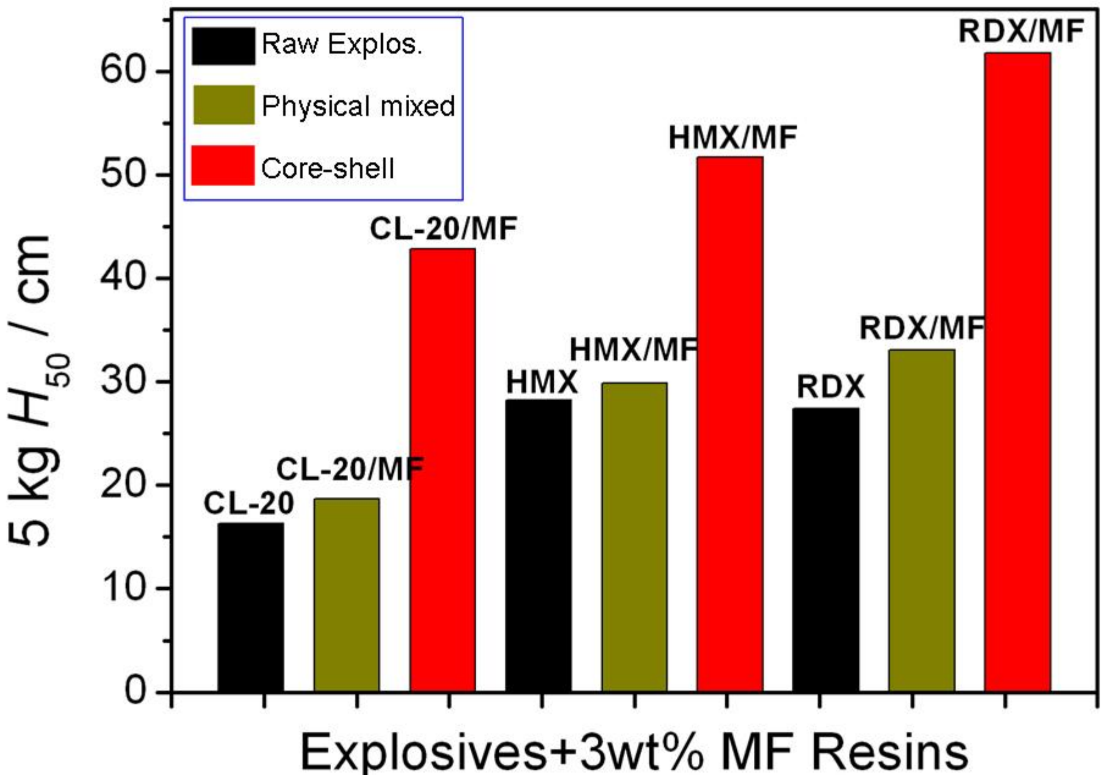
(FTIR)



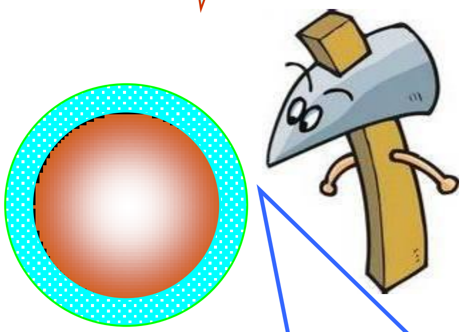
(XRD)

- ε-CL-20 form maintained

3.3 Impact sensitivity



Markedly reduced sensitivity!!

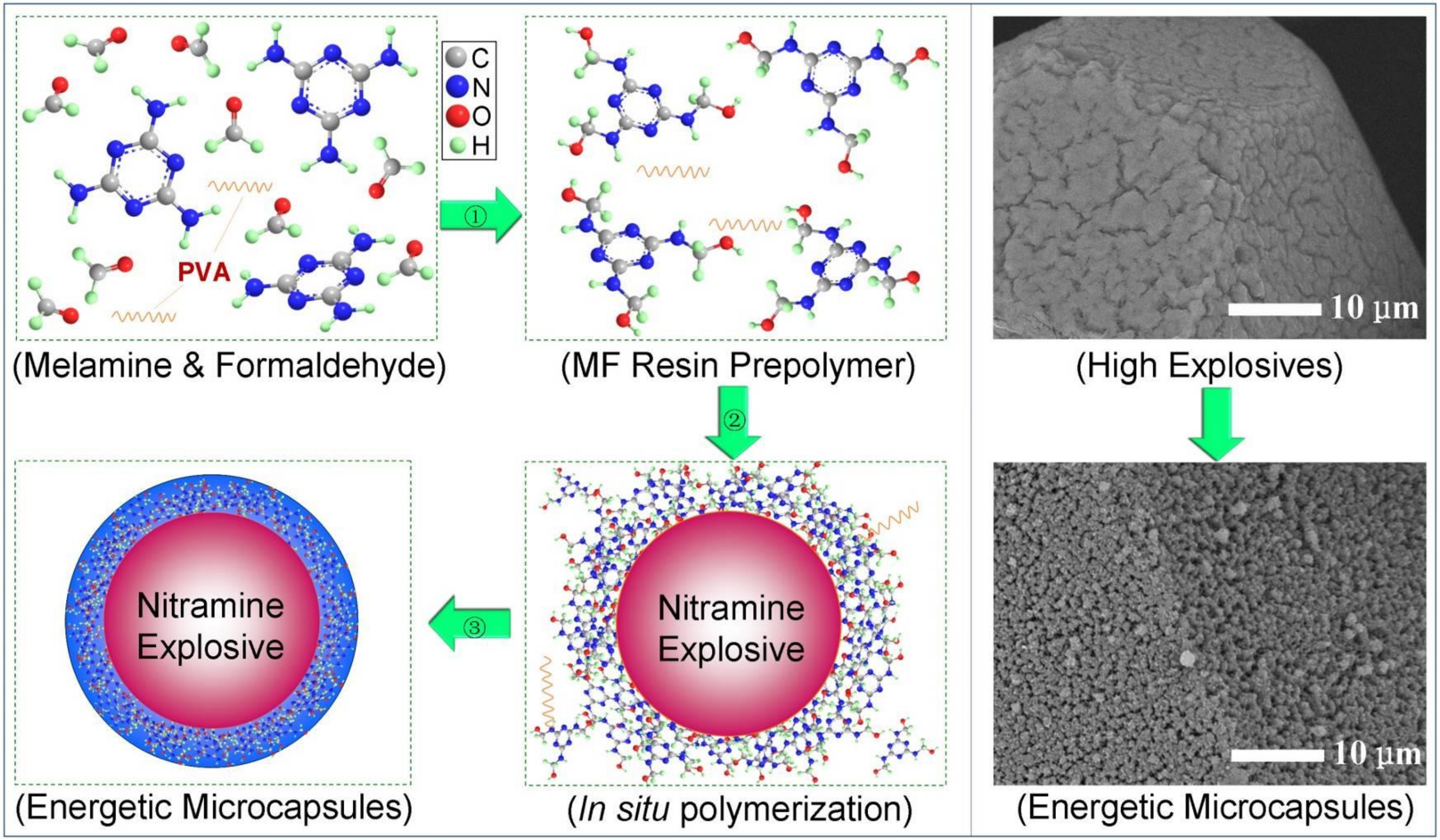


Polymer buffer system:

- **firstly attacked**
- **dissipate impact energy**

III. Microencapsulation via in situ polymeriza

3.4 Proposed mechanism



Schematic mechanism for microencapsulation via *in situ* polymerization

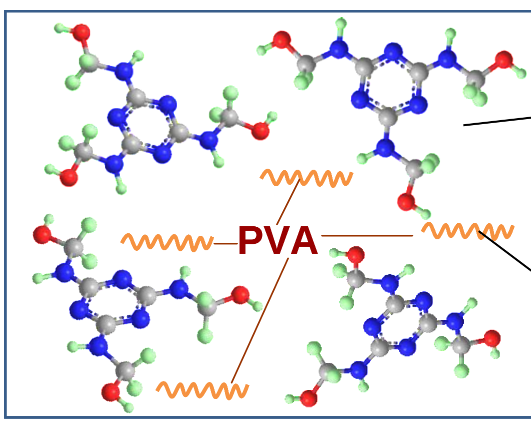
III. Microencapsulation via in situ polymeriza

3.4 Proposed mechanism

Key role of additive **PVA**

surfactant → surface wettability → high coverage

molecular skeleton → improve flexibility → reduce sensitivity

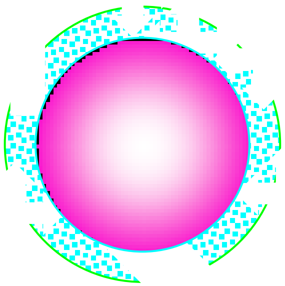


brittleness of MF resin

fiber-forming performance

Zhijian Yang, et al. *Chem. Eng. J.*, 2015, 268(1): 60-66.

An analogy



Traditional coating

loose, nonuniform, low coverage & strength

***In situ* polymerization**

compact, uniform, high coverage & strength

That is the *in situ*!!

IV. Multilevel and tridimensional desensitization

V. Multilevel and tridimensional desensitizati

Synergistic effect

Outstanding performances

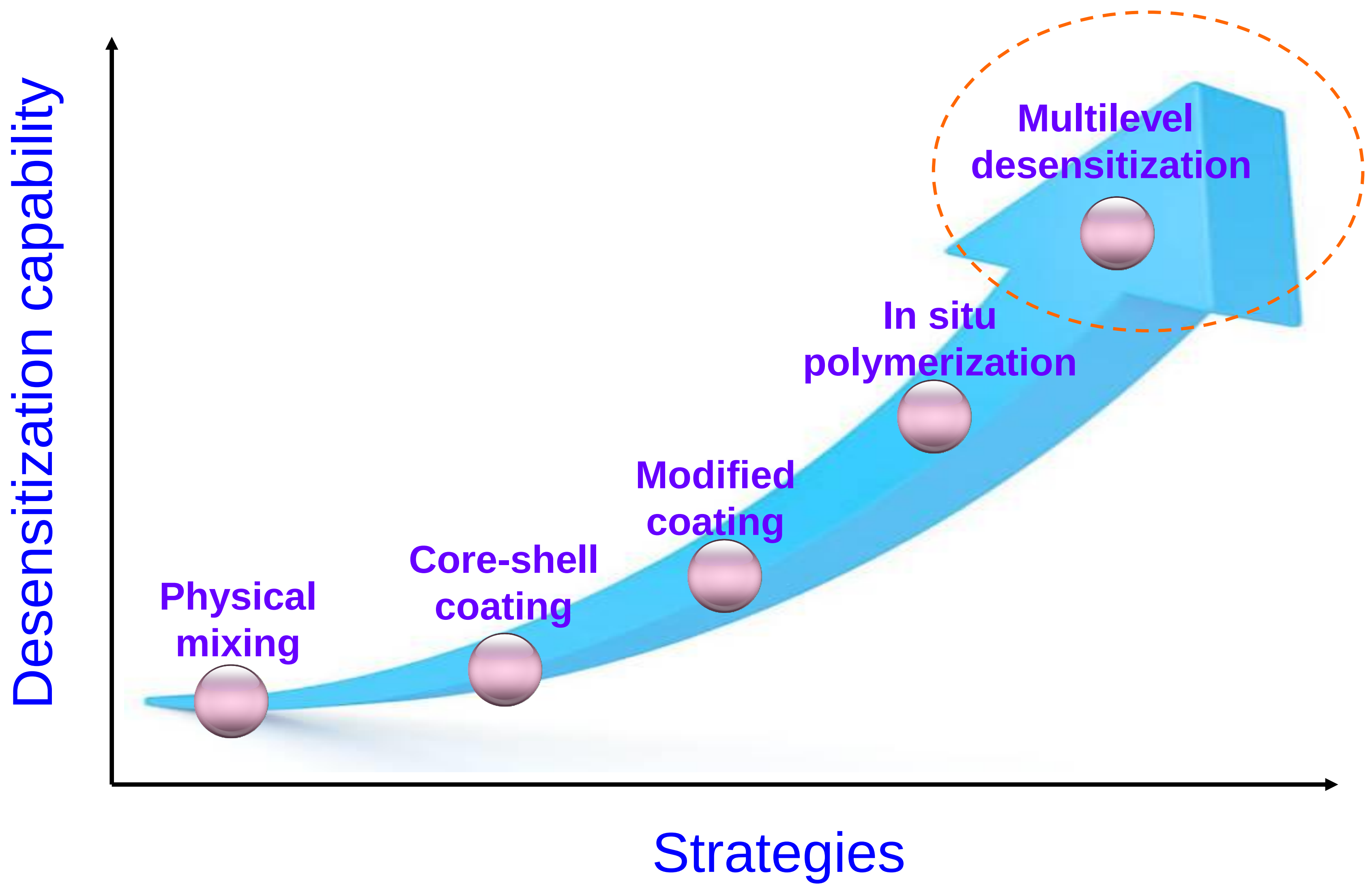
- **(CL-20) =90%**
- **D > 9000m/s;**
- **Impact E_{50} > 60J** (5kg H_{50}>120cm);
- **Friction P = 0%** (>360N).

V. Conclusions and summary

V. Conclusions and summary

- **Great potential for Several new strategies for reducing the mechanical sensitivity of CL-20;**
- **Structure: compact, uniform, firm, adjustable and synergistic;**
- **Performance: visible reduced impact sensitivity and reserved high energy;**
- **Our works will go on...**
  - **more systems**
  - **fine adjustment & control**
  - **molding performance**

V. Conclusions and summary

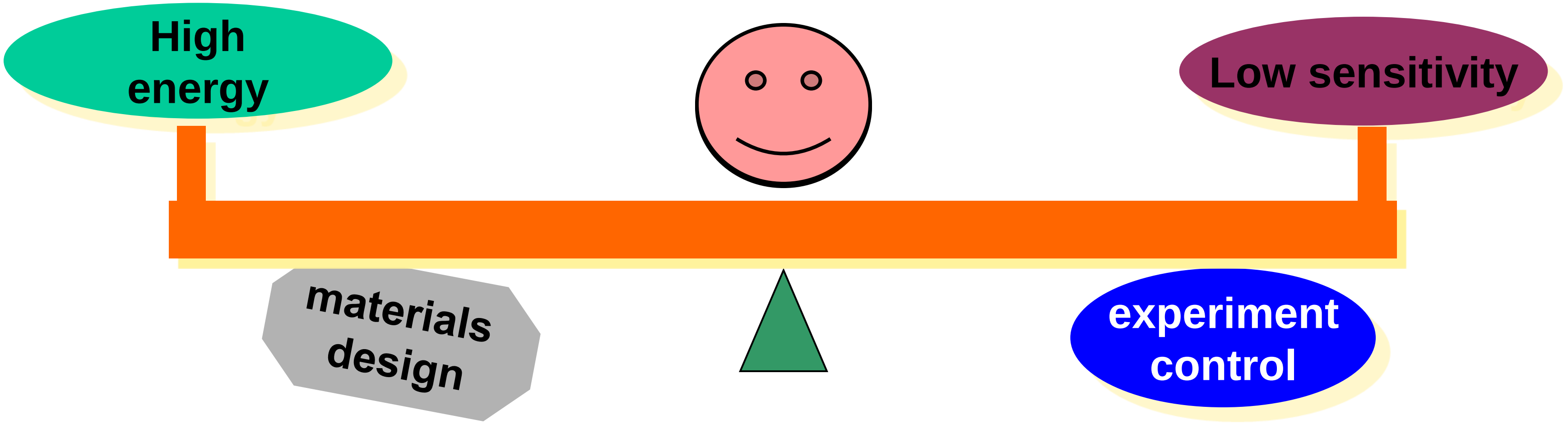


Energetic coating

***W**hat* is it?

***W**hy* do it?

HoW to…



Acknowledgments

- **Thanks** → **meeting affairs group of 2019 IMEMTS;**
- **Thanks** → **my group: ICM, CAEP, China.**