# Processing and Technologies Applied to Oxidizers and Strategic Particles for Rocket Propulsion

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**Abstract** — The main components of composite solid propellants are the polymeric matrix, the oxidizer particles, the metallic fuel, the curing agent, and other additives. A significant part of these components is incorporated into the matrix in the solid state, which might reach high solid loadings of over 80% in mass of the formulation, especially when aiming for high-energy performance propellants. This results in the necessity to employ technologies such as particle shape modification, the use of multimodal sizes, and high particle packing to manufacture a propellant that meets both energetic and processing requirements. Recrystallization techniques can be applied to synthesize and promote morphology adjustment and size control for energetic and strategic particles, while microencapsulation techniques can be used to tailor specific properties such as hygroscopicity and incompatibilities. This work summarizes the recrystallization, crystallization in emulsion, simple coacervation, and fluidized bed techniques with focus on the processing of ammonium perchlorate and ammonium dinitramide oxidizers, and in the association of their application to some key propellant processing specifications.

## I. INTRODUCTION

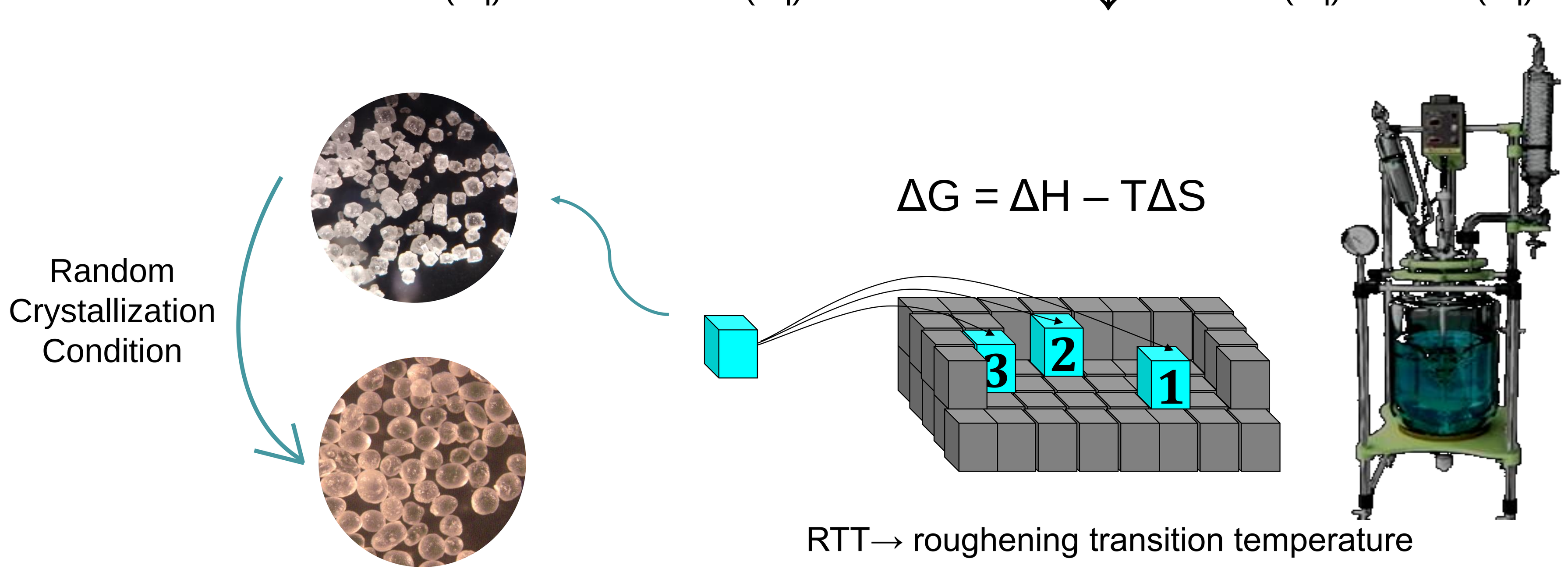
Ammonium perchlorate as synthesized by the double exchange reaction in water [1] produces faceted particles because its spontaneous crystallization happens in sites that result in said type of crystal. If recrystallized above a certain temperature, the roughening transition temperature [2], the spontaneity is no longer true, and the system begins to be entropic coordinated, which enables the random crystallization, in all directions, and can be applied to make spherical AP particles.

Ammonium dinitramide [3] can be recrystallized by melting it in a suitable inert and immiscible liquid, providing agitation into the system and rapidly decreasing the temperature. Meanwhile, microencapsulation by simple coacervation [4] and fluidized bed techniques [5] is one alternative being studied to address ADN challenges such as high hygroscopicity and incompatibilities. The crystallization in emulsion technique [6], one of the techniques applied to recrystallize ADN, can also be used to synthesize spherical paraffin particles [7] that, when incorporated into HTPB-based propellant grains for hybrid rocket motors, enhance the regression rate [8].

## II. RECRYSTALLIZATION TECHNIQUES

### (Re)Crystallization

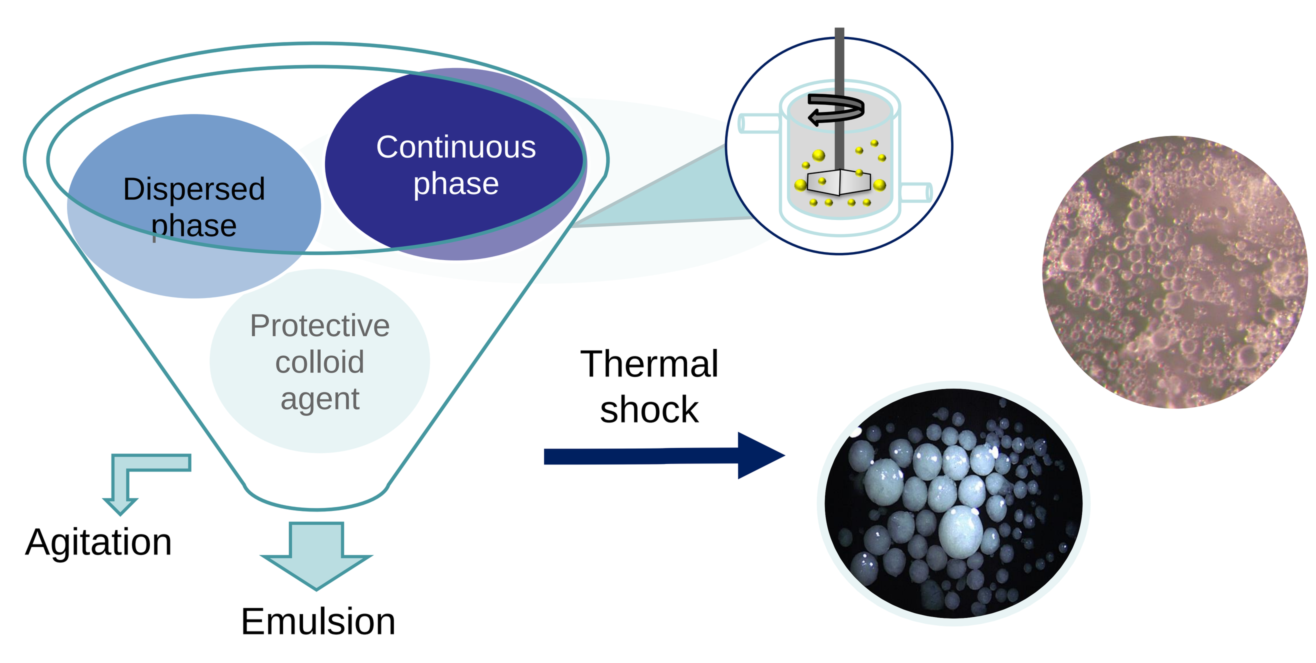
$$NH_4Cl_{(aq)} + NaClO_{4\,(aq)} \longrightarrow NH_4ClO_4 \downarrow + Na^+_{(aq)} + Cl^-_{(aq)}$$




RTT→ roughening transition temperature

### Crystallization in Emulsion

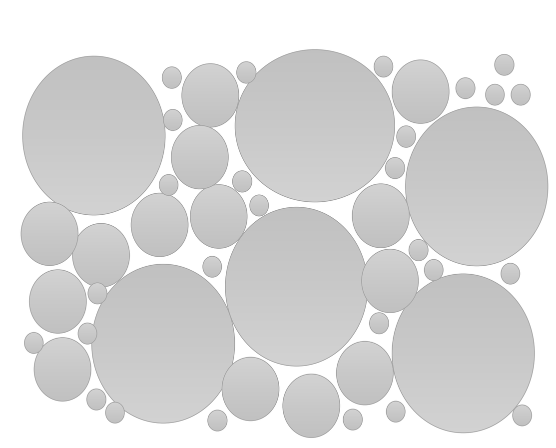
- Dispersed phase concentration;
- Type & concentration of the protective colloid agent;
- Agitation rate;
- Processing time.




### Spherical particles and propellant slurry

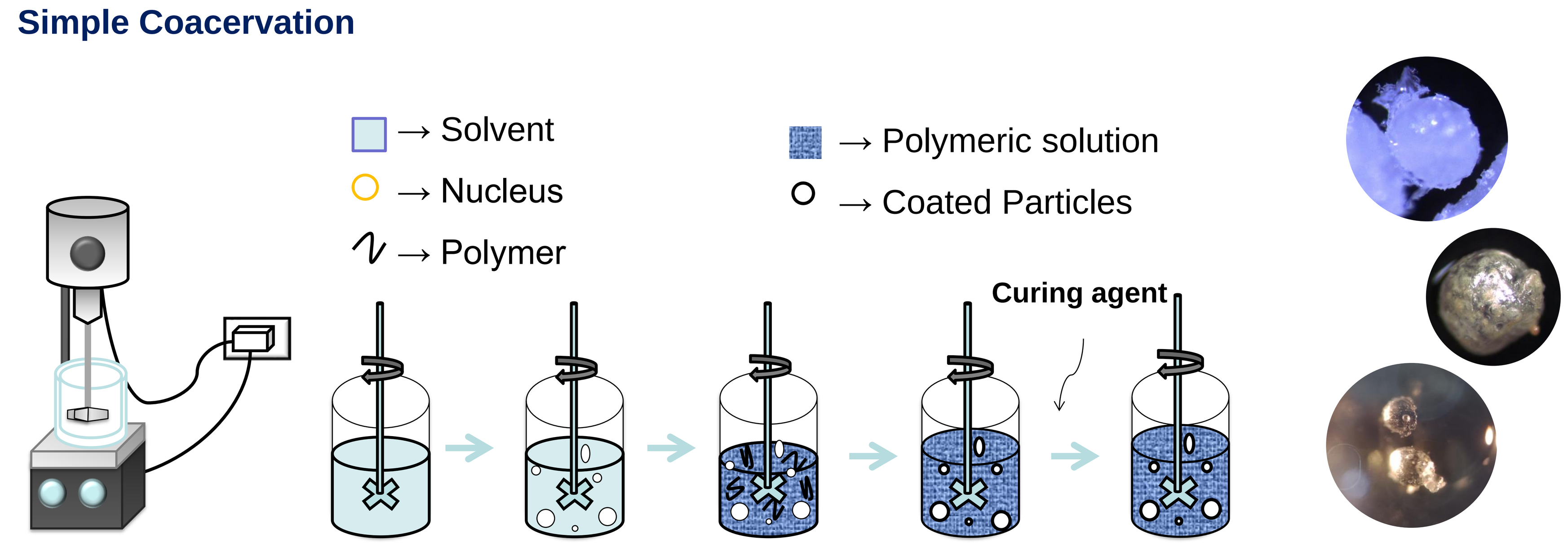
Spherical & multimodal particles:

- ↑ solid loads
- ↓ empty spaces;
- ↑ Polymeric film to promote fluidity;
- Slurry viscosity ~ 200000 Poise.

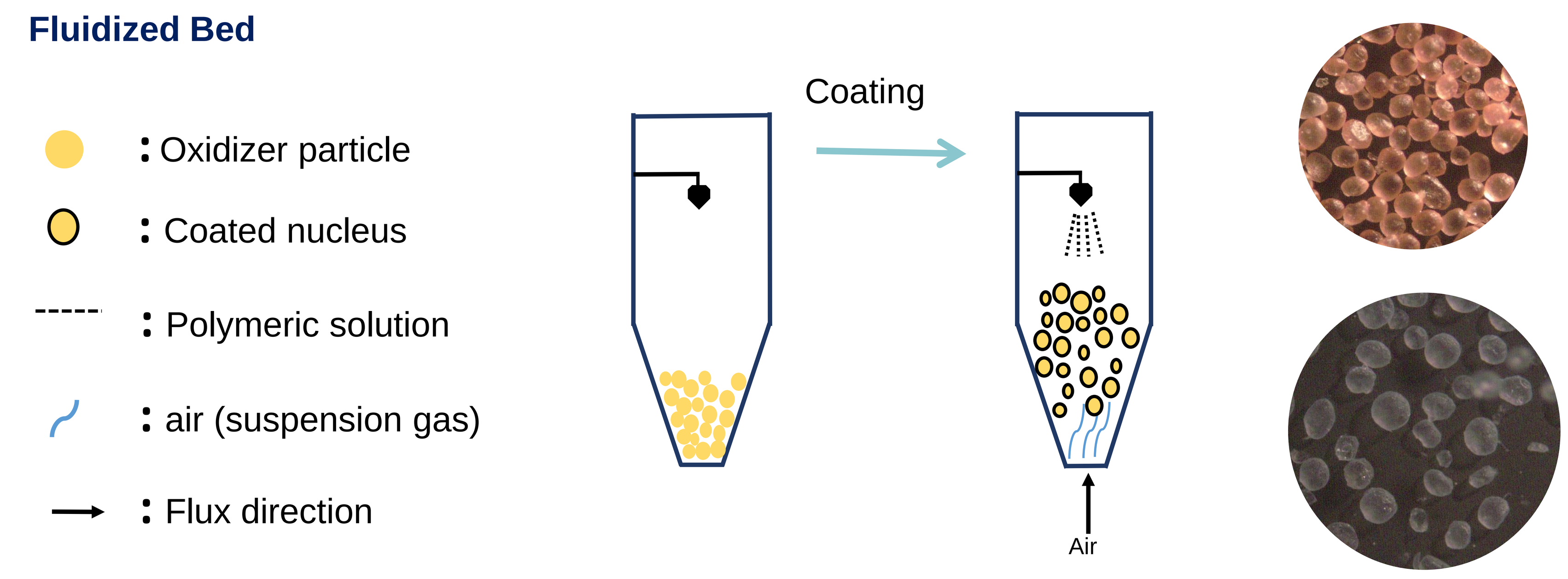


## III. MICROENCAPSULATION TECHNIQUES

### Simple Coacervation




### Fluidized Bed




## IV. CONCLUSION

The techniques described here are valuable tools to process particles applied to composite solid propellants and even for hybrid propulsion fuel grains. Recrystallization techniques promote morphology modification and diameter control, while microencapsulation techniques can address specific challenges, such as high hygroscopicity and incompatibilities of ADN. Particle shape and size control are essential to enable high solid loads in the propellant by aiming for high particle packing in the formulation. During the processing, these parameters, when reasonably chosen, result in lower viscosities for the slurry which is crucial for the casting of the mixture into the case. For the propellant grain, higher solid loads, of the oxidizer or oxidizer-metallic fuel pair, favor higher specific impulse.

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