Defence Academy
of the United Kingdom

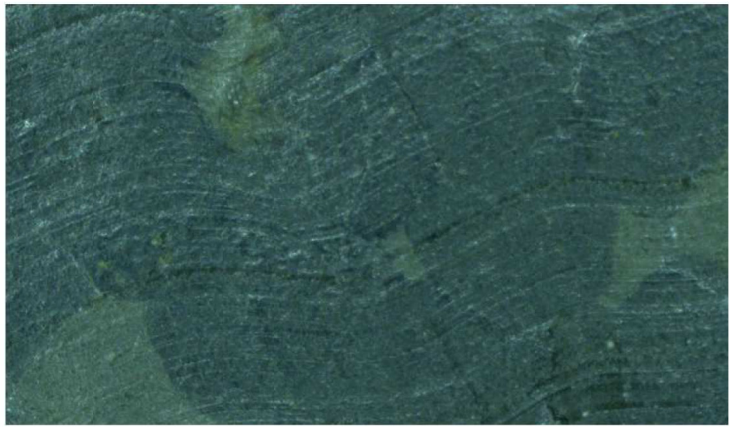
Cranfield UNIVERSITY

Nitrocellulose bonding

Rocket motor manufacturing processing effects

Nathan Flood *(PhD student)*

(E) n.flood@cranfield.ac.uk

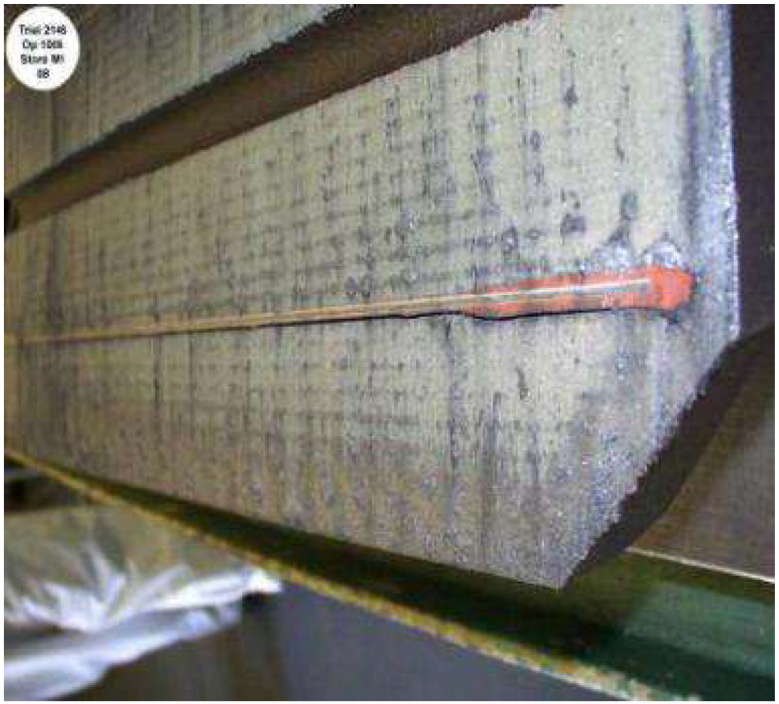


Nitrocellulose workshop 2014, 23 - 24 April 2014 at TNO in Rijswijk, The Netherlands

Nitrocellulose bonding

Manufacturing and processing's effect

1. Background
2. NC bonding mechanism
3. Propellant grain observations
4. NC plasticiser interactions
5. Effect of processing
6. Future!



1 – Martin Sloan DOSG 2007, 2010, 2012

NC Properties for Double Base Propellant

- Change in NC or
  - Change in Gelat
  - Change in 'gree
  - Change in Die S
    Plant, also batch
  - Which can all af

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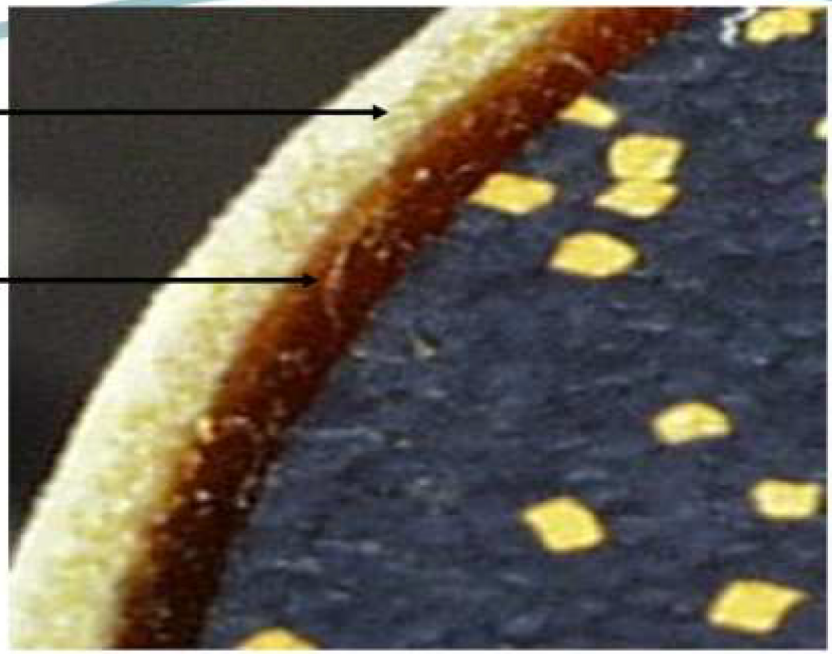
Propellant to Inhibitor Separation



de&S

1 – Sea dart failure

Weapons Science & Technology Centre

Propellant Bonding Programme 2011-15

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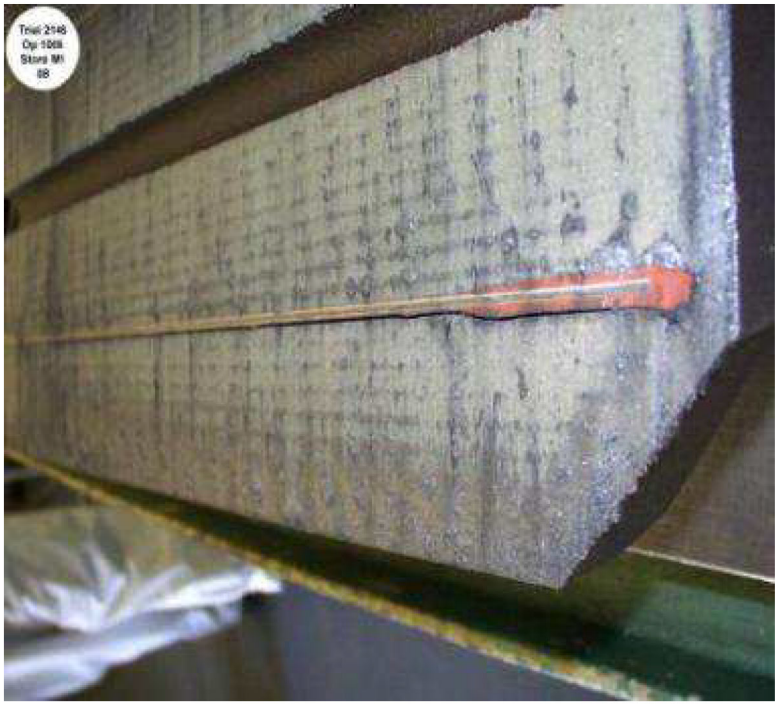


2- Nitrocellulose bonding mechanism

Discussion

Nitrocellulose (around 12.5 % N content)

Mixed with Plasticisers and additives

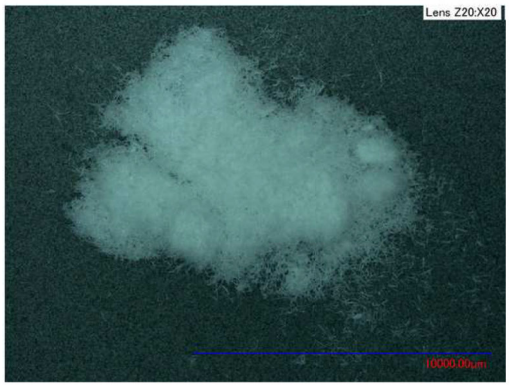
Then extruded and cut into grains

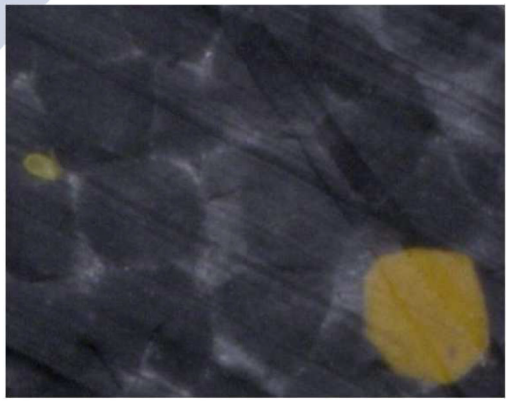
Casting Powder

Mixed with Casting Liquid (Plasticisers and Stabilisers)

temperature + pressure

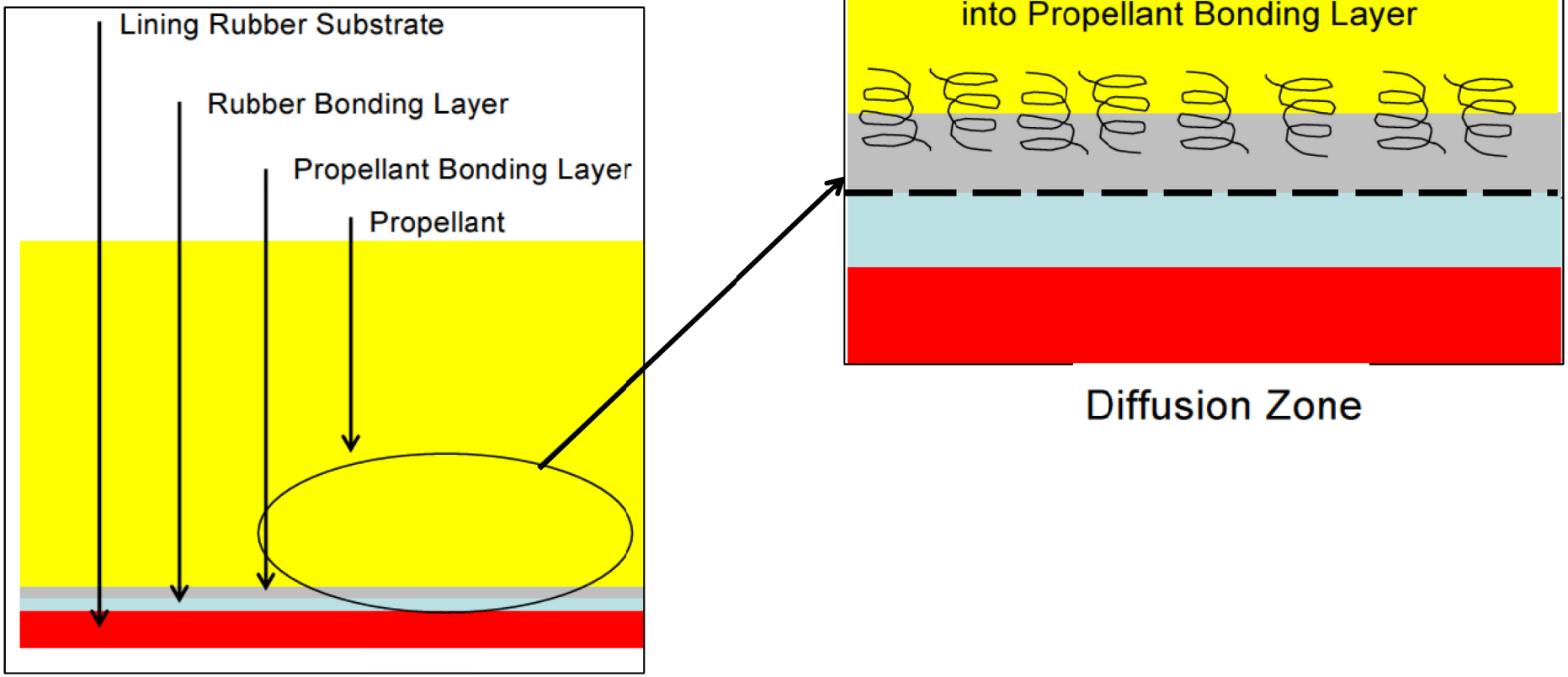
CDB Propellant





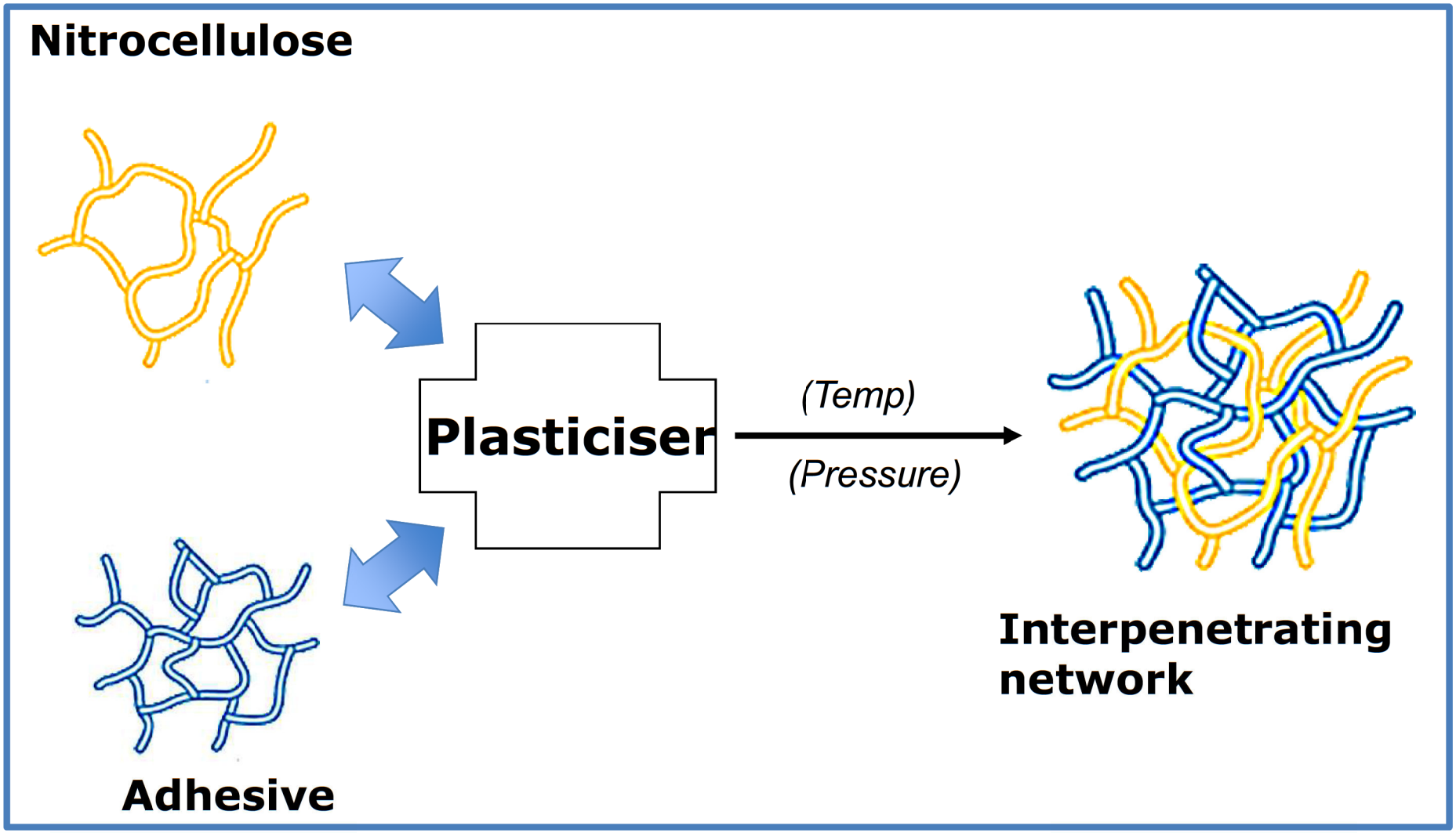
2- Nitrocellulose bonding mechanism

Discussion



2 - Nitrocellulose bonding mechanism

Discussion



2 - Nitrocellulose bonding mechanism

Discussion

Key Nitrocellulose variables for bonding:

- NC plasticiser solubility
- NC gelatinisation
- NC diffusion
- NC fibril structure
  - N content
  - M_W of NC

Nitrocellulose bonding

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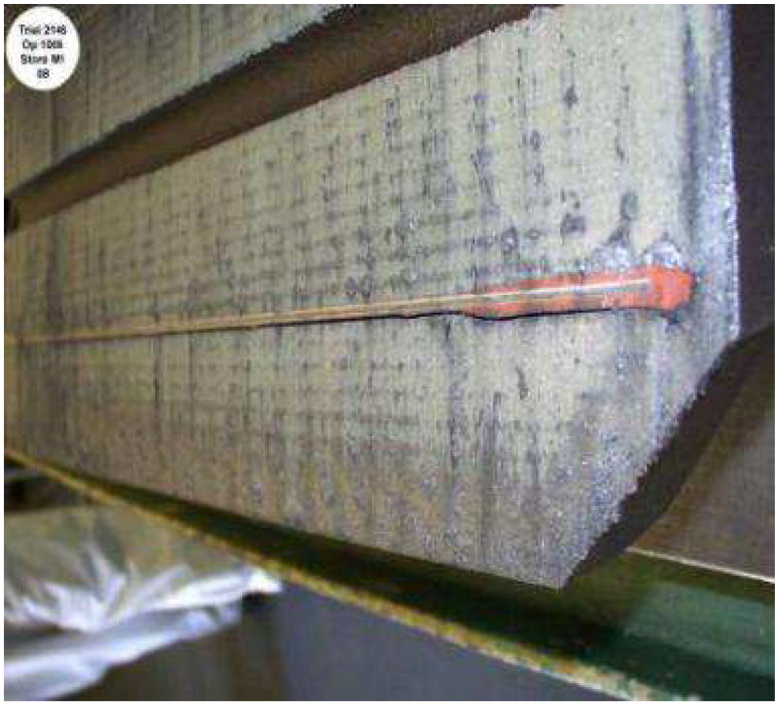
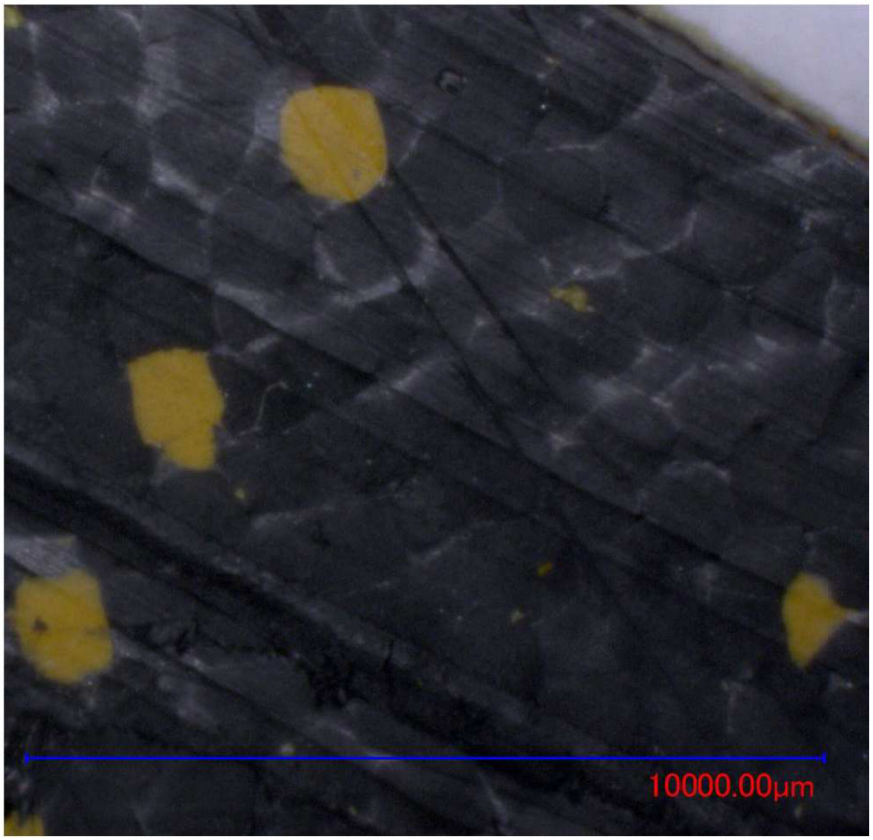
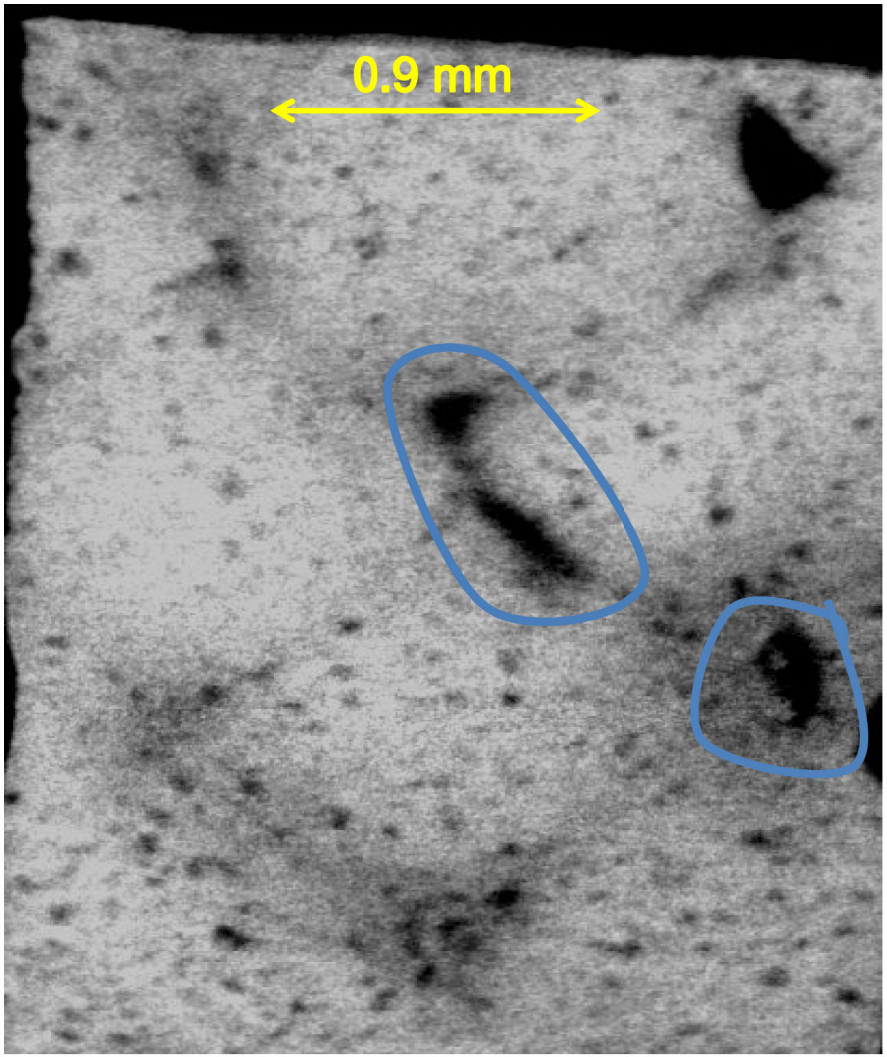


3 - Propellant grain observations

CT X-ray





3 - Propellant grain observations

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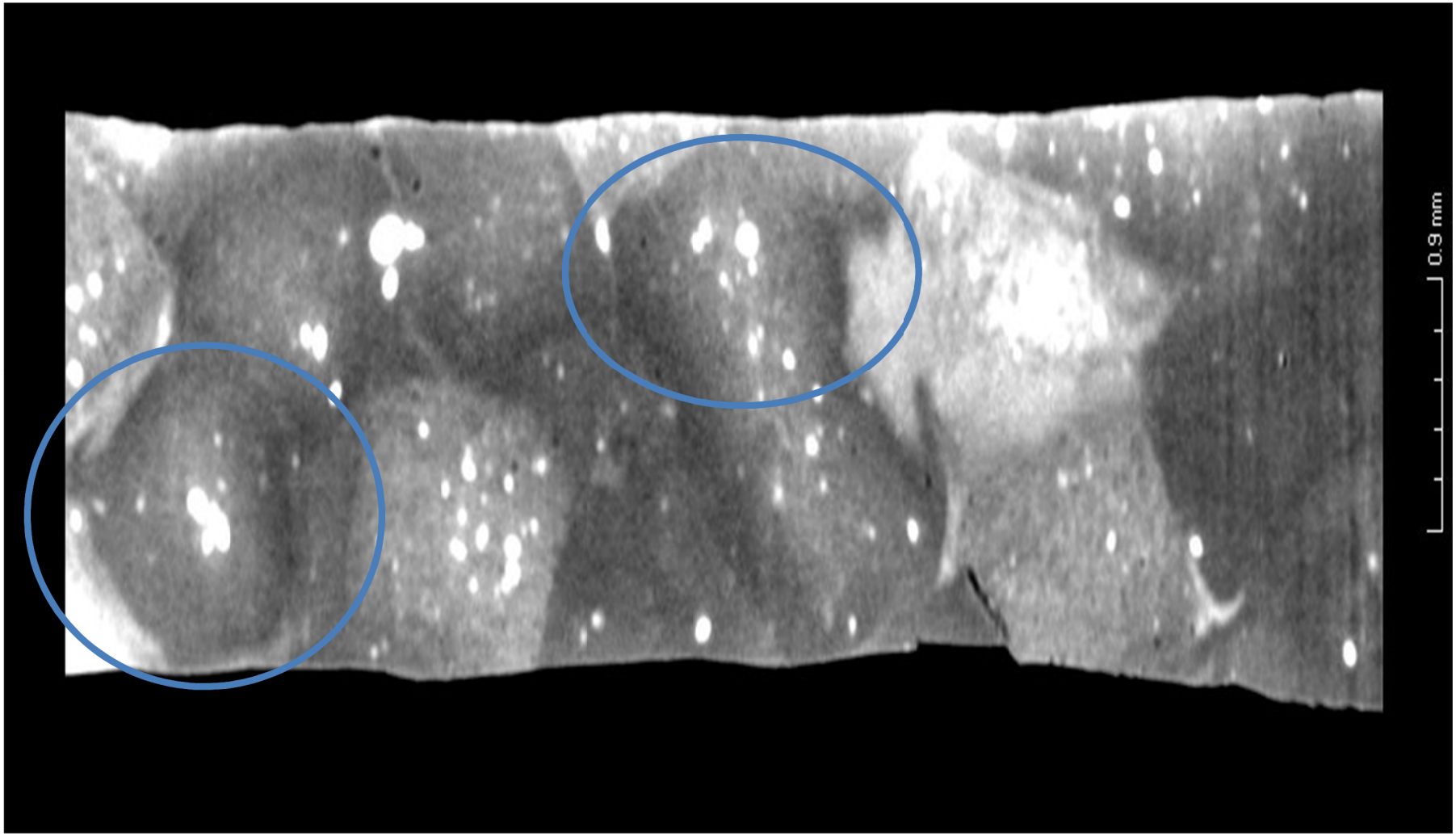

3 - Propellant grain observations

- Casting powder does not swell to produce a homogeneous propellant grain during casting

- NC bonding affected by:
  - N content
  - MMD
  - fibril structure

- How does N content, MMD, fibril structure vary across the casting powder and propellant grain?

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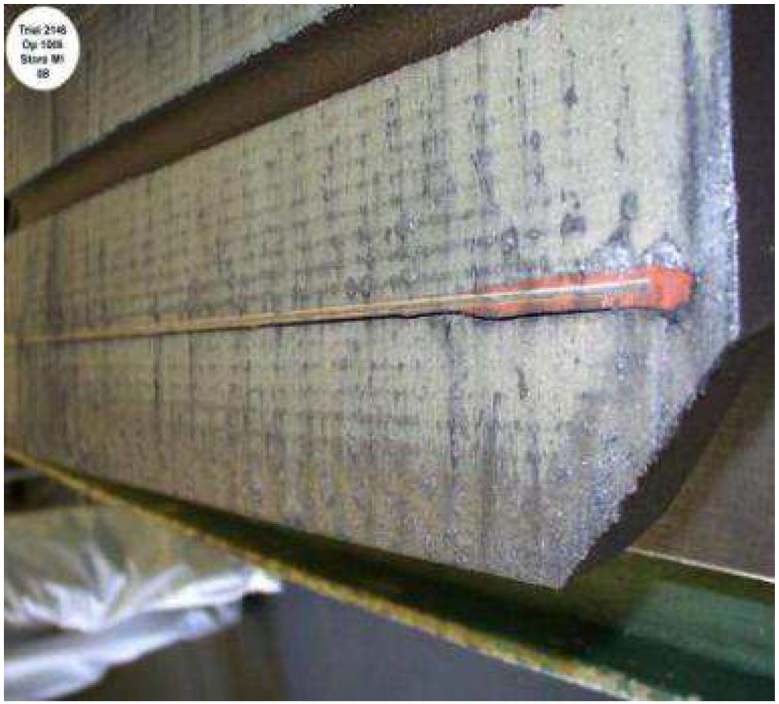
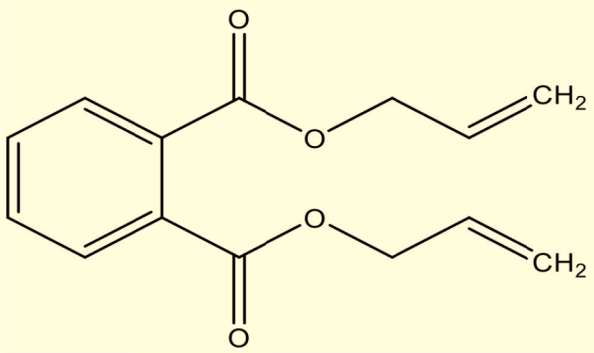


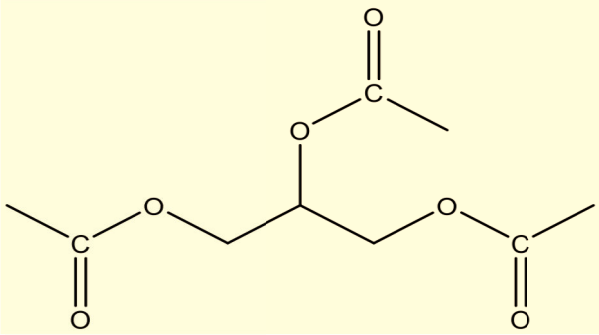
4 - Nitrocellulose plasticiser interaction

Experiment



Diallyl Phthalate (DAP) plasticiser

- Molecular weight 246 g/mol
- Poor NC solubility



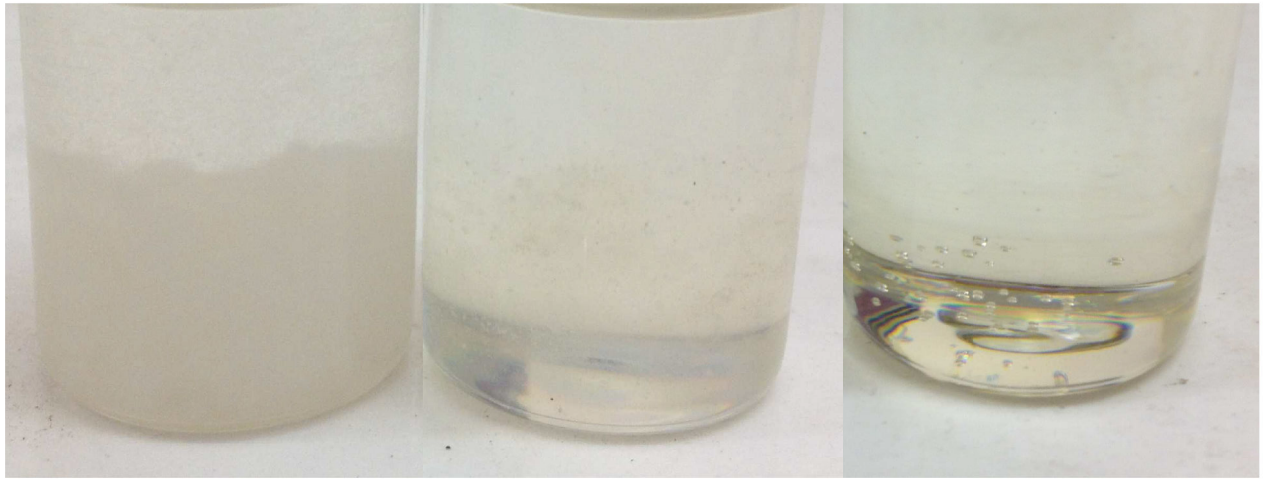
Triacetin (TA) plasticiser

- Molecular weight 218 g/mol
- Good NC solubility

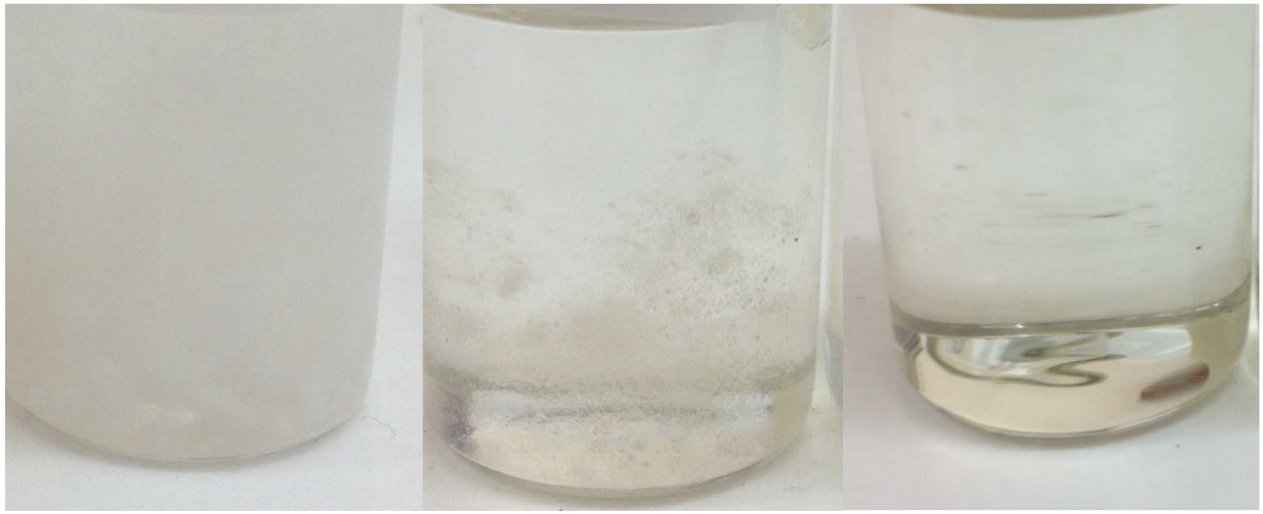
- 1g of NC mixed with 1g of each plasticiser separately
- Samples shaken for 1 week
- Left to settle for 1 week
- Samples formed a viscous gel

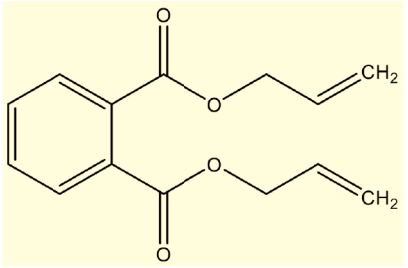
4 - Nitrocellulose plasticiser interaction

Experiment (observation)

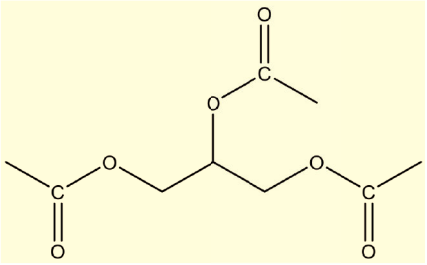


Day 1 **Day 3** **Day 7**





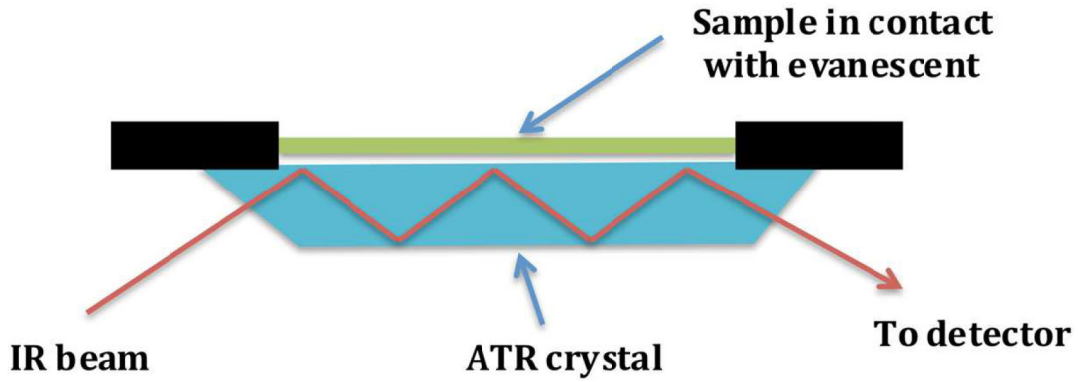
DAP plasticiser



TA plasticiser

4 - Nitrocellulose plasticiser interaction

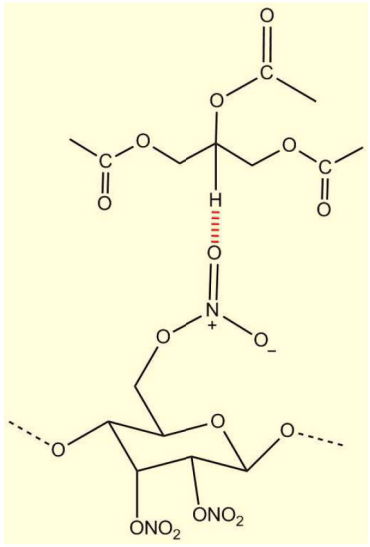
- Samples analysed using reflectance IR spectroscopy to measure molecular vibrations of functional groups

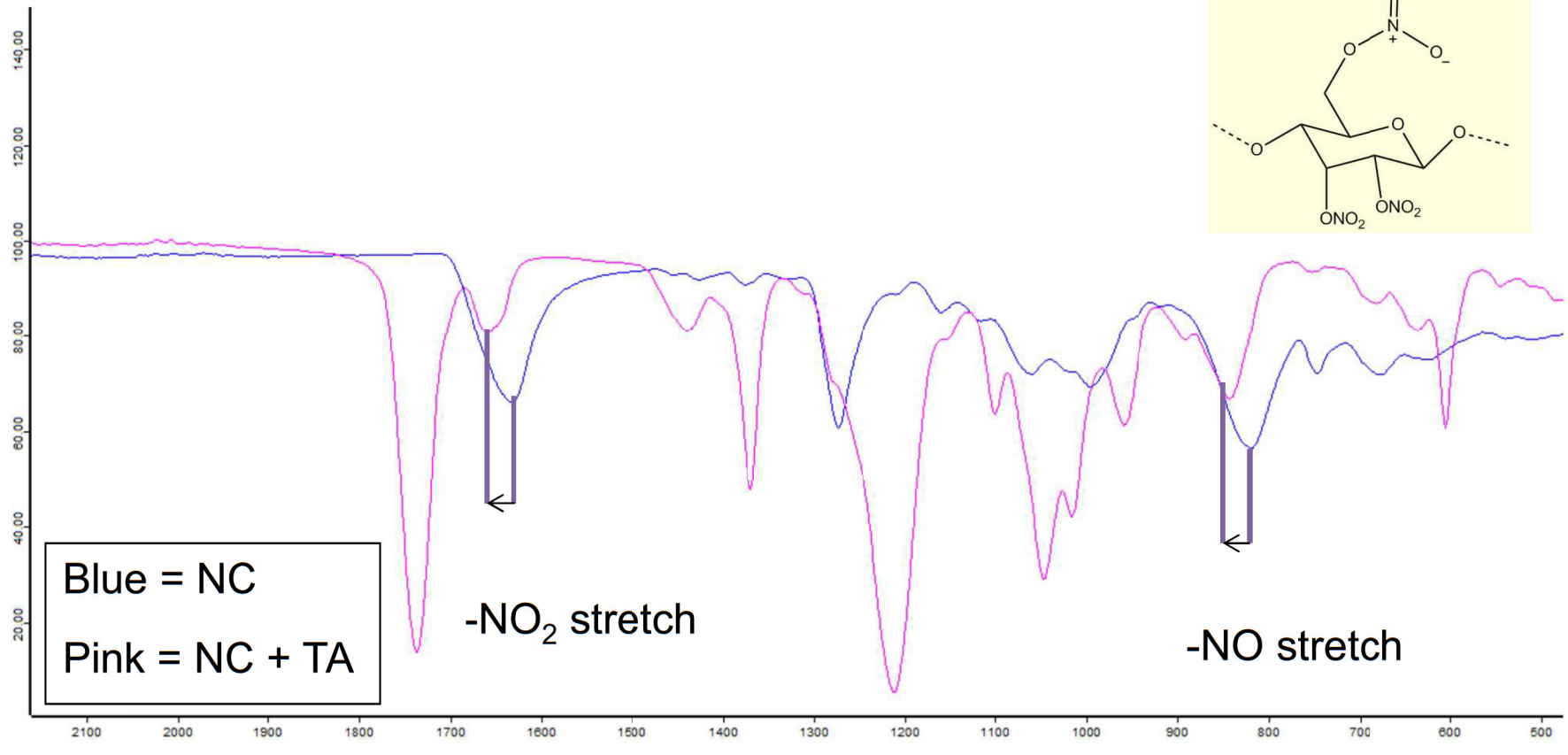


- It is well established in the literature that hydrogen bonding increases the wavenumber of functional groups due to partial covalent nature of IMF

4 - FTIR-ATR spectra

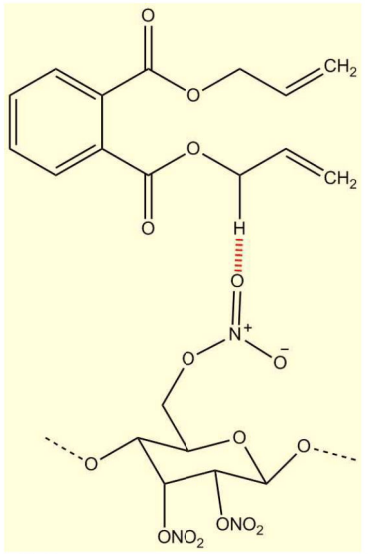
TA + Nitrocellulose



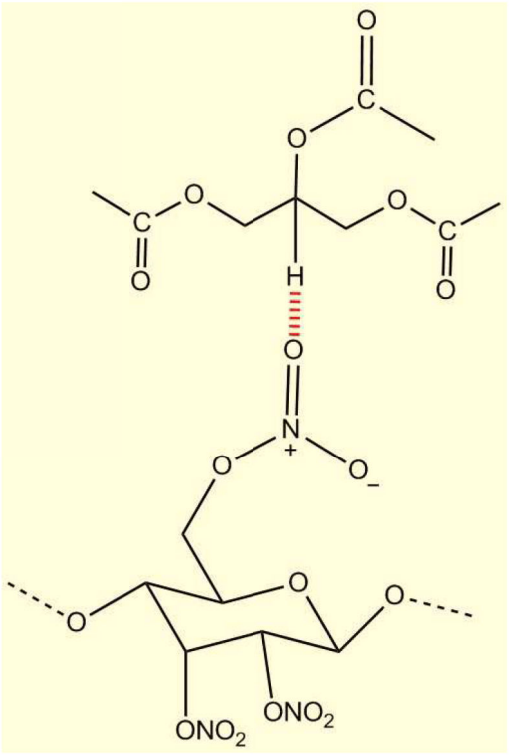


4 - FTIR-ATR spectra

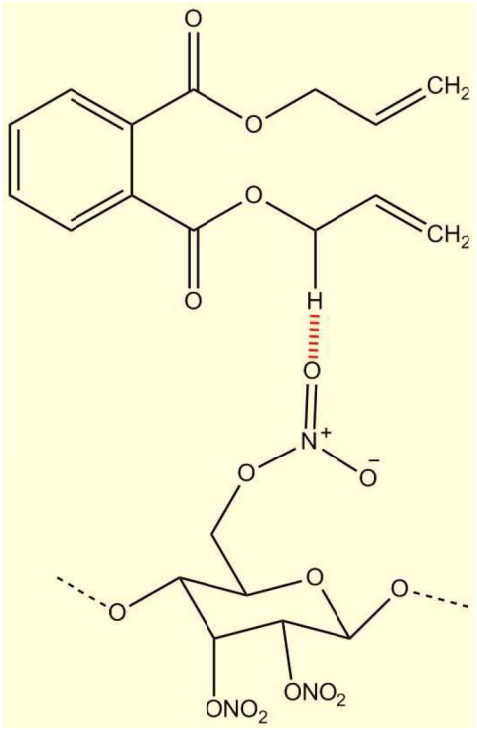
DAP + Nitrocellulose



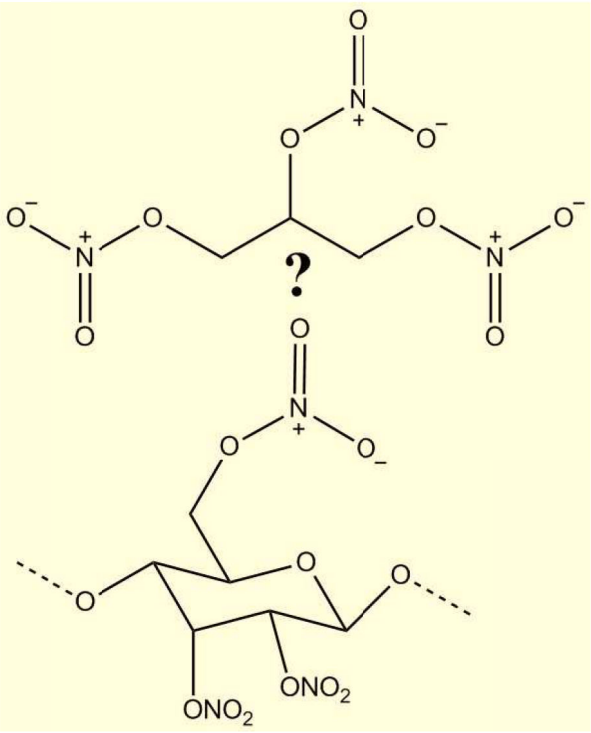
4 - Nitrocellulose plasticiser interaction



TA + NC



DAP + NC



NG + NC

Baker (1985) used Dielectric analysis: concluded no apparent hydrogen bonding was present and the Nitro-glycerine interacts with the ring structure in the Nitrocellulose

4 - Nitrocellulose plasticiser interaction

- NC has better solubility in TA than DAP
- The results show that both TA and DAP hydrogen bond with NC to a similar degree
- Therefore is the solubility independent of hydrogen bonding??
- Difference in solubility could be a result of the molecular weight of the plasticisers dictating their ability to diffuse into the NC fibres

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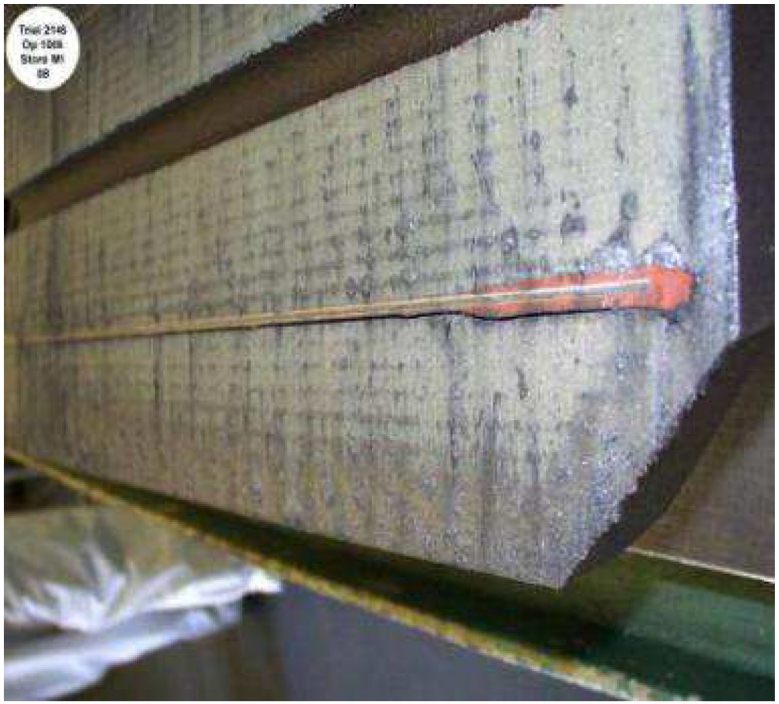
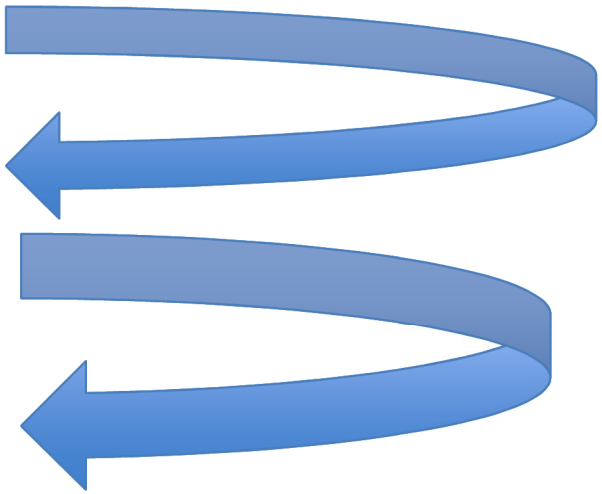


5 - Nitrocellulose Mw

Effect of processing

Experiment:

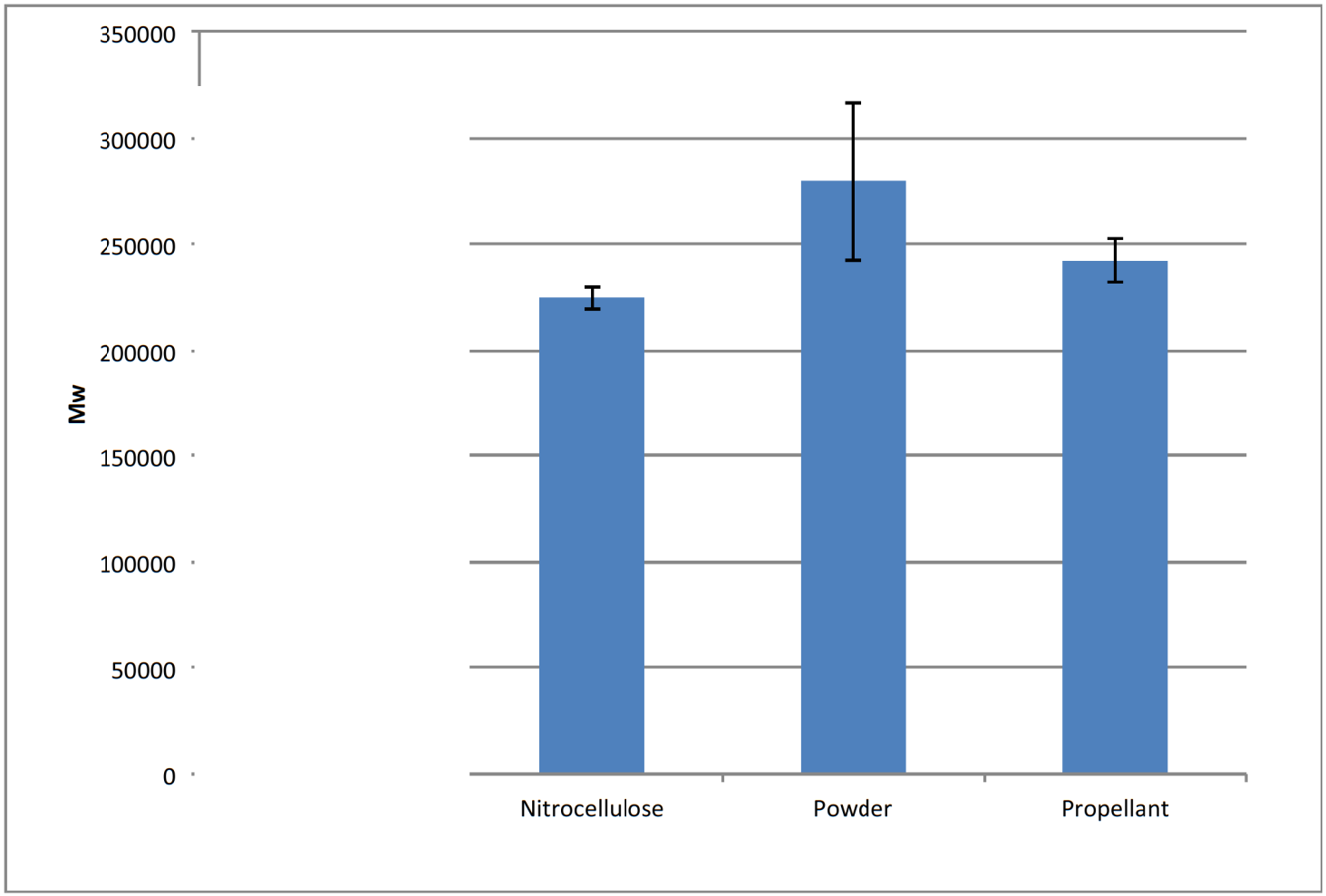
- x1 Nitrocellulose *(1-2 years old)*
  - One batch from one source
- x1 Casting Powders *(1-2 years old)*
- x1 Propellants *(1-2 years old)*



- Samples analysed using STANAG 4178 (ed2) method but using triple detector GPC

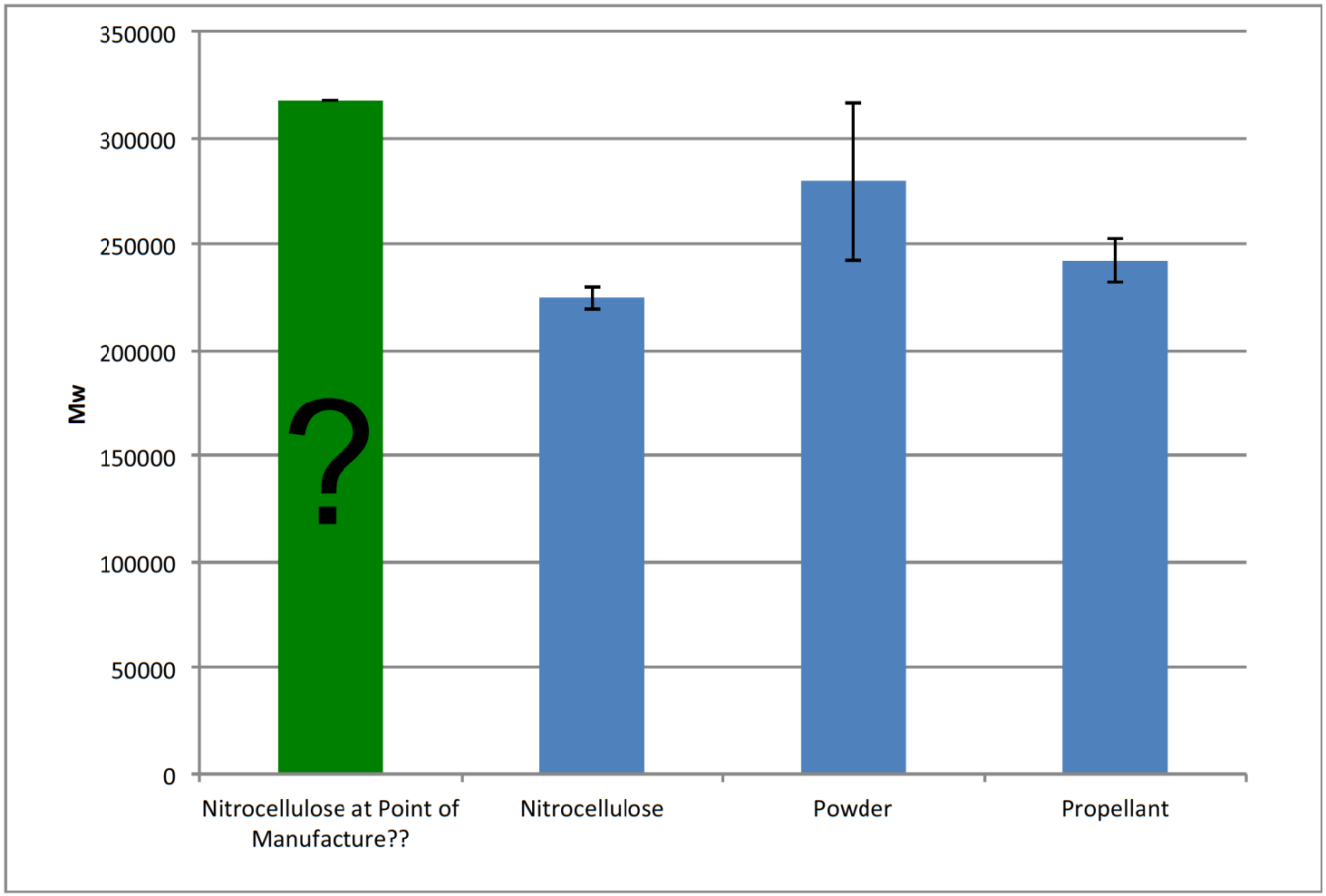
5 - Nitrocellulose Mw

Effect of processing



5 - Nitrocellulose Mw

Effect of processing



5 - Nitrocellulose Mw

Effect of processing

- Processing casting powder to propellant
  - Mw decreases during manufacturing process

- Change in Mw of NC is attributed to the mechanical/thermal processing from manufacturing process

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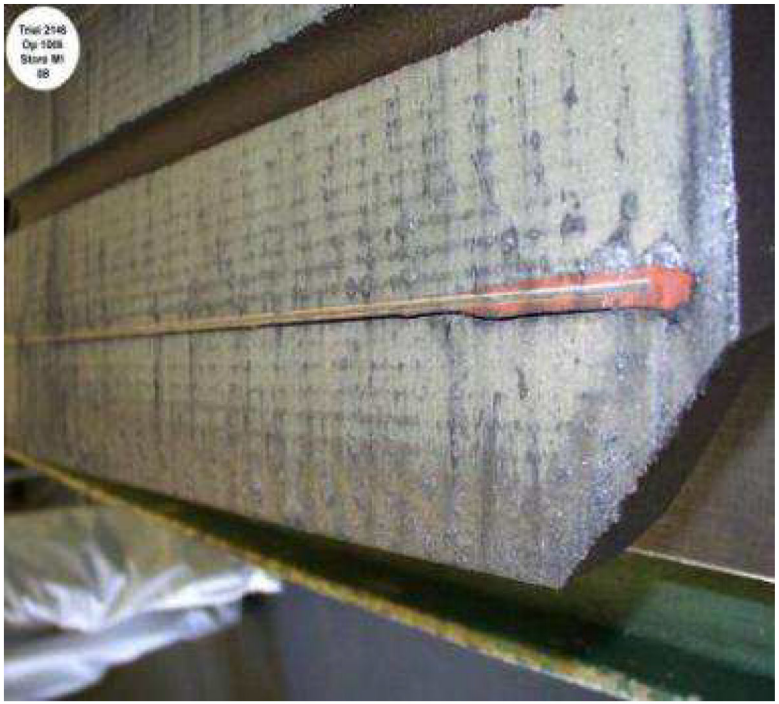

6 - Nitrocellulose bonding

Nathan Flood - PhD

- In the next stage of my PhD:
  - NC interactions with NG
    - Using IR method
  - NC/casting powder swelling
    - Measurement of degree of swelling in plasticisers
  - NC plasticiser solubility and diffusion rate
    - Diffusion measurements
    - Modelling

Acknowledgments

- MoD and Weapons Science Technology Centre for funding
- Roxel (UK Rocket Motors) Ltd
  - M Williamson
  - R Johnson

References

- Sloan, M. and B. Wall (2007). Rocket Propellant Characteristics as Influenced by Cellulose Type and Source. NC Workshop. Aldermaston.

- Sloan, M.P., *Nitrocellulose: DOSG Propellant Qualification Requirements*, in *The 4th Nitrocellulose Workshop*. 2010: Shrivenham

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- Baker, F.S., Jones, M., Privett, G., Crofton, D.J., and Pethrick, R.A., Dielectric studies of the effect of water on the relaxation properties of nitroglycerine-nitrocellulose mixtures. Polymer, 1985. 26(8): p. 1227-1230

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Chemistry/ material science/ physics with focus on:

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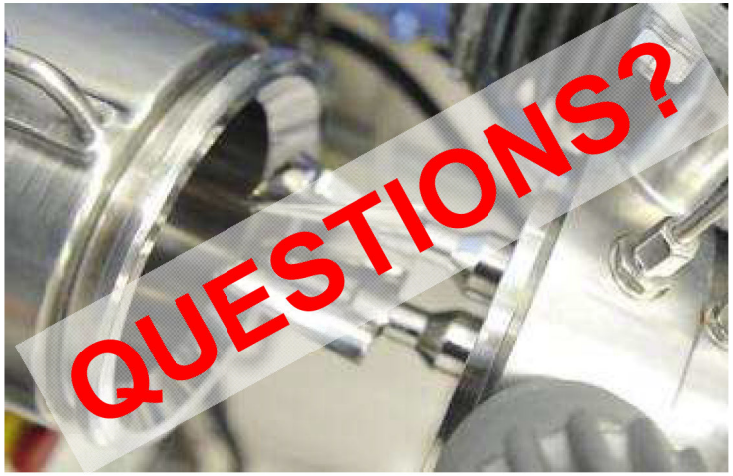
  - Synthesis & Formulation, Life Assessment, Safety & Reliability, Test and Evaluation
- **Environmental & Risk Management, Fuels, CBRN and Forensic Science**



Synthesis & Formulation	Characterisation & Ageing	Test & Evaluation	Chemical Safety, Fuels & Environmental