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Ministry of Defence

Synthetic thumb for residue creation

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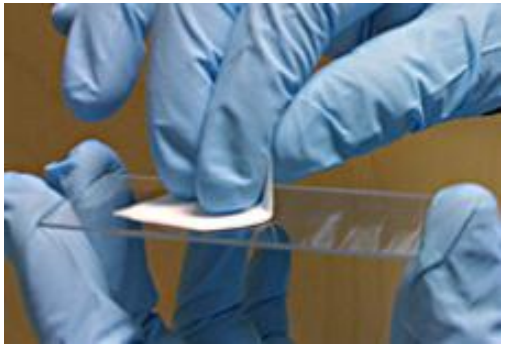
Background

- Detection of explosive traces underpins both high assurance search capability and aviation security screening
- Trace detection is an indirect technique inferring the presence of a larger bulk quantity
- Current swabbing protocols are derived from previous studies based on bomb-making simulations using plastic explosives

Aim

- Develop appropriate operational tools and protocols to detect emerging threats
  - Characterise primary and secondary contamination from a range of explosives on a number of realistic surface types
  - Understand the differences between plastic and crystalline explosives trace deposition, transfer and persistence



So what's with the thumb?

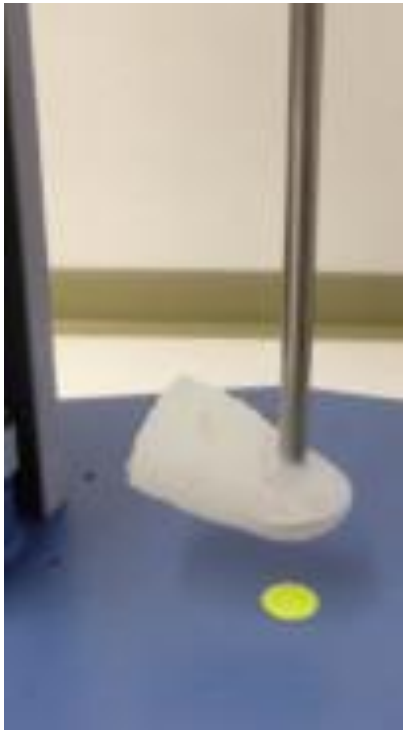
- Some crystalline explosives are sensitive to impact and friction
  - Prohibits working with bulk
  - Prohibits compression by human finger
- A valid comparative study requires a standard deposition method
  - Material, surface profile, force, contact angle etc
  - Variability in deposition is expected
    - but should as far as possible be due to the intrinsic properties of the explosives
- The thumb force rig is designed to deposit residue to enable comparative trace characterisation and aid the development of realistic quantitative standards
- **It is NOT intended to provide a quantitative standard!**

Dragon Skin®

- Dragon Skin® Series silicones are high performance platinum cure silicone rubbers that cure at room temperature with negligible shrinkage
- Cured Dragon Skin® will stretch many times its original size without tearing and will return to its original form without distortion
- Dragon Skin® with Shore Hardness of 10A selected for artificial thumb based on matching size of thumb print to real print under same force
- Not intended to replicate skin in other respects, but can be used with synthetic sebum
- Provides a reference combining ridge properties of fingerprints with dielectric properties of latex/ nitrile glove

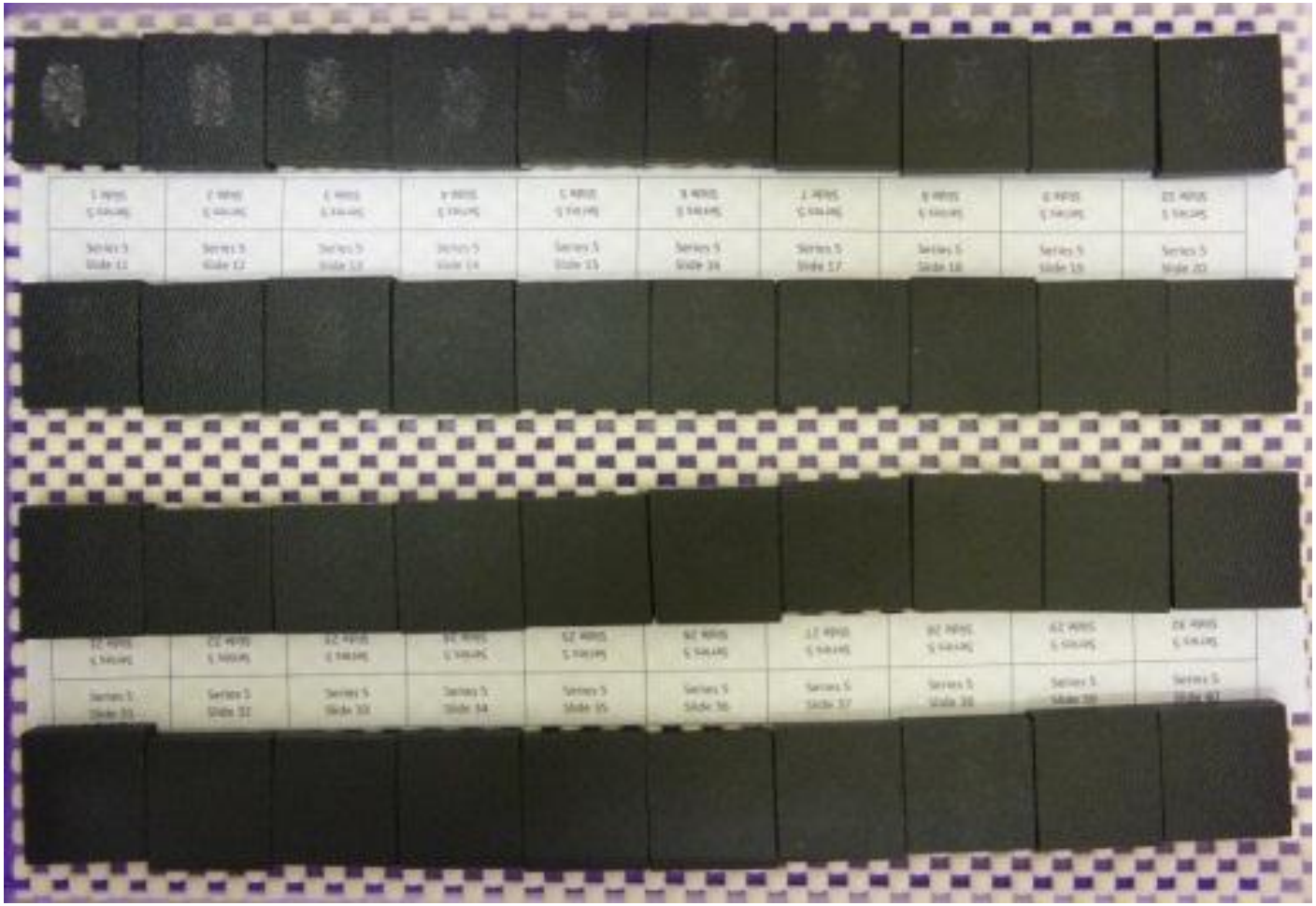
Method

- Dragon Skin® thumb cast from mould of thumb
- Supported by embedded disc attached to stainless steel rod
- Rod attached to Mecmesin force testing rig pressing thumb with 10N of force for 10s an approach speed of 5cm/s
- Initial loading by pressing into bulk
- Depletion series onto clean surface created
- Surface contamination studied by microscopy
- Samples extracted from surfaces and analysed by a validated LC-MS method

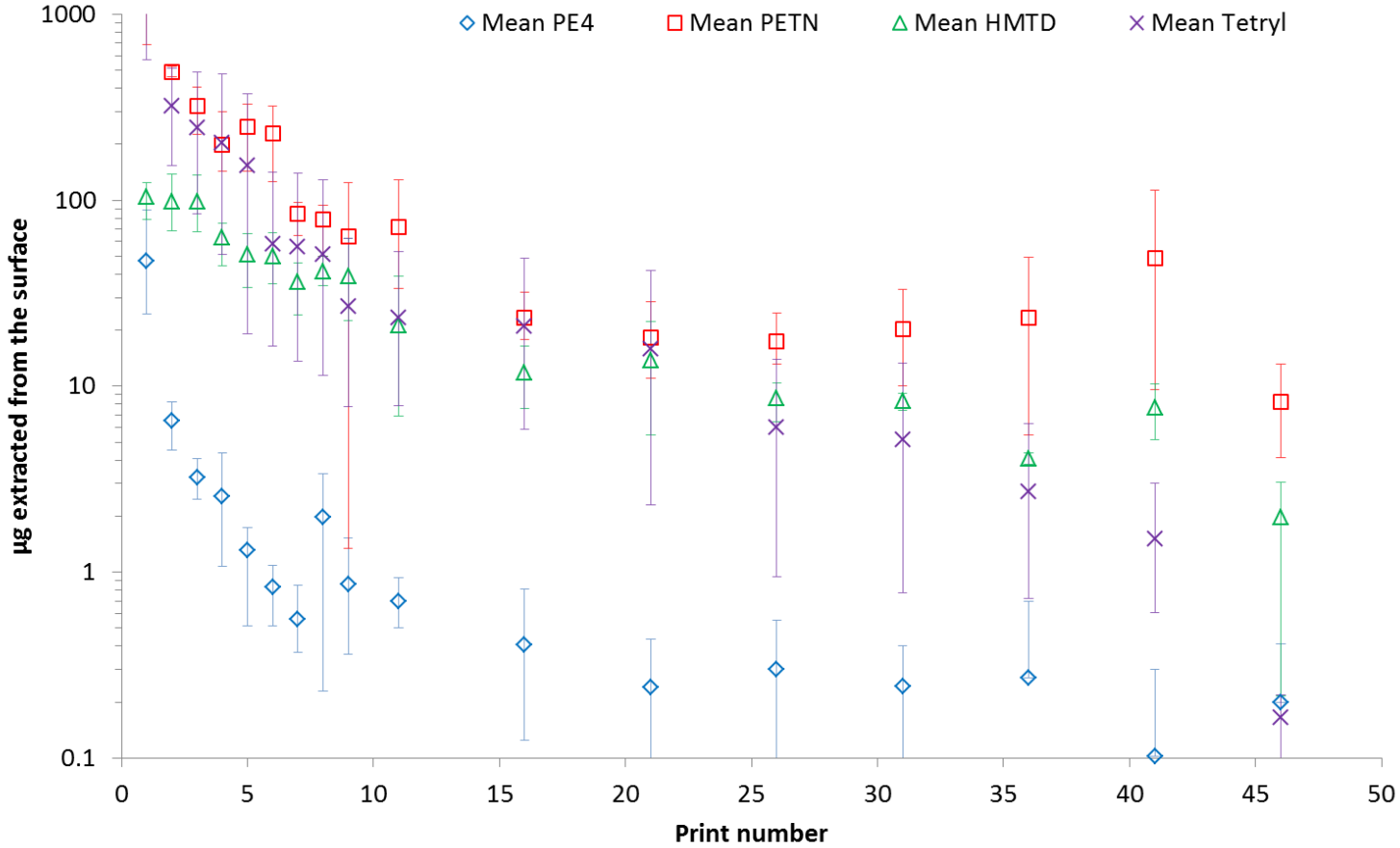


Deposition

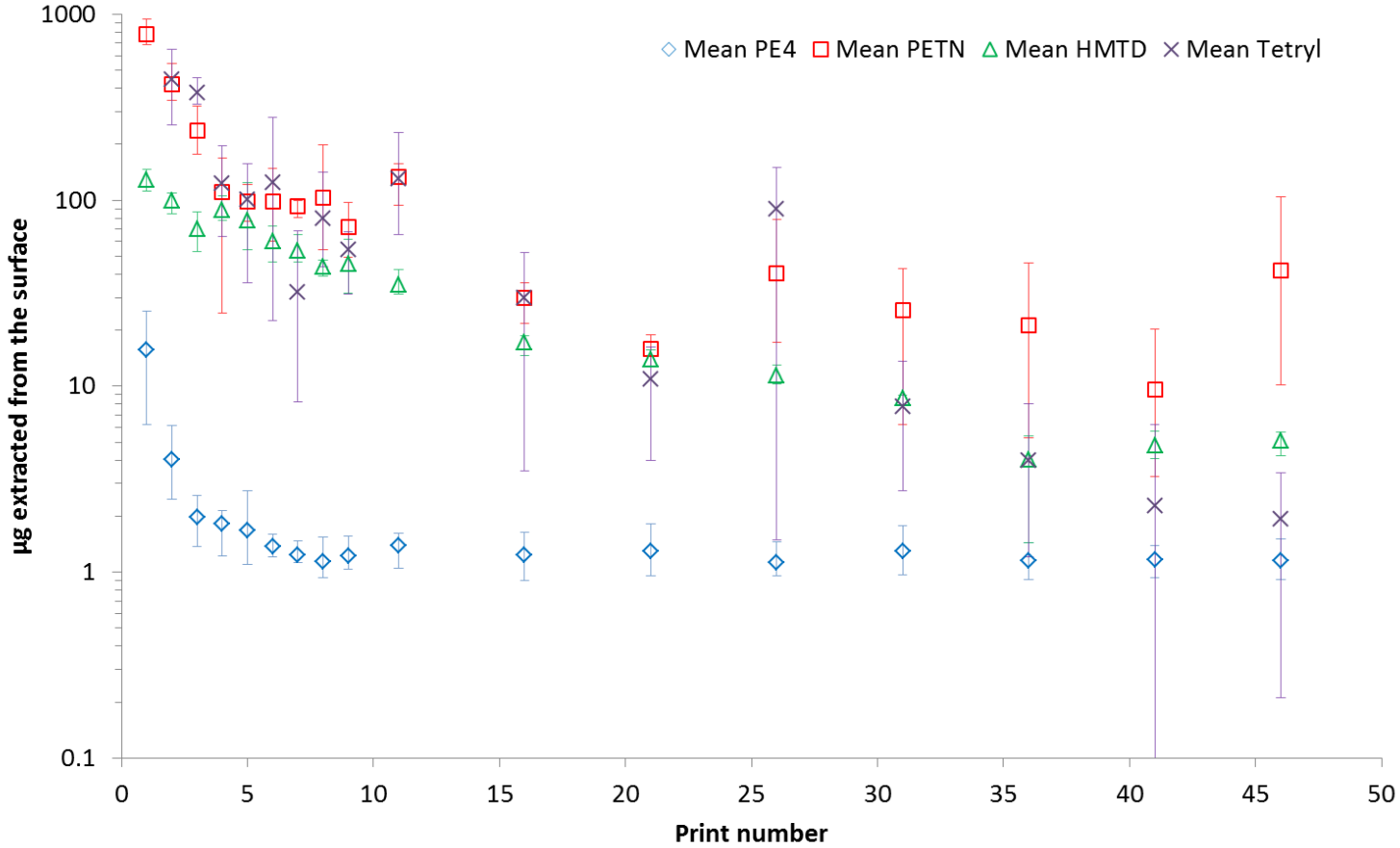
Deposition series



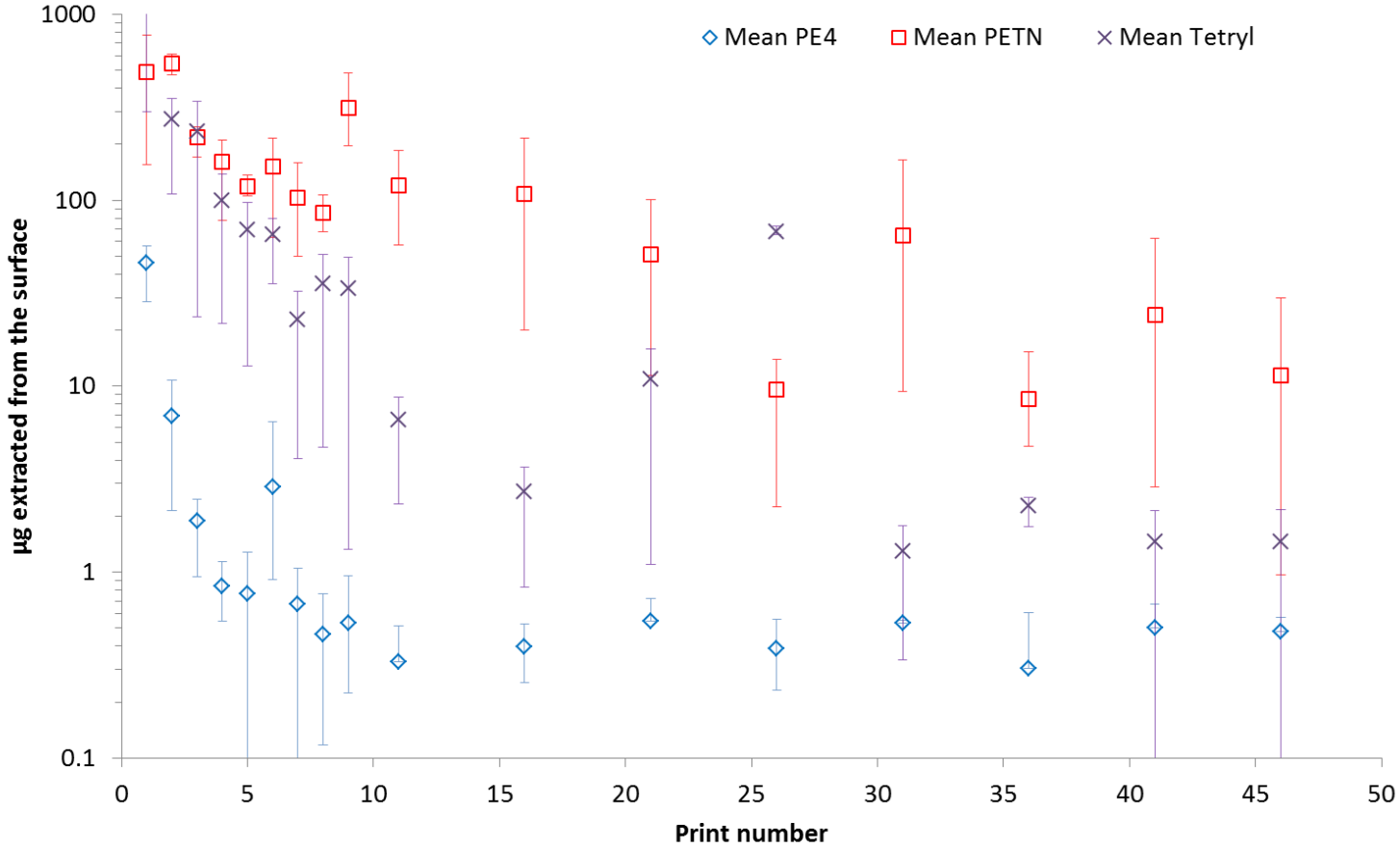
Contamination on glass



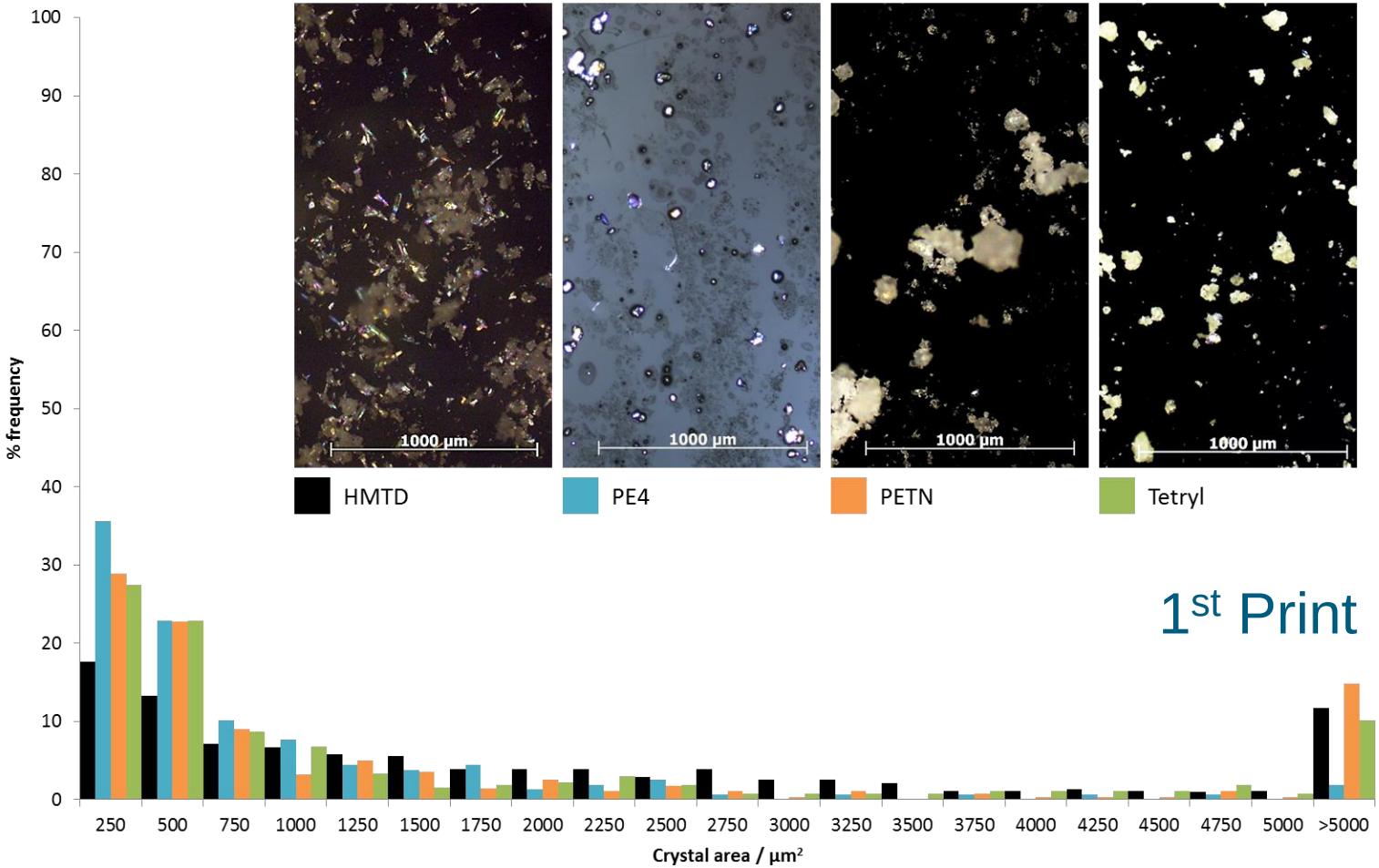
Contamination on ABS



Contamination on metal

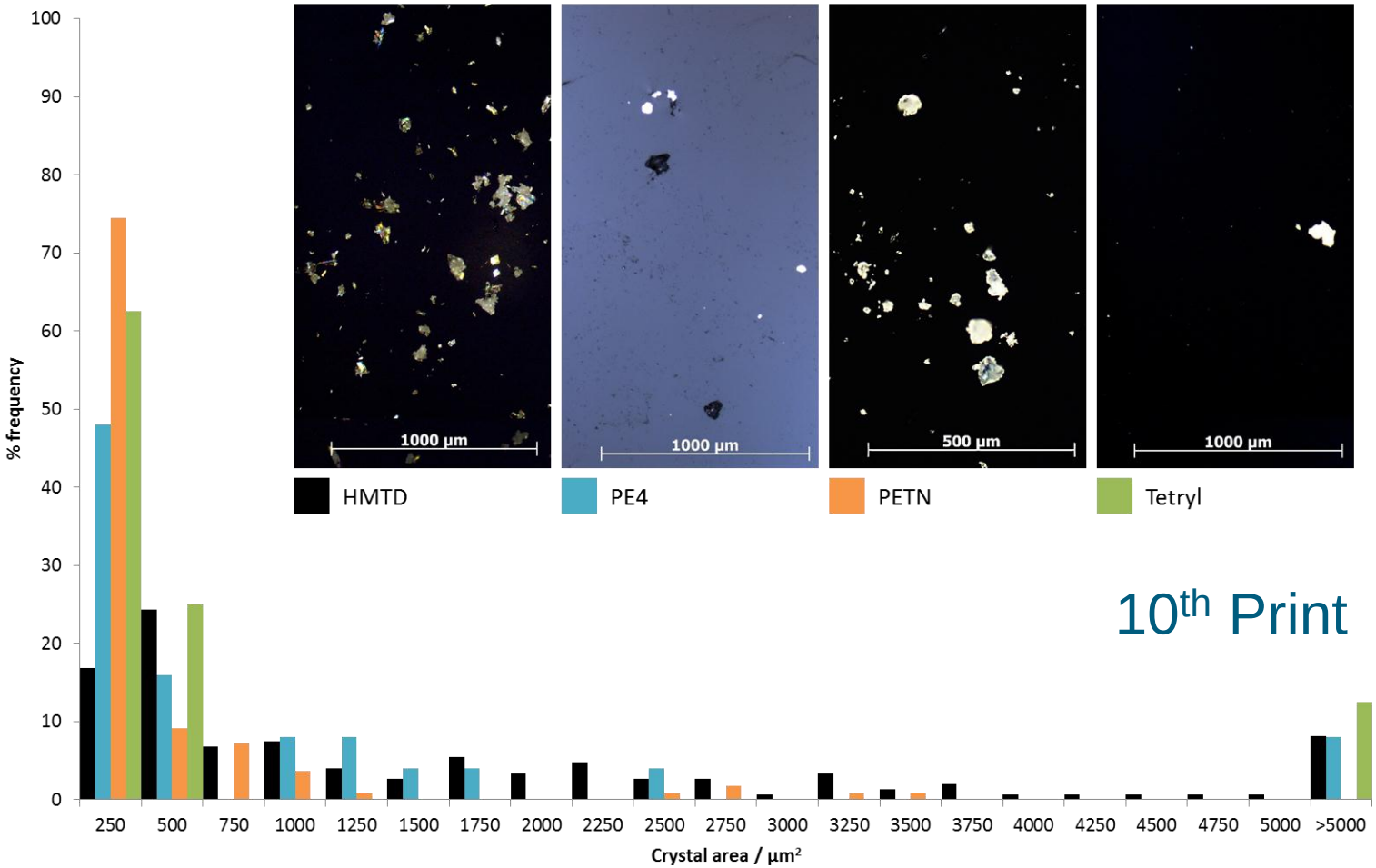


Particle sizing on glass

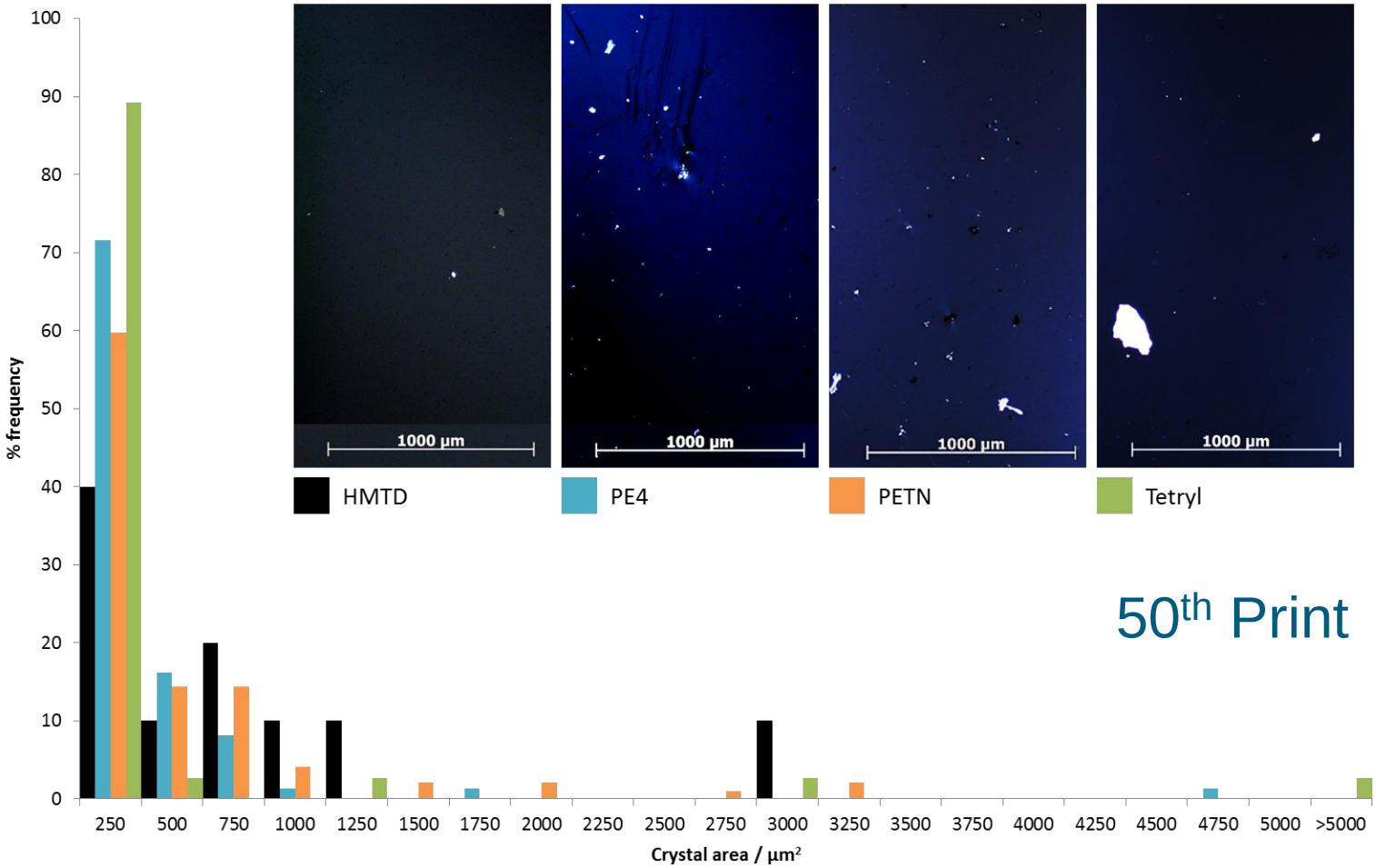


1st Print

Particle sizing on glass



Particle sizing on glass



50th Print

Results

- The crystalline explosives HMTD, PETN and Tetryl generally produce higher levels of absolute surface contamination than the plastic explosive PE4
- The most common particle size distribution for the 50th print for HMTD, PETN, Tetryl and RDX in PE4 is 0 - 250µm^2, but much larger particles are also present
  - NB Distribution will underestimate 0 – 250 um particles because some will be too small to visualise

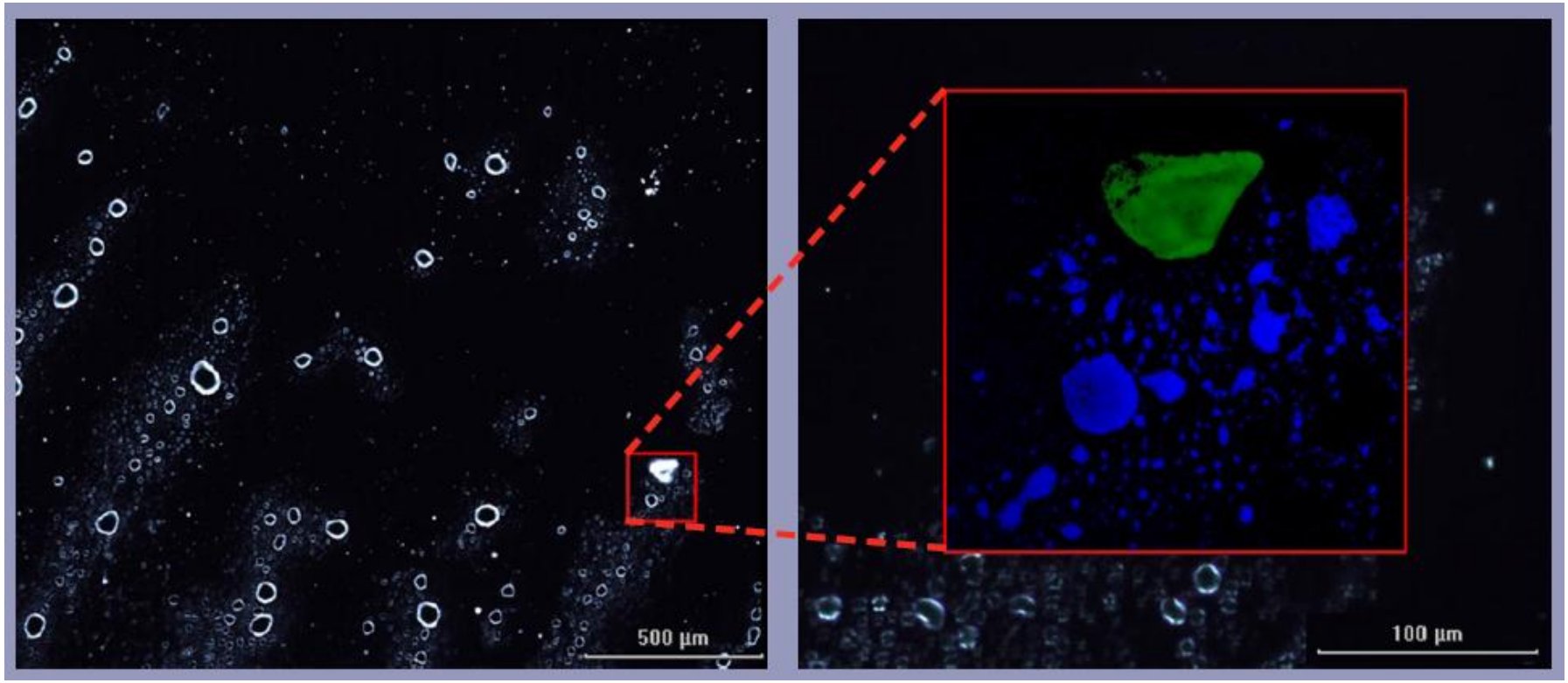
	RDX (PE4)	HMTD	PETN	Tetryl
Density / g cm^{-3}	1.82	1.57	1.76	1.73
1000 µm^2 particle mass / ng	43.3	37.3	41.9	41.2
250 µm^2 particle mass / ng	5.4	4.7	5.2	5.1

(Spherical particle approximation)

Raman chemical mapping

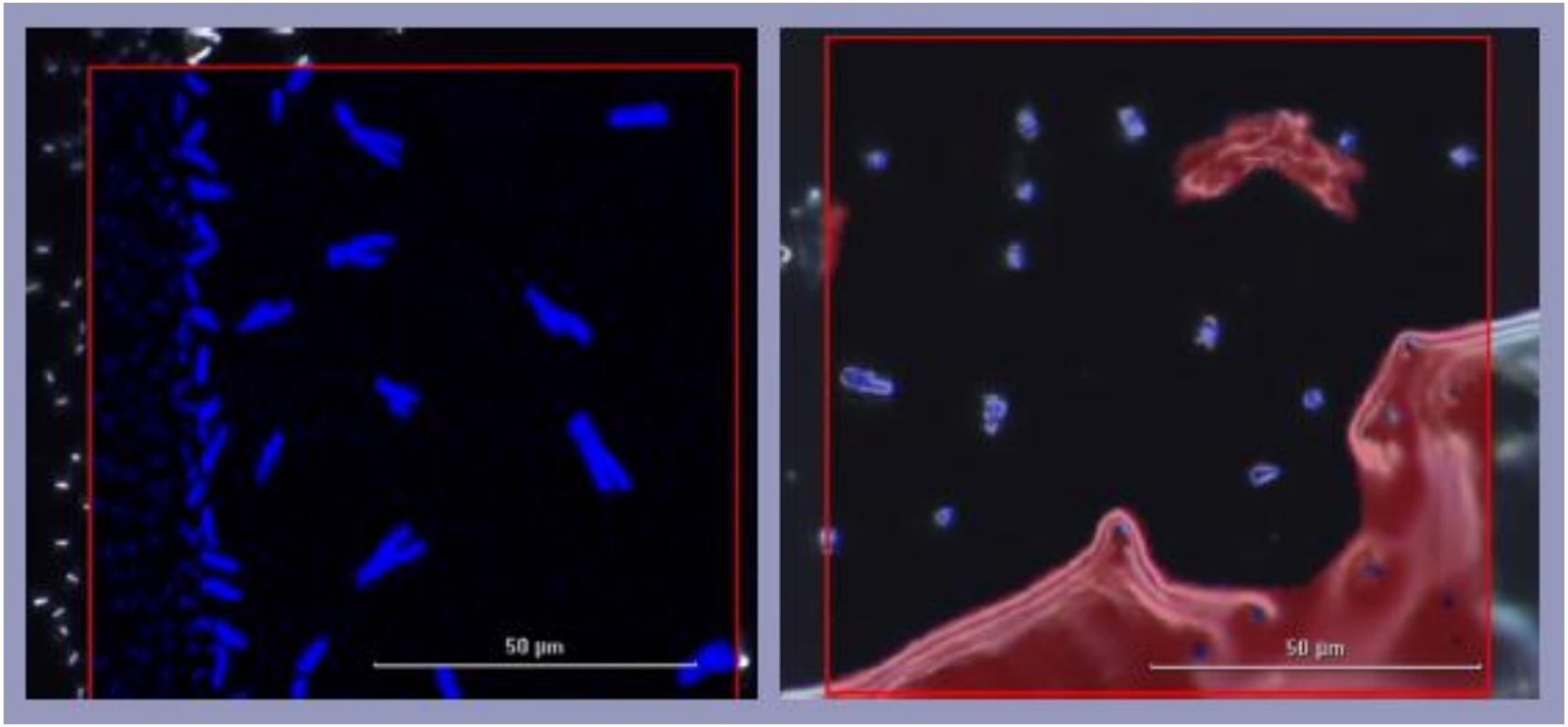
- Provides powerful automated capability to image and map chemical species
- Eg Thermo DXRxi

RDX print using sebum-coated synthetic thumb



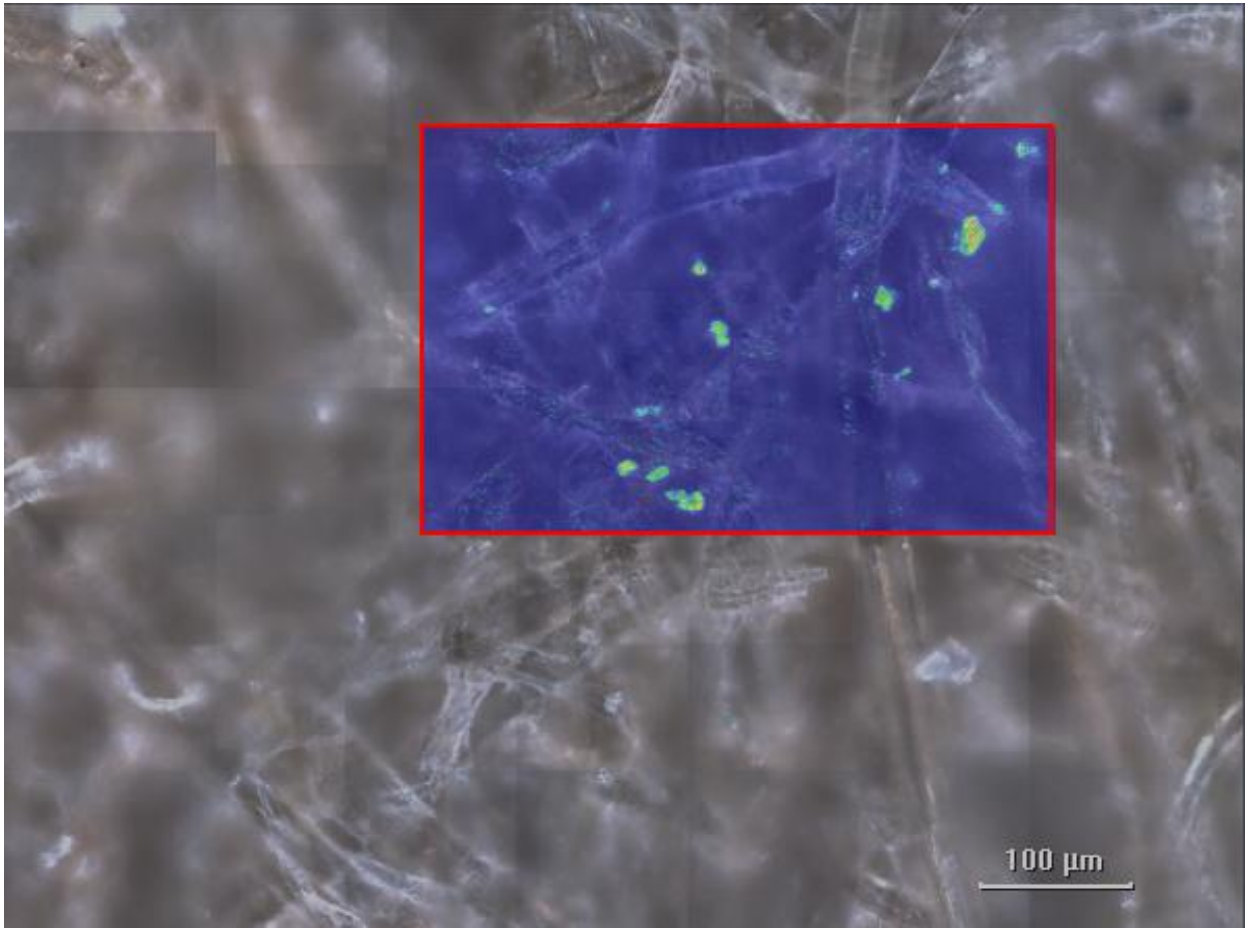
Optical image (left), Raman image (right), α-RDX = green, sebum = blue

Inkjet printed RDX



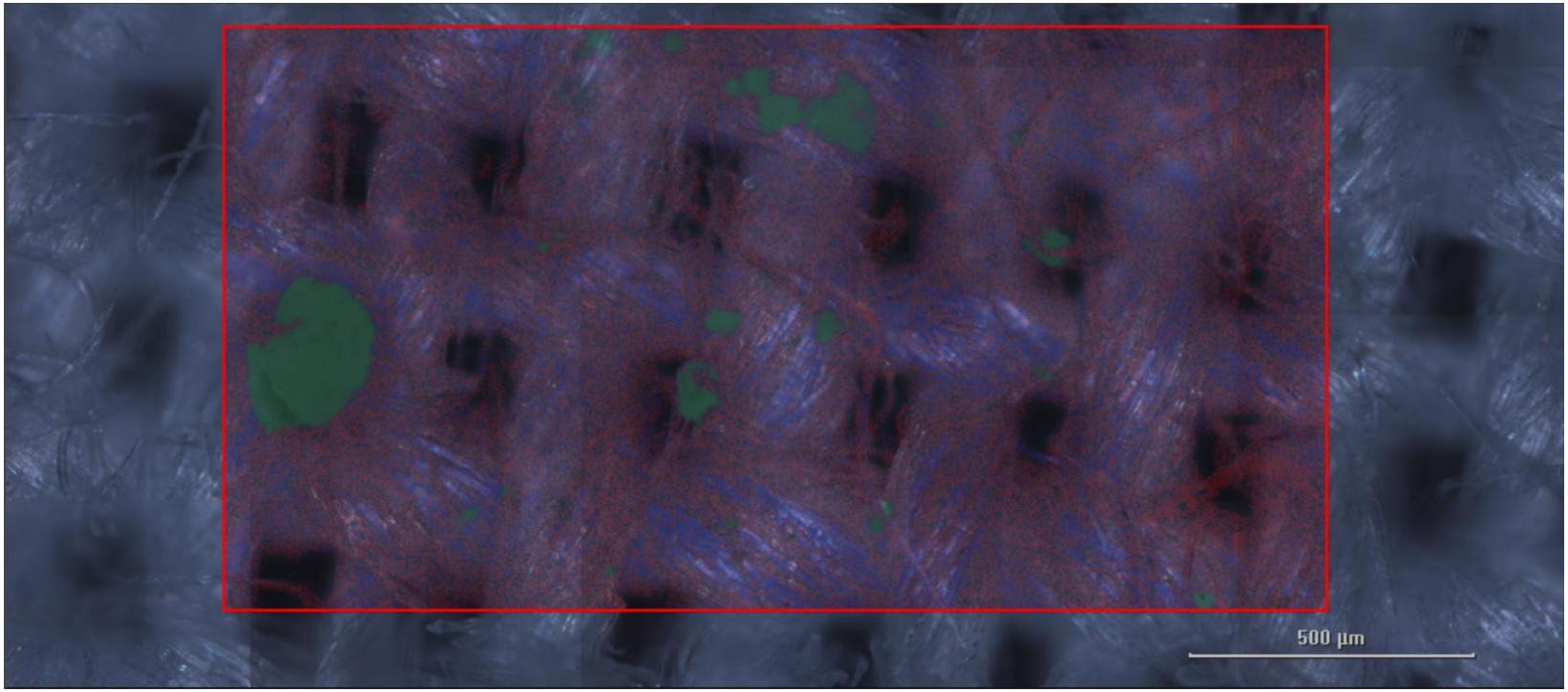
RDX ink showing β-RDX in blue (left), RDX and sebum ink showing β-RDX in blue and sebum in red (right)

PE4 thumb print on cardboard



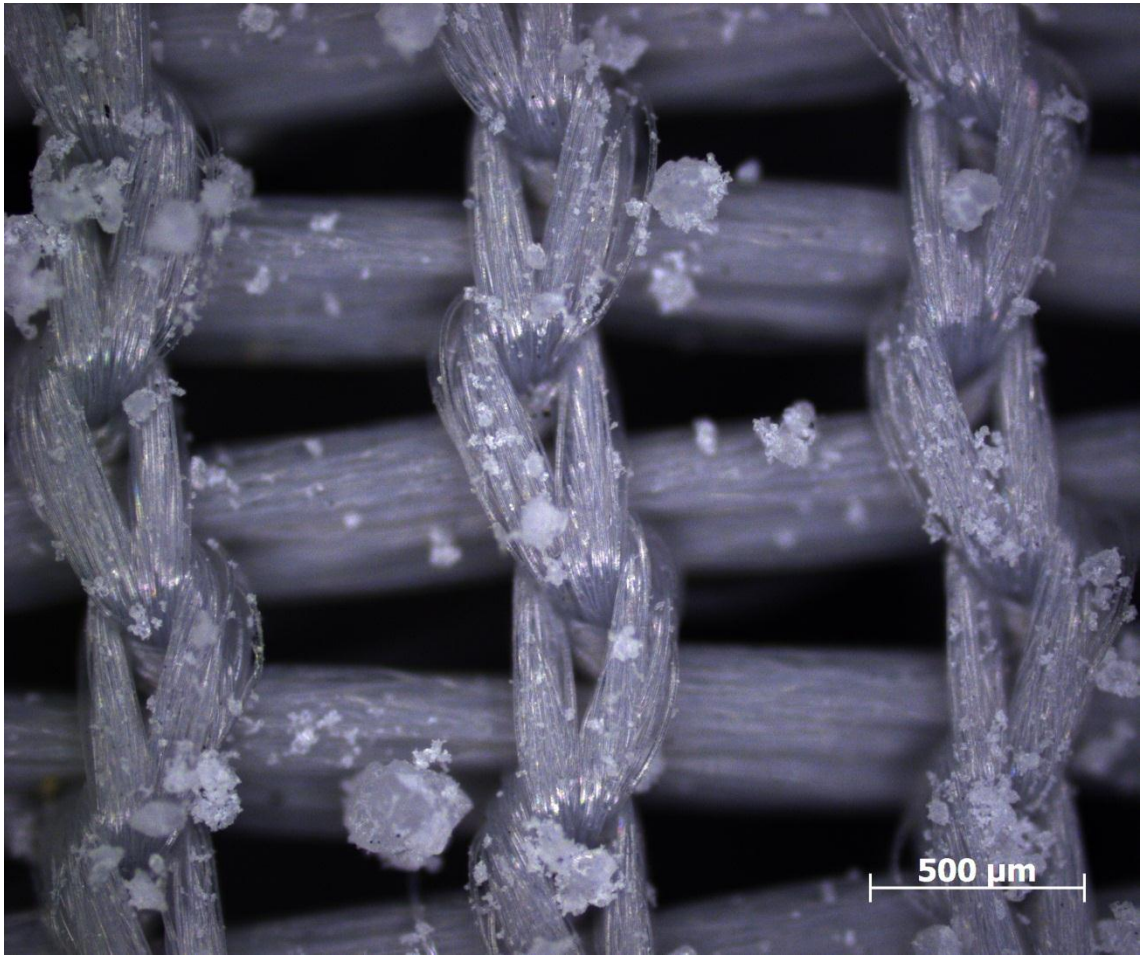
Inset shows Raman mapping of RDX and binder

PETN print on polyester-cotton



PETN = green, cotton = red, PET = blue

PETN thumb-print on sports shoe

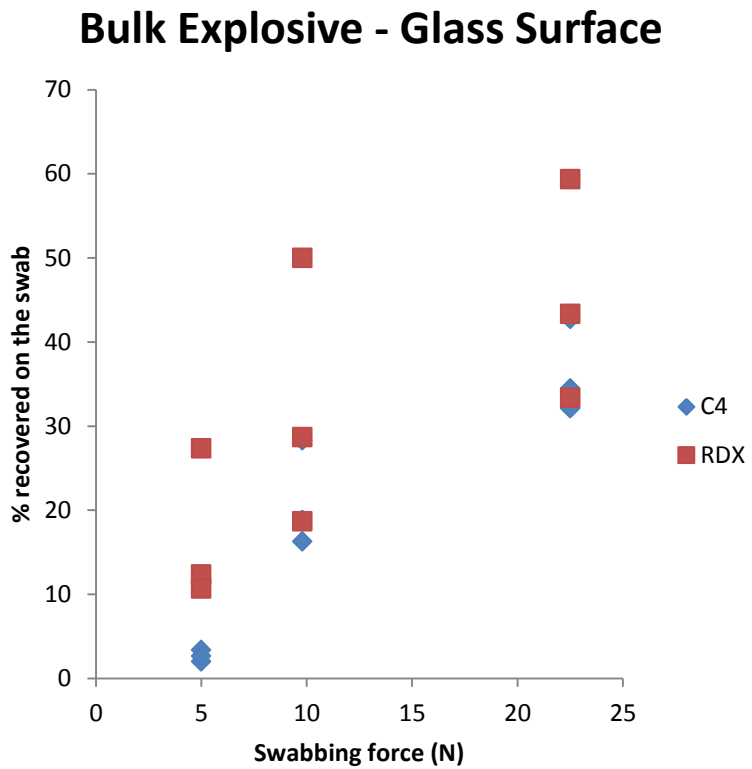


Automated swab sampling

- Crockmeter system designed to produce repeatable ‘rub’ of material across surface
- Range of forces can be applied and swabbing at two speeds
- Develop a protocol for sampling of explosive trace from surfaces

Automated swab sampling

- Crockmeter performed well under test conditions
- Swabbing effectiveness increases with force
- Smooth surfaces >> Rough surfaces
- Natural materials outperformed synthetics
- System mimics ‘expert manual user’



Conclusions

- The synthetic thumb force rig is a powerful characterisation tool
  - Not intended to produce *quantitative* standards, and cannot be used to do so
- Enabled the first comprehensive comparative study of crystalline and plastic explosives contamination
  - HMTD, PETN and Tetryl generally produce higher absolute levels of primary surface contamination than PE4
- Optical microscopy provides crucial insights into particle sampling challenges that quantitative analysis alone cannot
- Raman chemical mapping enables rapid characterisation and validation of printed quantitative standards

Ongoing work

- Additional explosives
  - RDX, TNT, C4 and Semtex
- Wider range of operationally relevant surfaces
  - e.g. cardboard, fabrics etc
- Secondary contamination
- The effects of cleaning
- The effects of transport and agitation
- The effect of moisture and ‘finger oils’

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