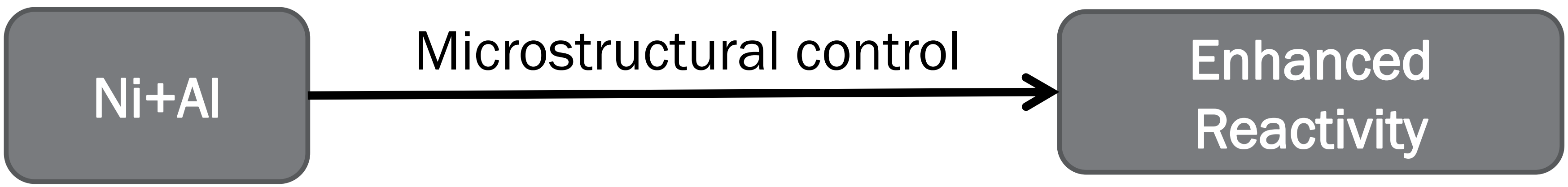
INFLUENCE OF HIGH ENERGY BALL MILLING ON REACTIVITY IN NI-AL GASLESS HETEROGENEOUS SYSTEM

Motivation of the Research

Reactive exothermic mixtures of **nickel and aluminum** may be applied for

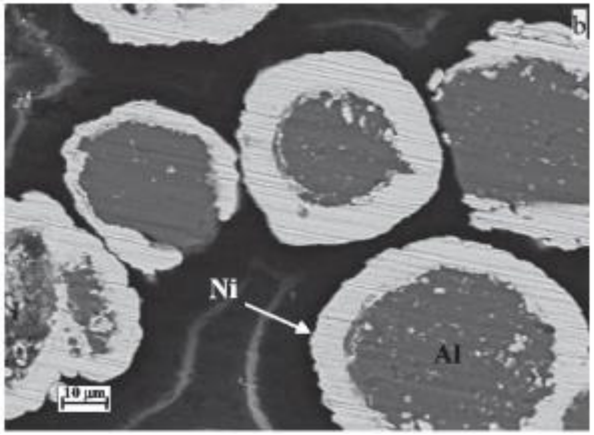
- chemical energy storage,
- nano-scale energetic devices
- materials synthesis and other applications



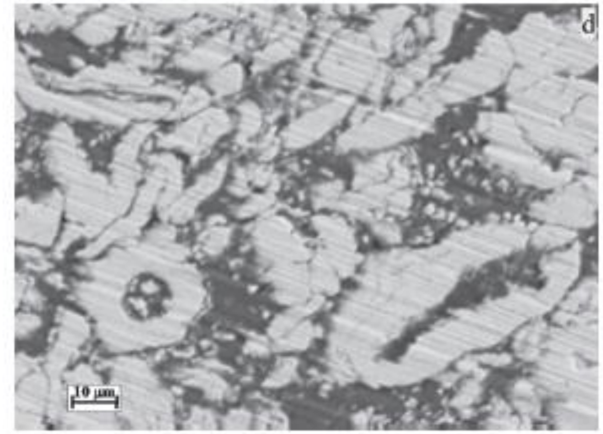
Microstructural control
- high energy ball milling (HEBM)
- production of multilayer nano-foils, etc

Ignition temperature (T_{ig}) - the lowest ambient temperature at which the self-propagating reaction initiates.

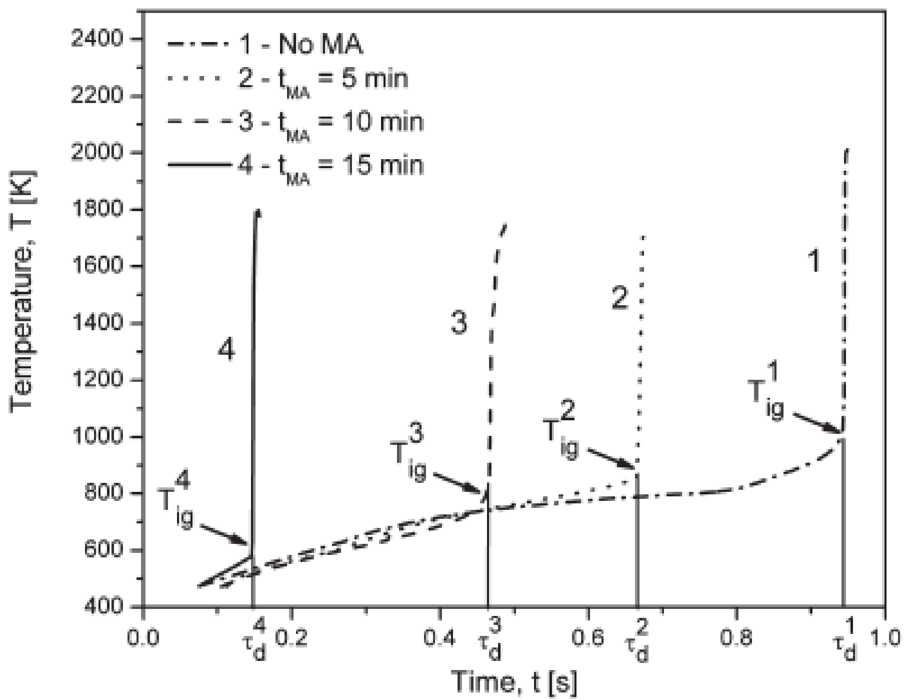
Effect of HEBM on the reactivity of Ni-Al system



Ni-Al clad particles

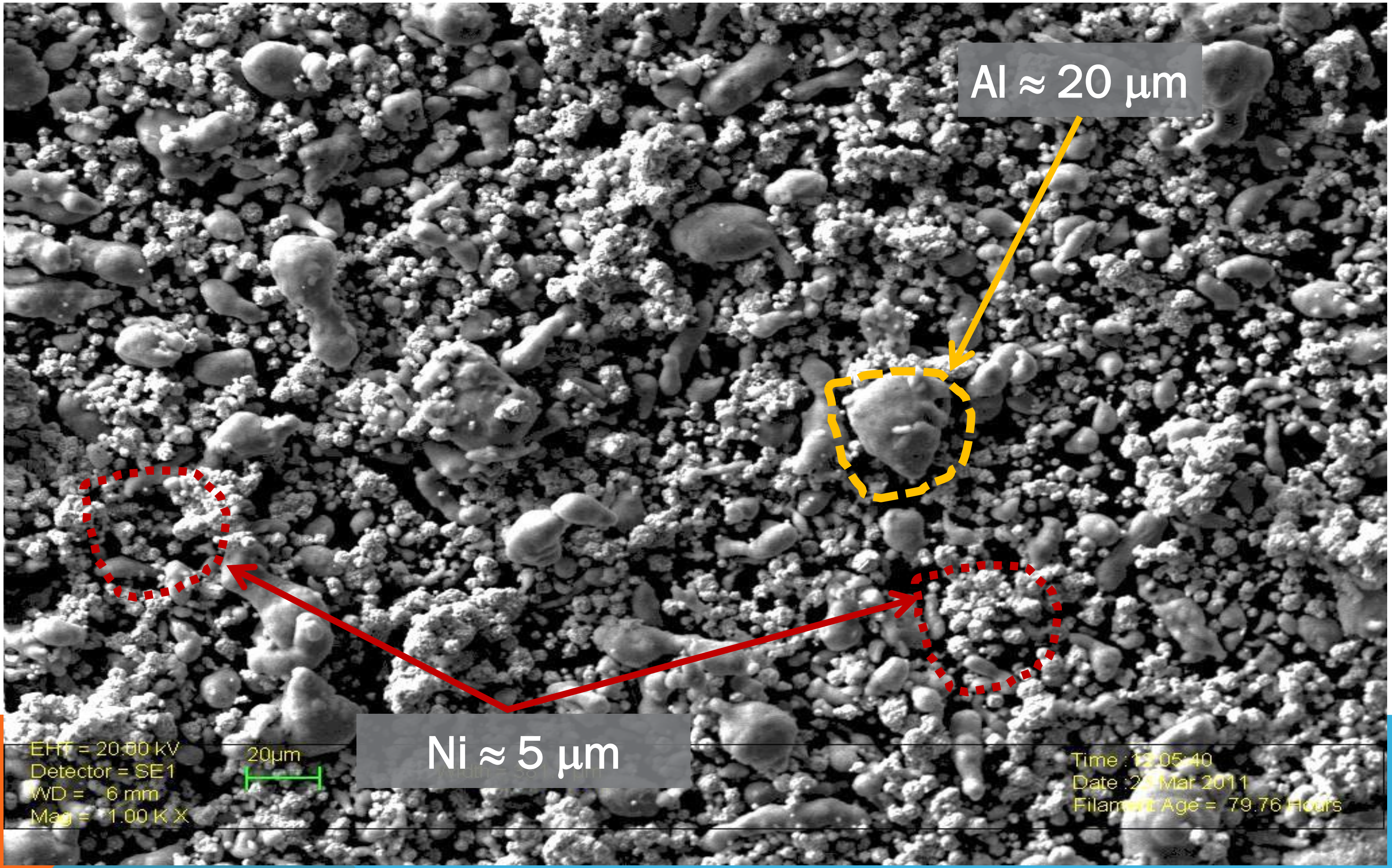


Ball milled material



Ref. J.D.E. White, R.V. Reeves, S.F. Son and A. Mukasyan, *J. Phys. Chem. C* 2009 *113,* 13541–13547

Initial Ni + Al mixture



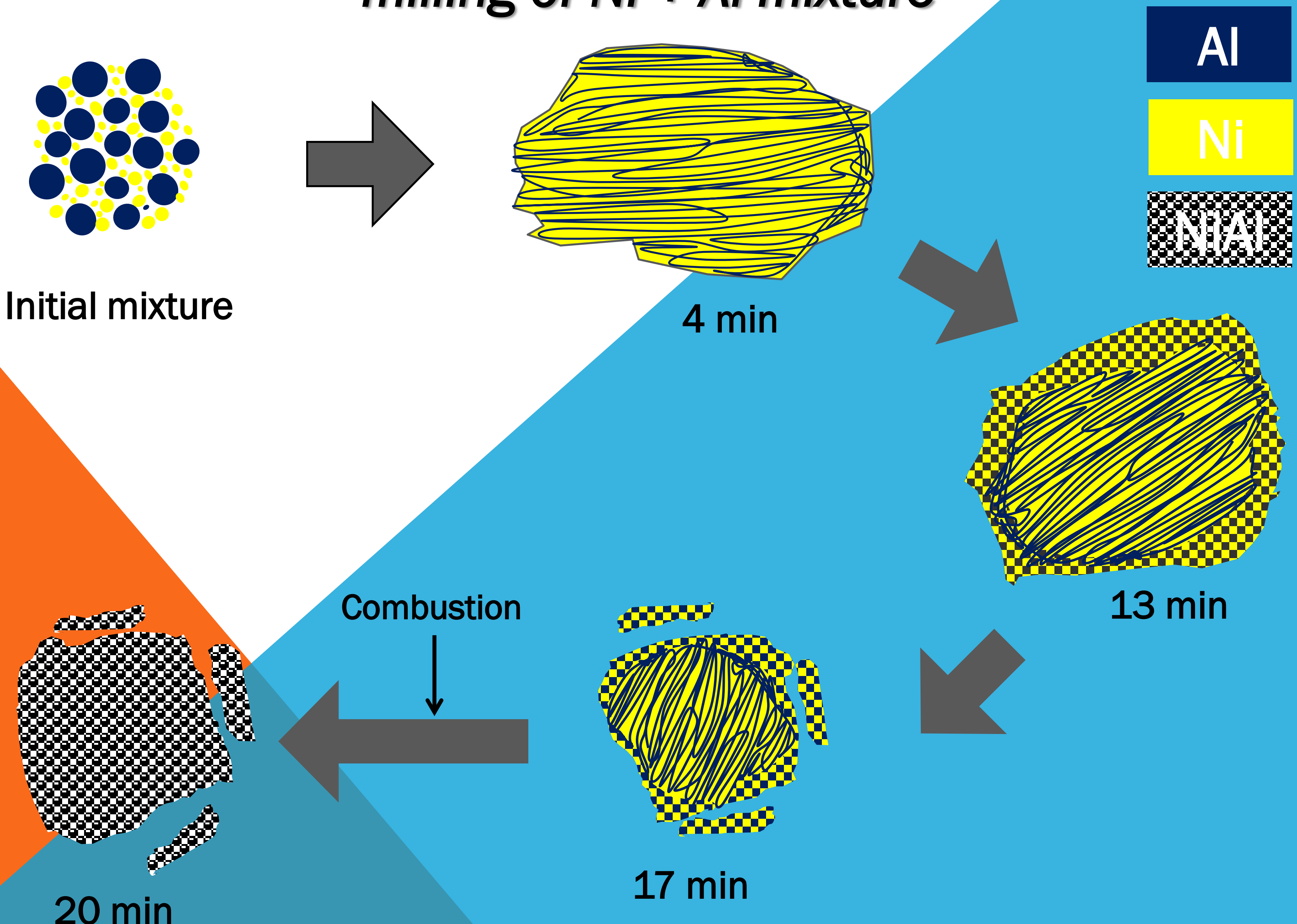
High-Energy Ball Milling

Milling conditions	
Planetary mill	Retsch P100
Stainless steel vial	250ml
Ball / powder ratio	5:1
Ball (stainless steel) size	10 mm
Total wt. of ball during milling	170g
Rotational speed	300 rpm
Environment	argon

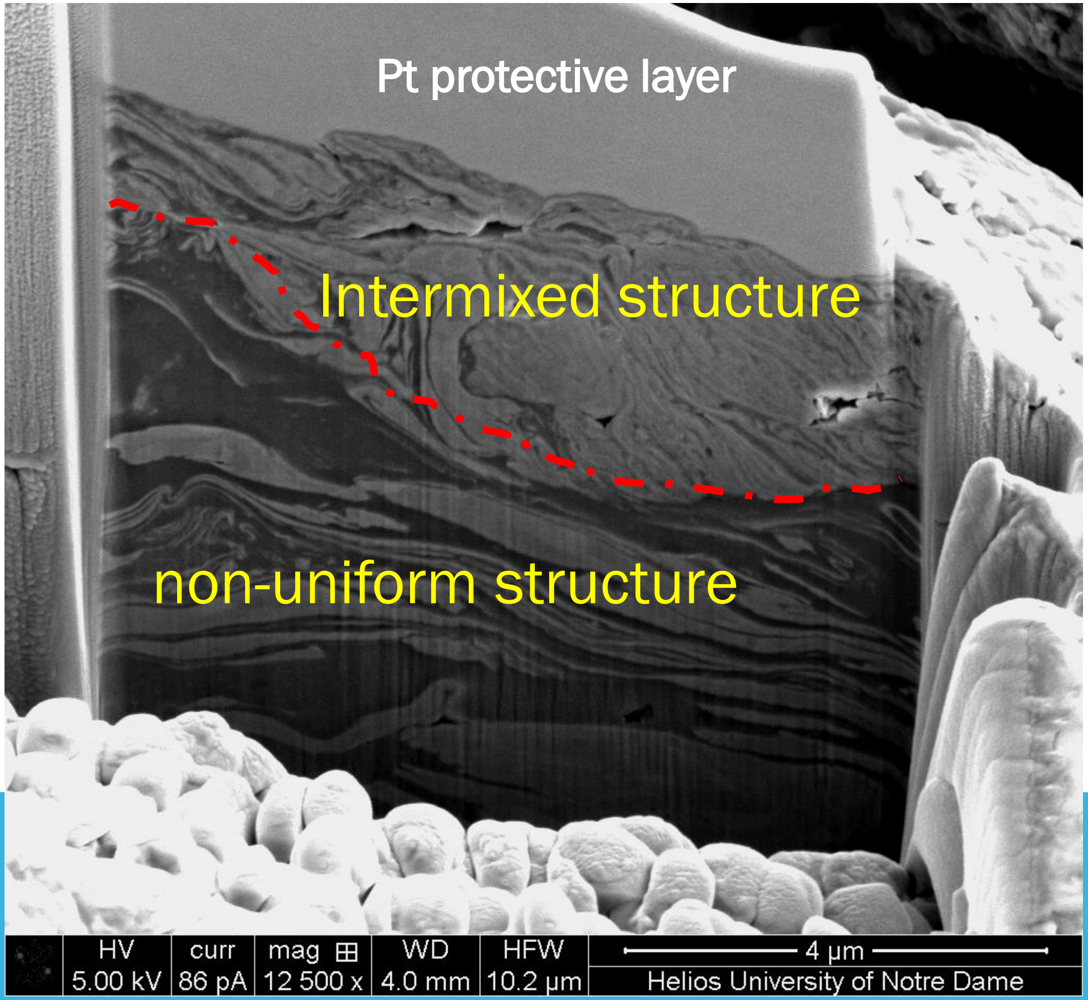
	Time, min					
Dry Milling	0	4	8	13	17	20 (Reacted)
Dry + Wet Milling	0 + 10	4 + 10	4 + 10	13 + 10	17 + 10	
Process controlling agent – Hexane						

Microstructural transformations in Ni + Al mechanically treated mixtures

Structural transformation during the Dry ball milling of Ni + Al mixture

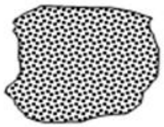
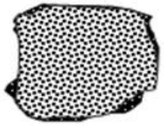
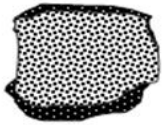
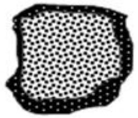
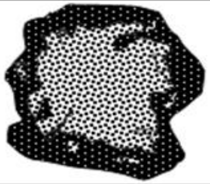


Two microstructures in Dry Ball Milled materials

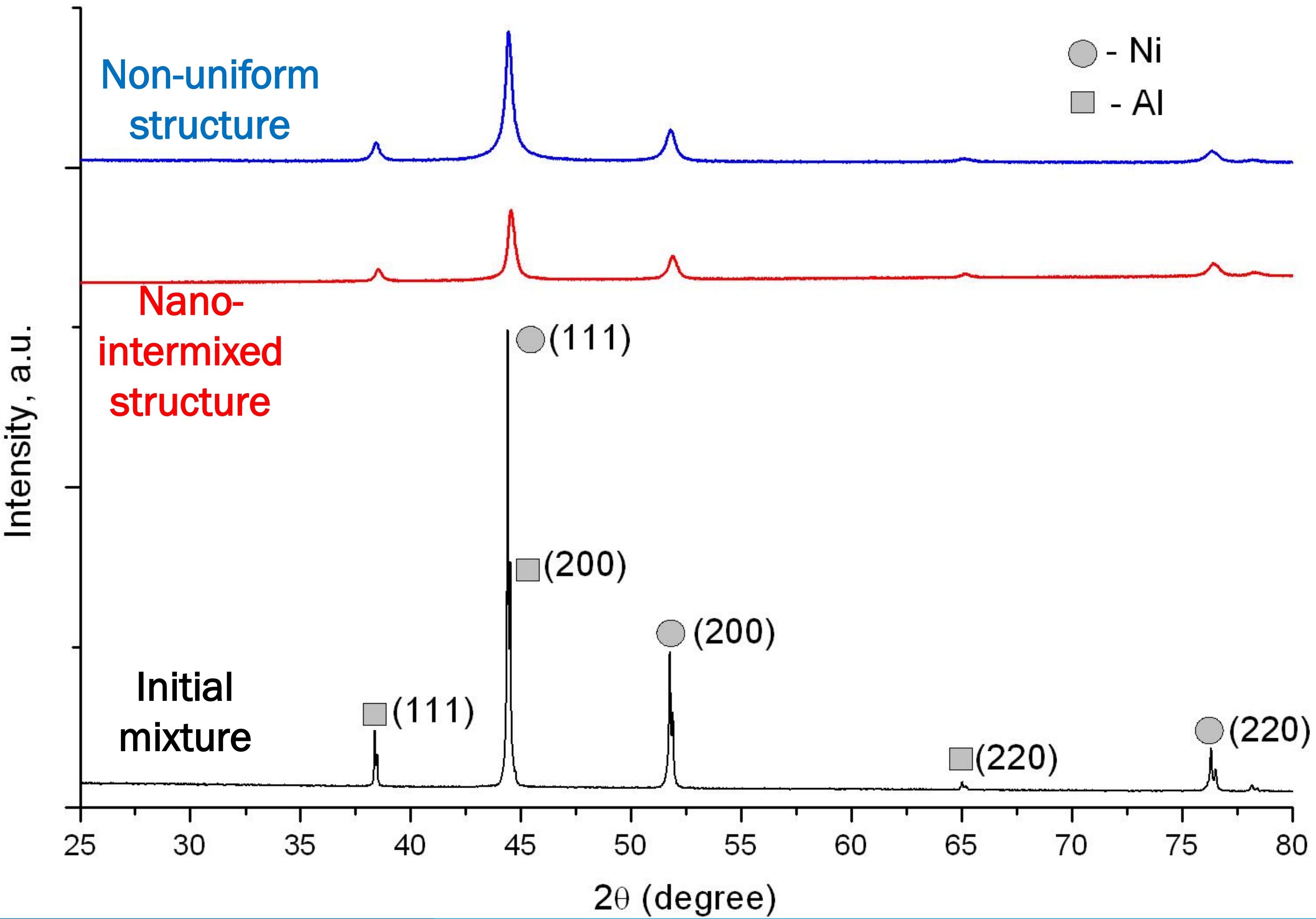


Two microstructures in Dry + Wet Millings Ni+Al mixtures

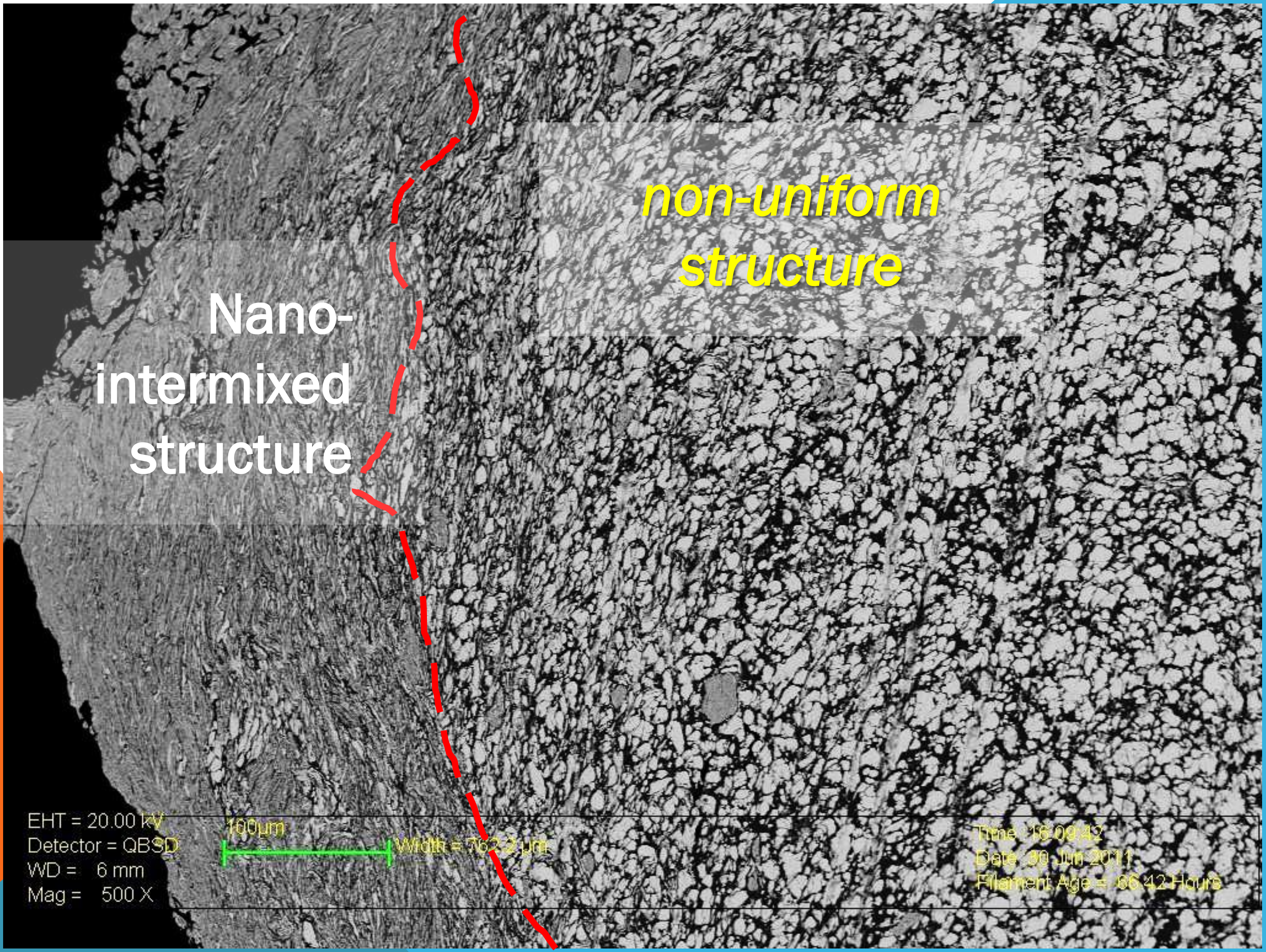
intermixed structure   non-uniform structure

	Particle sizes by fractions					
Mechanical treatment conditions	F1 Below 25 μm	F2 25-53μm	F3 53-106 μm	F4 106-355 μm	F5 355-850 μm	F6 More than 850 μm
0 min DM + 10 min WM						
4 min DM + 10 min WM						
8 min DM + 10 min WM						
13 min DM + 10 min WM						
17 min DM + 10 min WM						

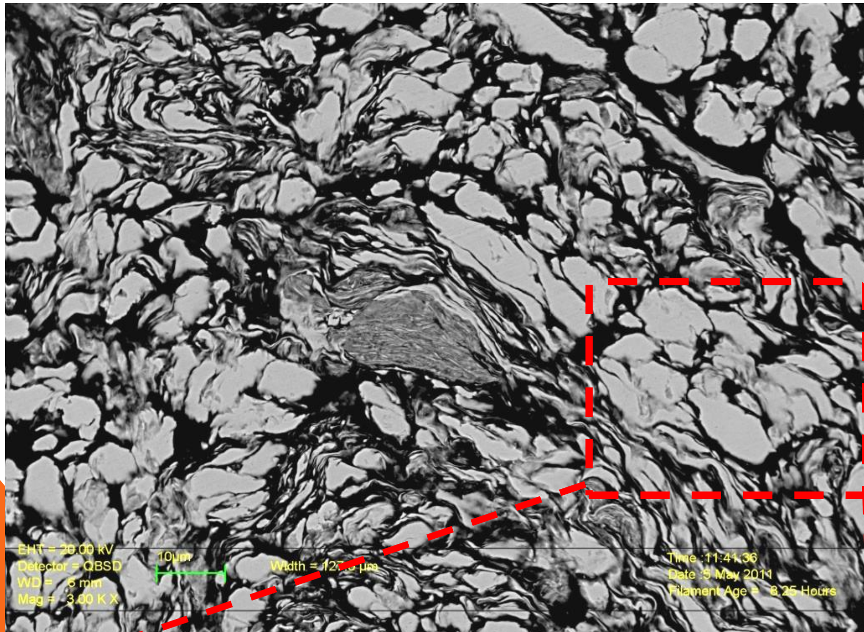
Phase Compositions of Ni + Al mixtures

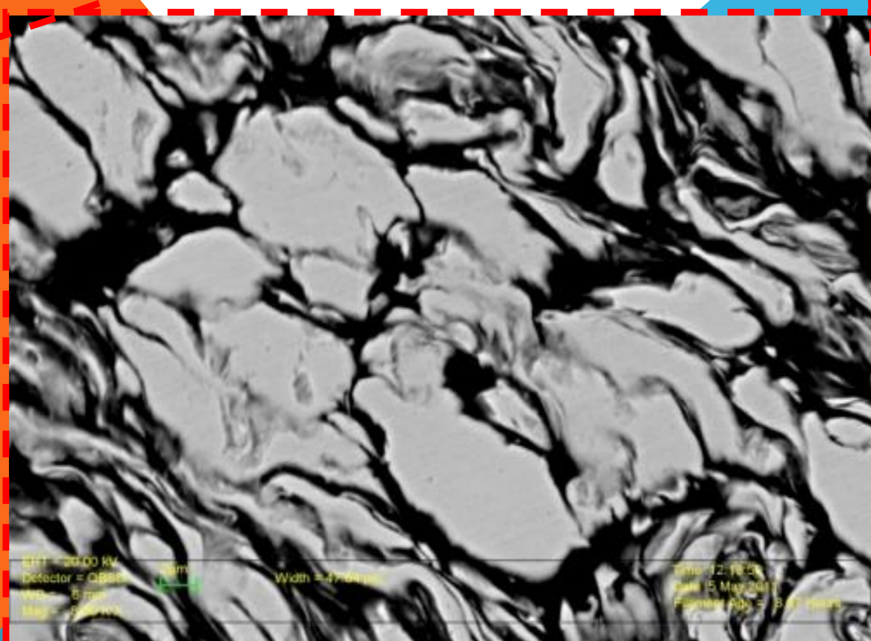


Microstructure of the Ni-Al composite particle

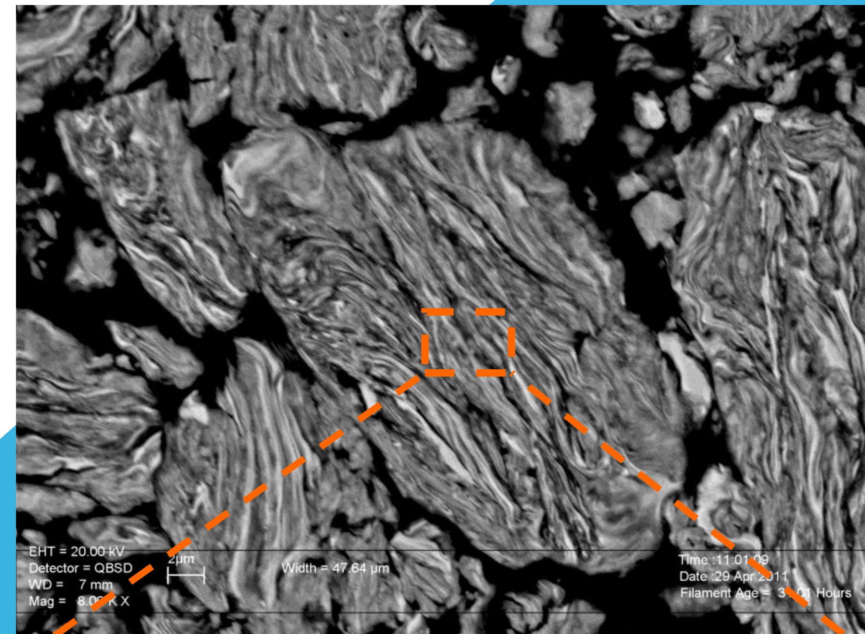


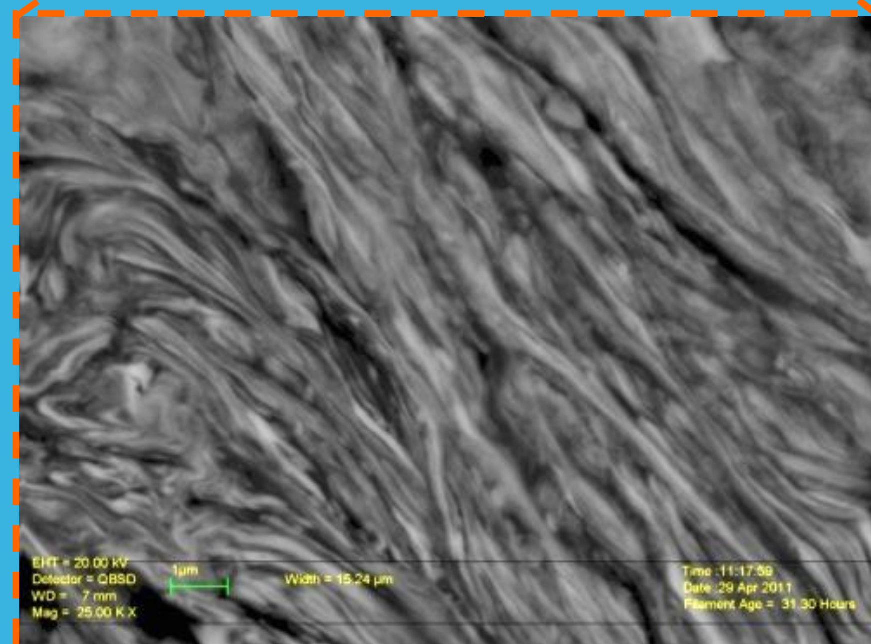
Non-uniform structure



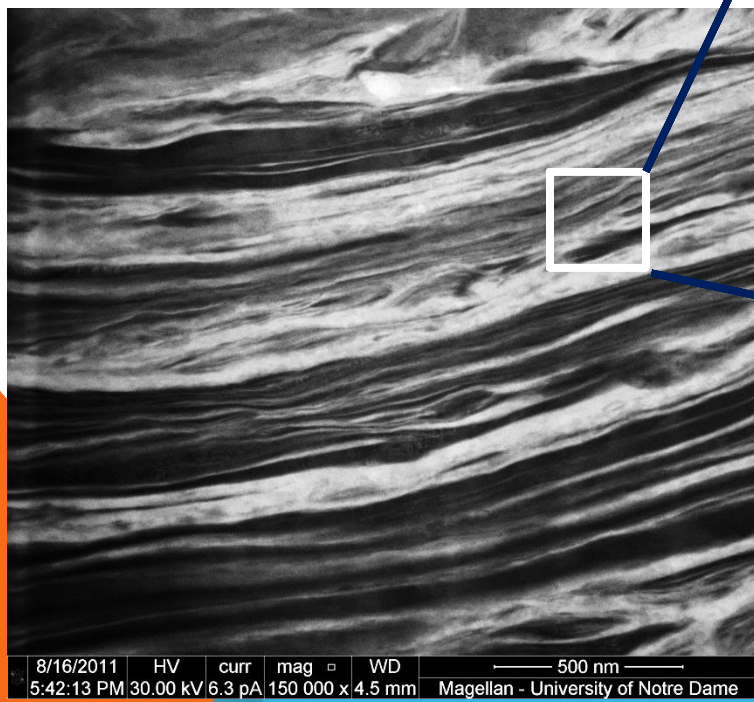


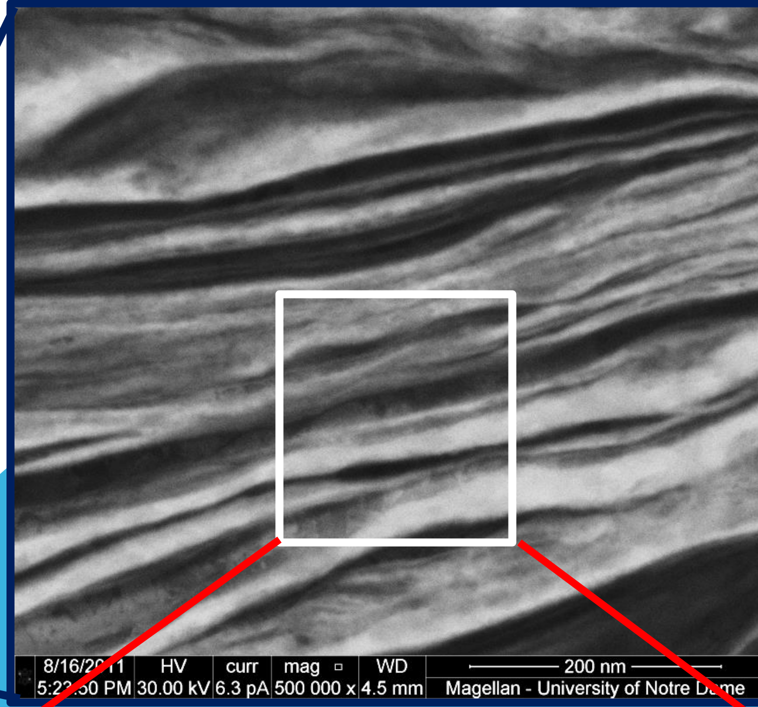
Nano-intermixed structure

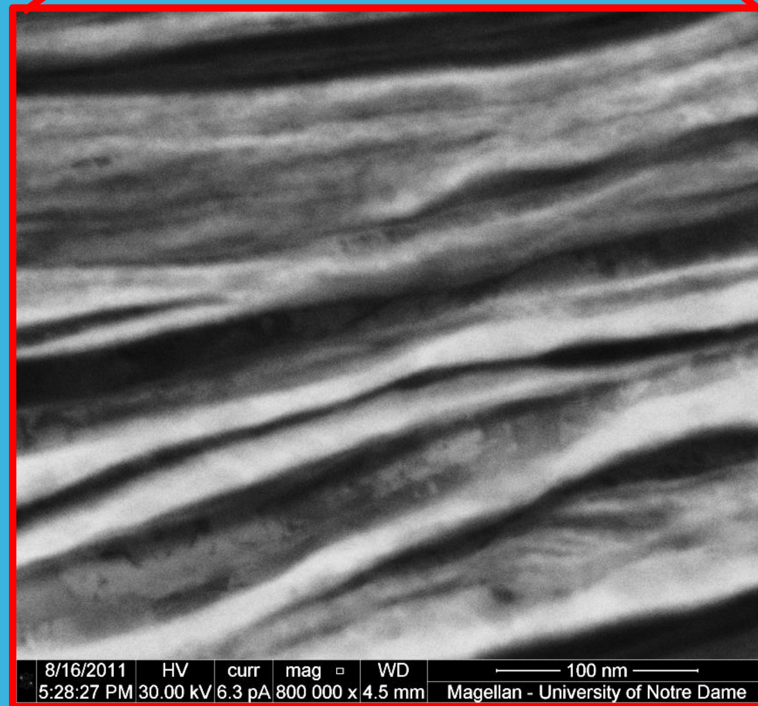




STEM images of Nano-intermixed structure



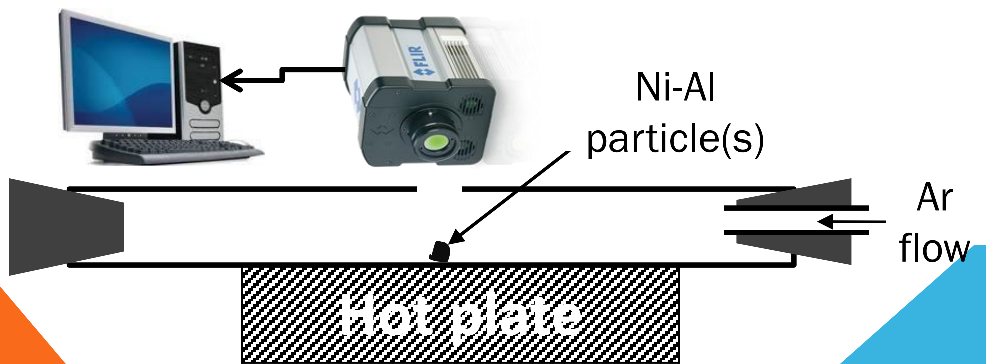


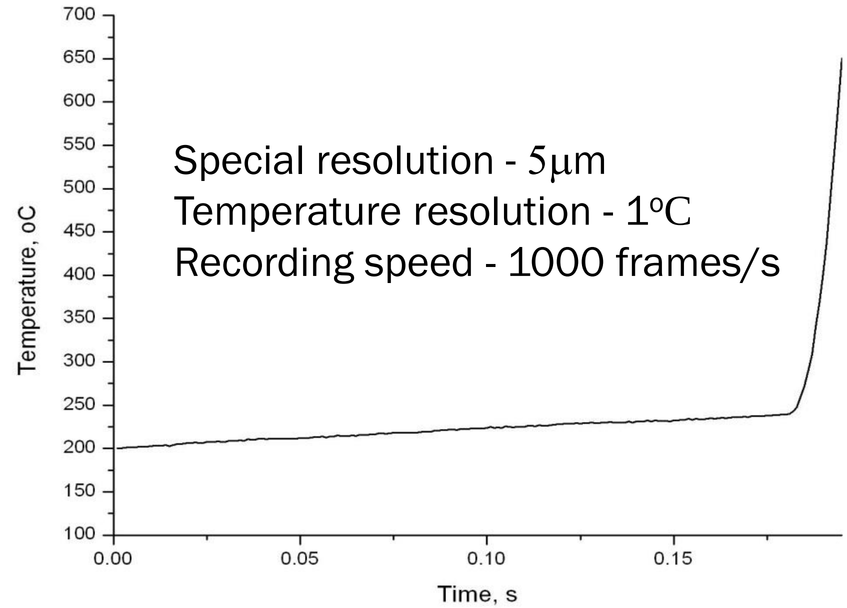


Reactivity of Ni + Al mechanically treated mixtures

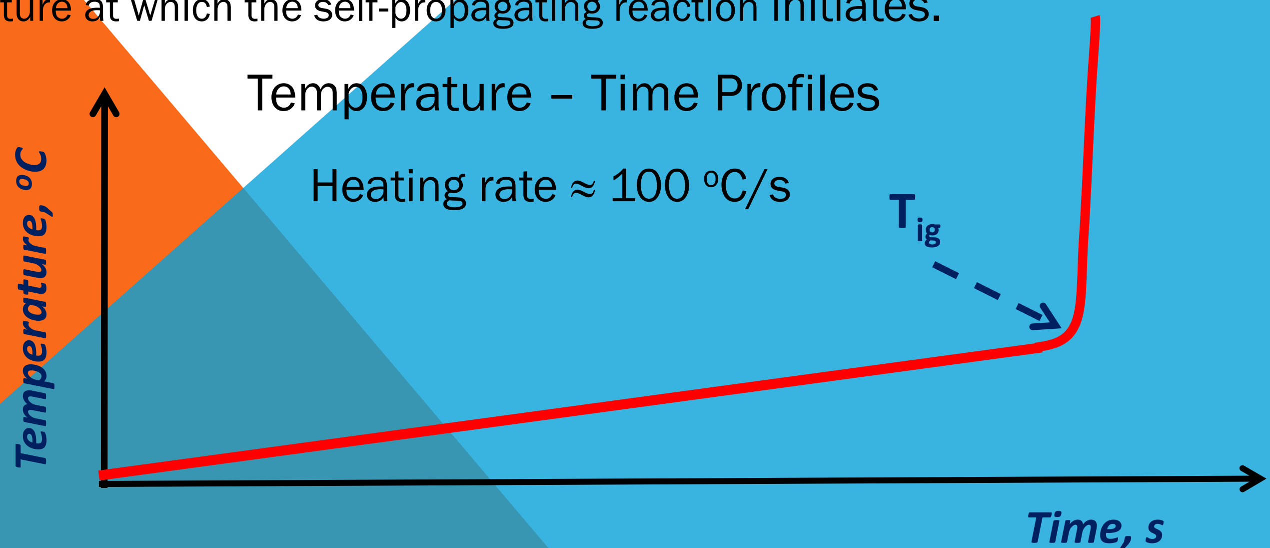
Setup for measuring Ignition temperature of Ni+Al composite particles

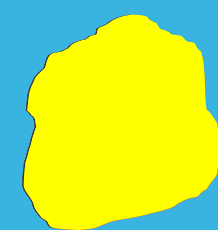
High speed IR





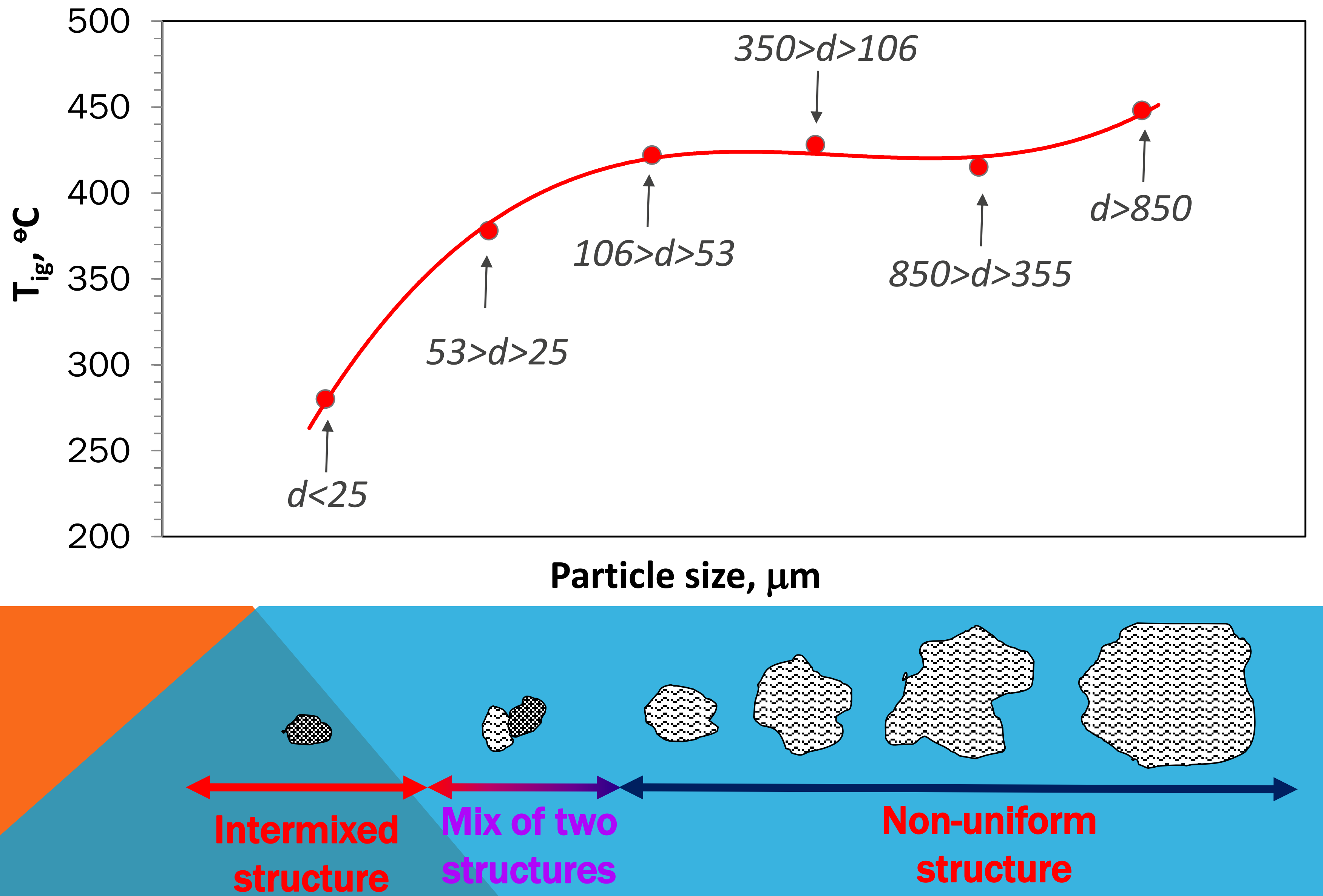
Ignition temperature (T_{ig}) - the lowest ambient temperature at which the self-propagating reaction **initiates.**



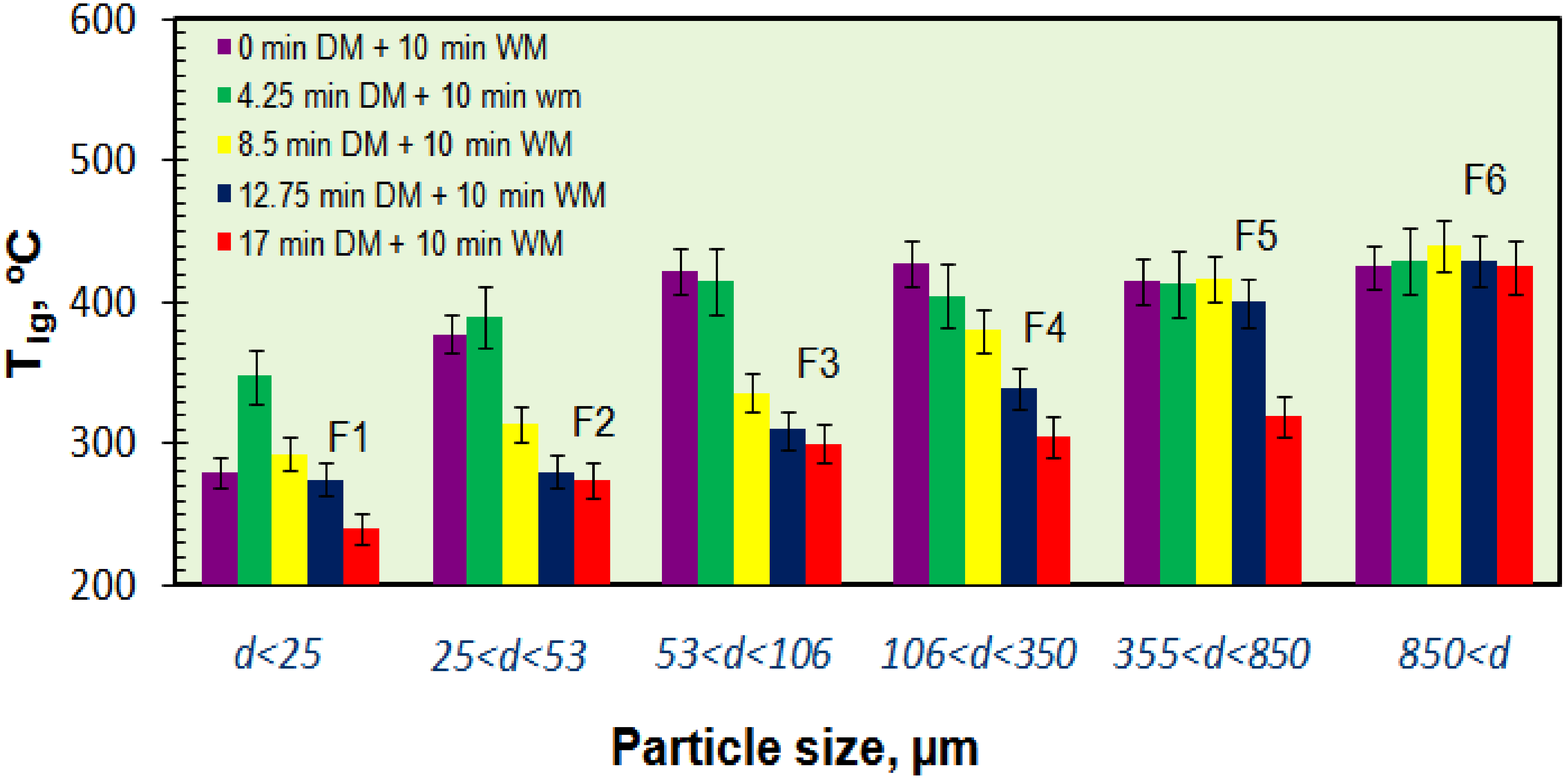


Ni – Al particles

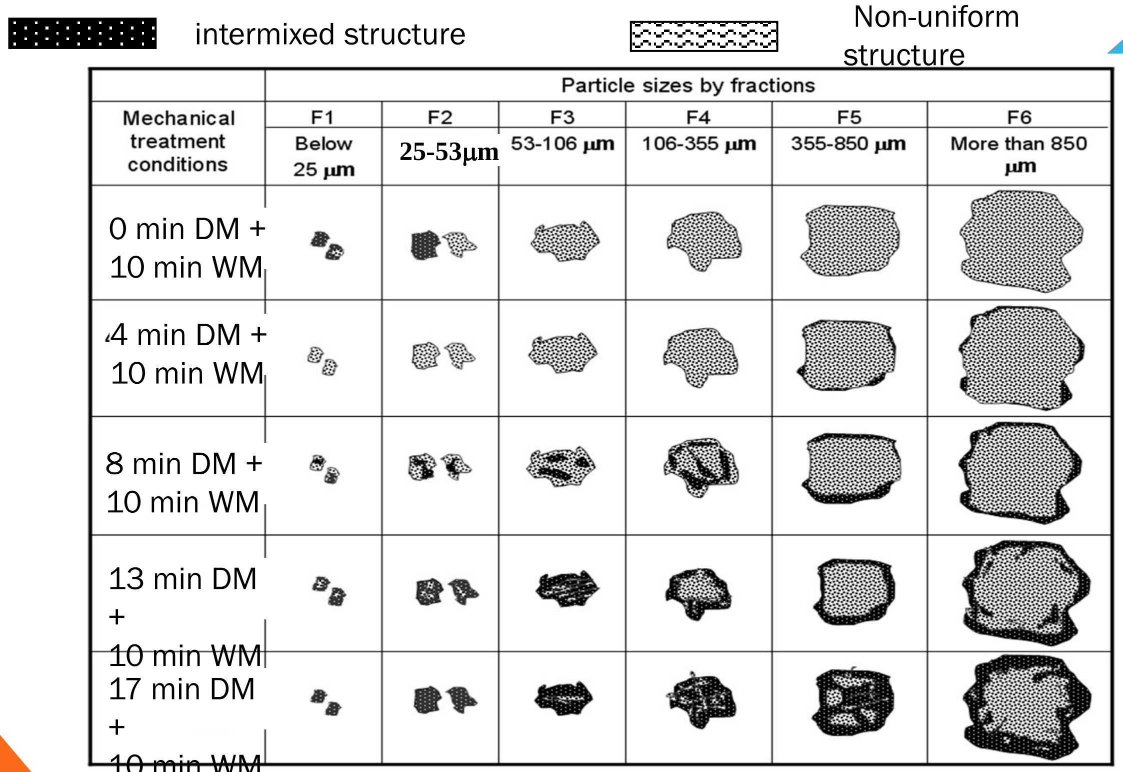
T_{IG} VS. PARTICLE SIZES OF NI-AL MIXTURE AFTER 0 MIN DM + 10 MIN WM

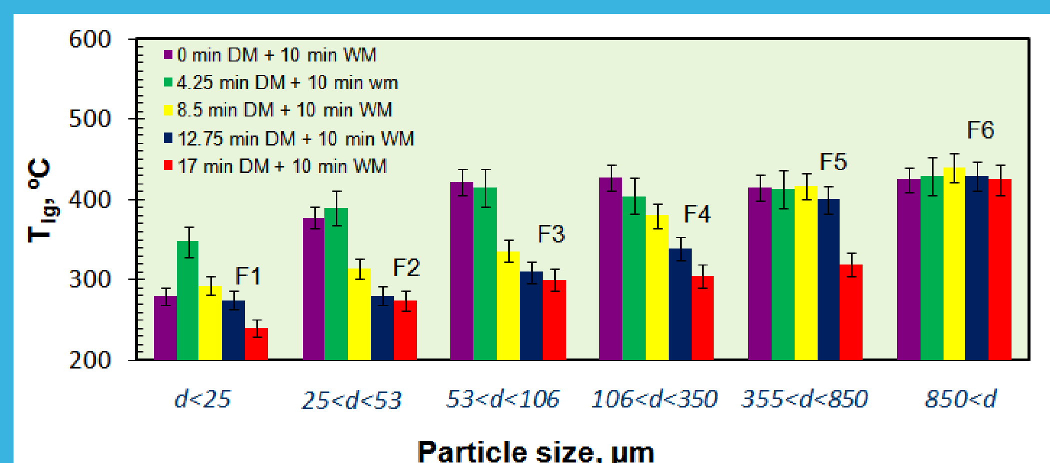


T_{IG} OF NI+AL MECHANICALLY TREATED MATERIALS

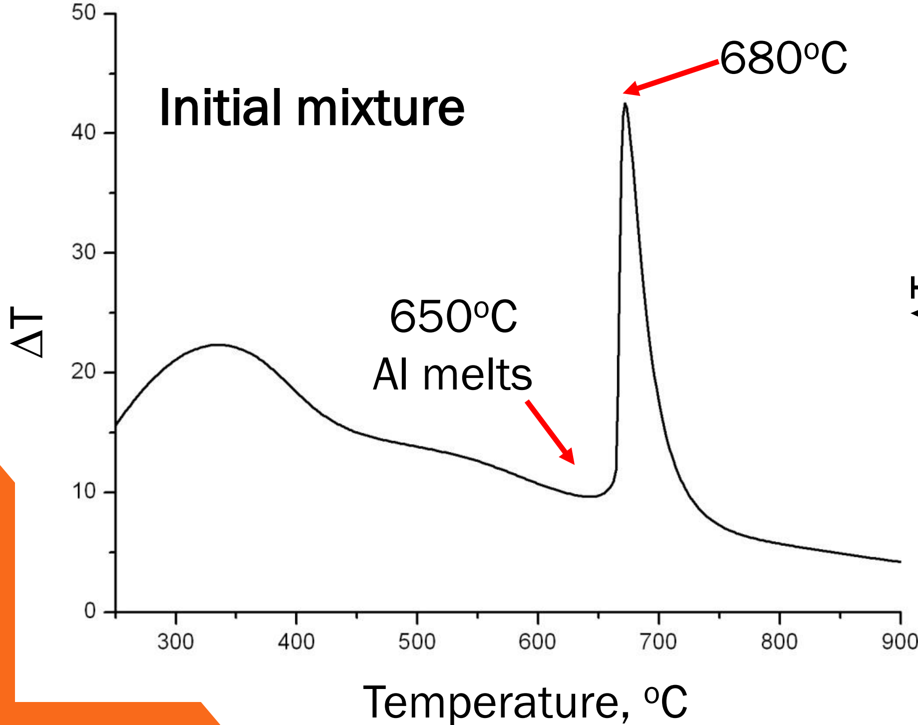


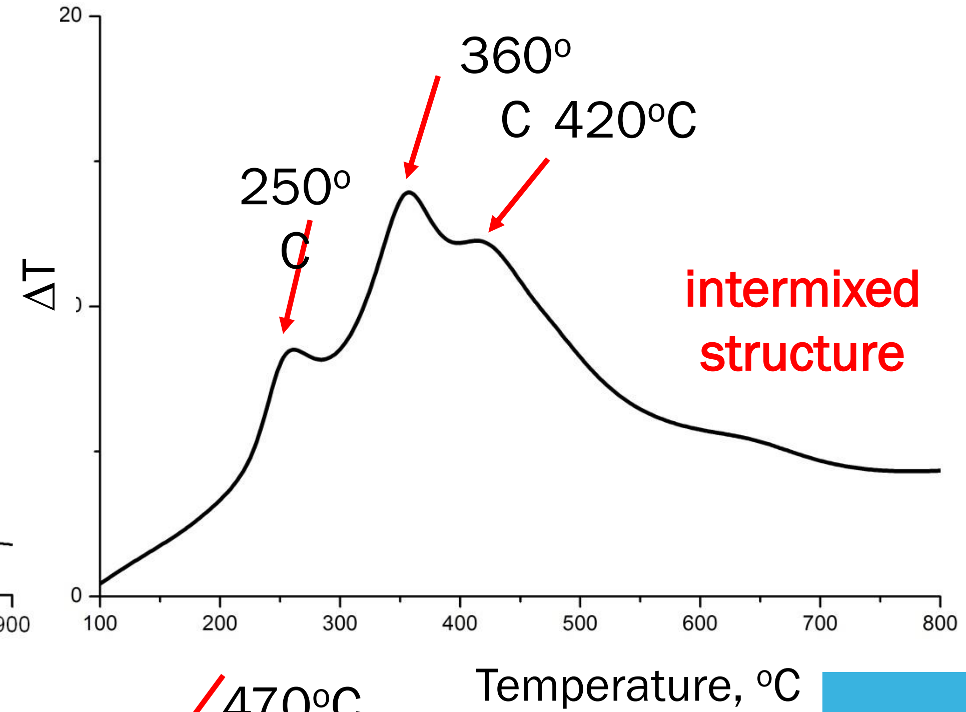
MICROSTRUCTURE – REACTIVITY RELATIONSHIP



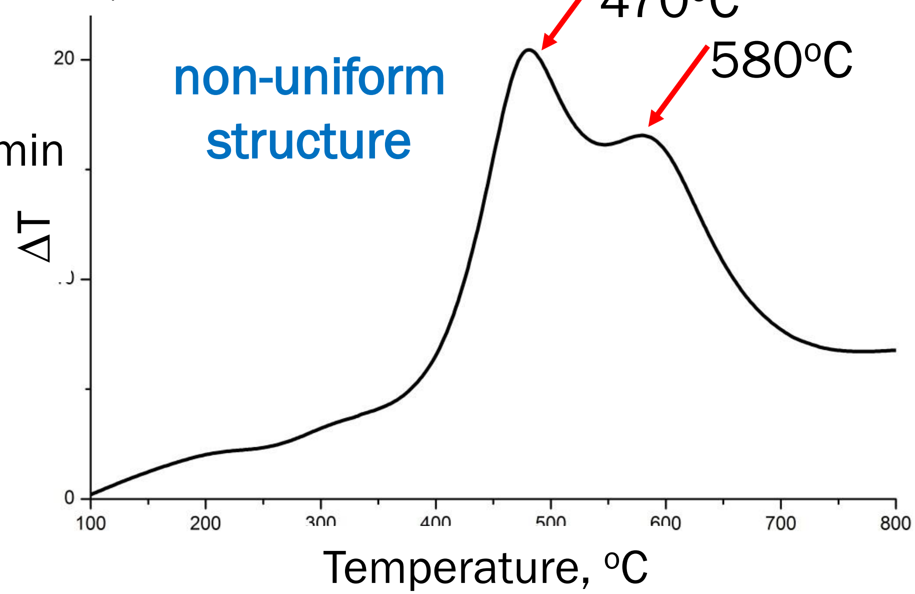


DTA analysis of Ni + Al mixtures

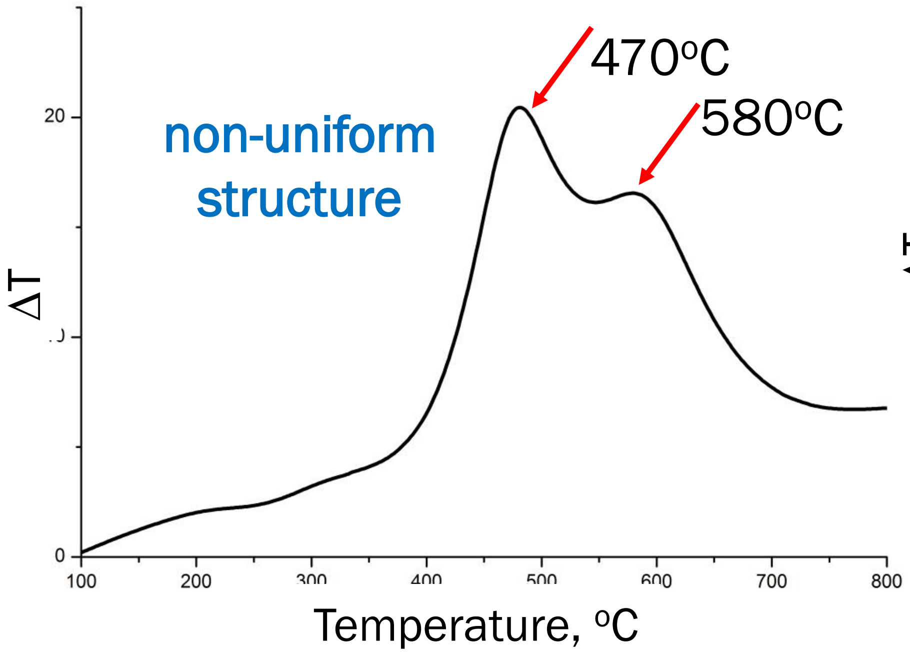


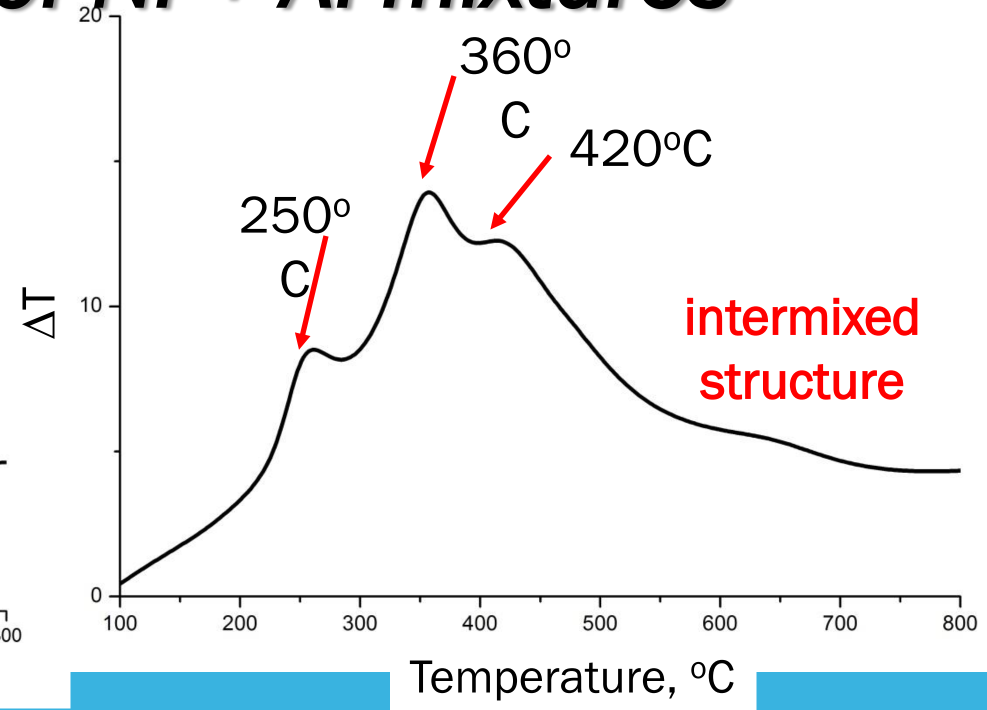


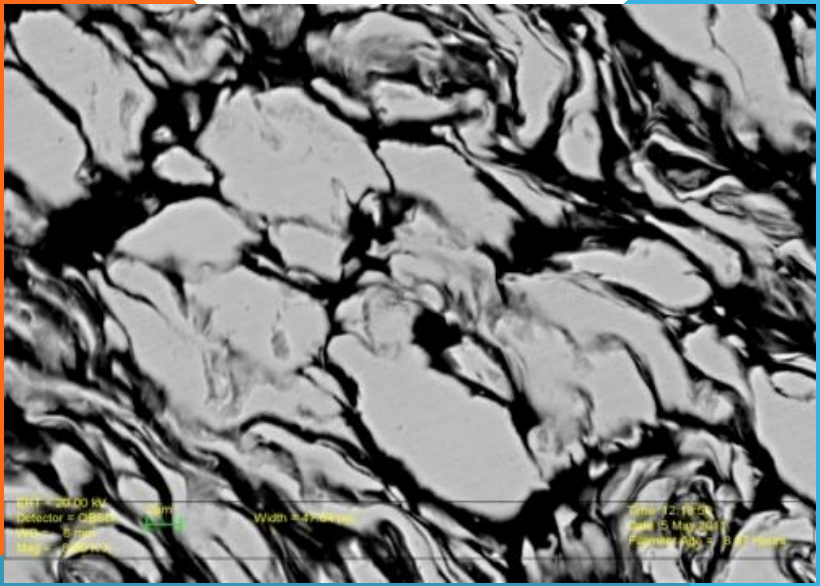
Heating rate =50 °C/min

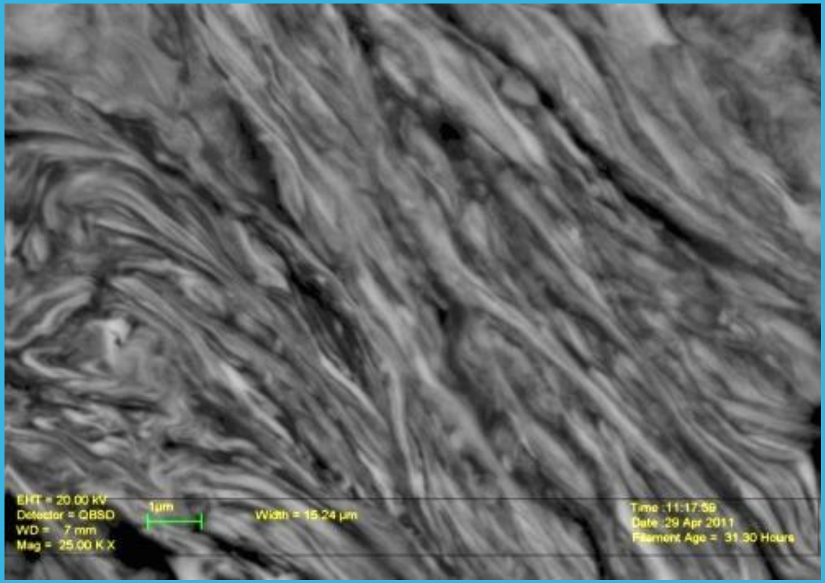


DTA analysis of Ni + Al mixtures









Conclusions

- *Two types of microstructures (non-uniform and mamo-intermixed) is observed in the Ni+Al composite particles produced by high energy ball milling*
- *The Ni-Al composite's microstructure can be tailored by adjusting the milling conditions*
- *Reactivity of Ni+Al composite particles is primarily depend on the microstructure, and intermixed nanostructure results in very low thermal ignition temperatures (~250^{o}C).*