Institution: Loughborough University		
Unit of Assessment: UOA8 - Chemistry		
Title of case study: Transforming the forensic capabilities of criminal investigation with the *Recover* fingerprint development system		
Period when the underpinning research was undertaken: 2007-19		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Dr Paul Kelly	Reader in Inorganic Chemistry	1994-present
Dr Leanne James	Post-Doctoral Research Associate	June 2010-May 2011
Dr Roberto King	Post-Doctoral Research Associate	January 2009 – May 2014
Period when the claimed impact occurred: 2014-20		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact (indicative maximum 100 words)

While the development of fingerprints is a key forensic capability that has a long and effective history, there are situations where standard techniques prove impossible, such as those involving Improvised Explosive Device fragments, ammunition casings, or cleaned knives. Building on research that discovered how to develop fingerprints from metal surfaces that have been washed or subject to thermal and/or pressure related stress, Loughborough University developed the *Recover* system which has led to two impacts. 1) *Recover* has been installed and utilised by international police forces and agencies, and thus transformed their ability to retrieve evidence capable of identifying suspects in scenarios previously unresponsive to forensic technology. 2) Commercially available since late 2018, *Recover* has brought economic benefit for the global leader in forensic equipment manufacture.

2. Underpinning research (indicative maximum 500 words)

The retrieval of usable fingerprint data from many media is extremely problematic. This is important given that, despite the growth in technologies such as DNA analysis, the development of prints is still a key weapon in the forensic arsenal. One challenge comes when metal surfaces are subject to washing or stress. Ostensibly, removal of the physical print would appear to render recovery of evidence impossible. In practice, the presence of corrosion "signatures" for removed prints has led to imaging techniques being applied to retrieve the original print details; such techniques are tediously slow, however, and are limited in their ability to deal with convoluted surfaces.

Led by Kelly, the research team deployed its expertise in handling Group 16 nitrides, a class of compounds studied by only a handful of groups worldwide. Until the team's research, tetraselenium tetranitride was considered too difficult to handle due to its explosive nature. The team focused on its conversion to the long sought-after compound diselenium dinitride, and this was successfully accomplished [R1]. The research also required investigations into the sulfur analogue, and in 2007 Kelly's team showed for the first time that its polymerisation to (SN)x molecular wires within zeolite channels can occur [R2].

It was during the latter work that serendipitous observations on the ability of the polymerisation process to visualise latent fingerprints were first made. The two original papers which reported these results ([R3, R4]) highlighted the unexpected, but nevertheless welcome, observation that the process develops prints from a range of surfaces. The first of these detailed how the preparation of disulfur dinitride (S_2N_2) was refined and made as safe as possible within a custom-built apparatus (that still employed the standard, hazardous, cracking of S_4N_4). This was based on previous set-ups but designed specifically for our work and built through in-house glass-blowing capabilities. The study revealed successful print development on some fabrics, mixed metal/plastic surfaces (such as fired shotgun cartridges) and paper. The fact that the latter results included polymerisation on inkjet traces confirmed just how sensitive the technique could be to surface changes.

[R4] included metals where the actual fingermark material had been removed. Crucially, the team found that only a short timescale for the initial presence of the print on a metal surface was required. Thus a few minutes on brass (or tens of minutes on steel) followed by thorough washing, drying and then treatment, revealed prints with detail down to the level of pores within the print. It was apparent at this stage that the corrosion signatures left behind by prints were driving polymerisation and hence rapid imaging, and the potential of the technique was clear. Further investigation tested limitations on exposure times, reaction chamber volumes, sample preparation and alternate means of S_2N_2 production. These were detailed in reports to DSTL (then funding the work) and subject to security classification. The research continues to demonstrate *Recover*'s efficacy and commercial capabilities [R5].

3. References to the research (indicative maximum of six references)

[R1] S.M.Aucott, D.Drennan, S.L.M.James, P.F.Kelly and A.M.Z.Slawin,"The reaction of $[Bu_4N]_2[Pd_2Br_6(Se_2N_2)]$ with [14]aneS_4; an effective source of the diselenium dinitride unit", *Chem. Commun.,* 2007, 3054-3056. DOI: 10.1039/b707450f

[**R2]** R.S.P.King, P.F.Kelly, S.E.Dann and R.J.Mortimer, "Rapid polymerisation of S_2N_2 within Na-ZSM-5 channels"*, Chem. Commun.,* 2007, pp 4812-4814. DOI: 10.1039/b711290d

[R3] P.F.Kelly, R.S.P.King and R.J.Mortimer, **"**Fingerprint and inkjet-trace imaging using disulfur dinitride**",** *Chem. Commun.***,** 2008, pp 6111 - 6113. DOI: 10.1039/b815742a

[R4] S.M.Bleay, P.F.Kelly and R.S.P.King, "Polymerisation of S_2N_2 to (SN)x as a tool for the rapid imaging of fingerprints removed from surfaces". *J. Mater. Chem.***,** 2010, **20**, 10100-10102. DOI: http://doi.org/10.1039/c0jm02724c

[R5] S.M.Bleay, P.F.Kelly, R.S.P.King and S.G.Thorngate, "A comparative evaluation of the disulfur dinitride process for the visualisation of fingermarks on metal surfaces" *Sci. Justice*, 2019, **59**, 606-621. DOI: 10.1016/j.scijus.2019.06.011

[R4] was supported by a 2009 grant from The Government Communications Planning Directorate "Assessing the Forensic Use of Disulfurdinitride" (£59,649) while subsequent development was started via 2011 DSTL funding "Fingerprint development from challenging surfaces" (£93,363). The first four works appear in peer-reviewed RSC journals that are not specific to forensic matters, reflecting the fact that the discovery stemmed from work that originally looked at fundamental chemistry of chalcogen nitrides. The results from [R3] and [R4] led to an award of Best Oral Presentation at the ANZFSS conference in Sydney 2010 and, as noted, to ongoing support from DSTL, the results of which were detailed in classified reports.

4. Details of the impact (indicative maximum 750 words)

After refinement of the technique and declassification, the Loughborough team and DSTL's commercial arm *Ploughshare Innovations* invited tenders for a commercial version. This was awarded to Foster & Freeman Ltd, forensic manufacturers with a global presence. They in turn designed the hardware to house the chemistry, now under the *Recover* banner. In addition to this **pathway to impact**, the original publications garnered a lot of interest both from forensic practitioners and general science news reports (e.g., in *Nature Chemistry*, RSC's *Chemistry World*). The research led to the following impacts.

1. Improved forensic fingerprint recovery capabilities and practice internationally

Our research on the use of S_2N_2 polymerisation on substrates to act as a forensic tool has transformed the ability of forensic professionals to develop fingerprints from crime scene evidence and overcome the inability of standard techniques to obtain this kind of crucial information. As reported in 2017 by the UK government the (then) Minister for Defence Procurement, Harriett Baldwin, attending the formal announcement of the start of commercialisation, stated that

> "Whether it's used on a foreign battlefield or a British crime scene, this pioneering fingerprint technology will make it much harder for criminals to escape justice" [S1].

In an independent study of *Recover*, the Royal Canadian Mounted Police highlighted the inability of standard techniques to obtain fingerprint evidence from ammunition casings retrieved from shooting incidents, indicating the clear need for new technology:

> "For police officers worldwide this is a source of frustration because often a handful of spent cartridge cases is the only physical evidence associated with serious gang-related crimes such as homicides" [S2].

Recover has been used to directly address the issue of ammunition by Toronto Police who undertook a study in which casings from actual crime scenes in the city were collected over the course of a month and then processed. Print details were retrieved from just under 10% of the exhibits. They put this in perspective by noting that in the previous five years of experience in processing casings by other means at their disposal, the two investigators involved had "yet to see any ridge detail on crime scene cartridge case evidence, despite having looked at many thousands of examples". As they note,

> "the technology has positively impacted our examination of cartridge cases. We look forward to continuing to utilize *Recover* and optimize our procedure to assist in our ongoing efforts to combat gun crime capabilities." [S3]

Such confidence is backed up by the RCMP work that revealed (in this case in tests not involving crime scene evidence) a success rate of 12 % (fully identifiable, with a further 19% showing comparison level detail) in samples touched before loading and firing [S2]. Investigators at Orange County Sheriff's department in California have also used *Recover* to allow DNA swabbing to be undertaken concomitantly on exhibits as well. This reflects the fact that as the system works on corrosion signatures, the item can be cleaned/swabbed *before* processing.

> "That was just the game-changer for me, that said, we have to have this…and now, because of the less-intrusive *Recover* system, the Forensics Unit can also gather DNA evidence from that object" [S4].

The effectiveness of the technology is evidenced by the RCMP, who adopted the system to retrieve identifiable prints from detonated Improvised Explosive Devices, an aim which was at the heart of original DSTL interest both from military and civilian anti-terrorism perspectives. After cleaning (post-detonation using commercial explosives) they noted identifiable marks on the metal remains, even from "depleted" prints which had been deliberately laid down with less residue.

Finally, in addition to IED and ammunition work, *Recover* has also been used to extract fingerprint data from knives. This is well illustrated in work by Foster & Freeman as revealed in the commercial brochure for *Recover,* a document that also highlights the design of the device itself [S5].

Impact 2: Economic benefit for Foster & Freeman Ltd

The commercialisation of *Recover* has been delivered by Evesham-based Foster & Freeman Ltd , who are global leaders in forensic equipment manufacture, exporting their products to over 80 countries in 2018, and who designed the final version of the unit after licensing from DSTL's *Ploughshare Innovations.* The resulting system fully utilises Loughborough's results and expertise, in a stand-alone unit that is readily incorporated into basic lab set-ups and requires minimal specialist training.

Commercial returns from *Recover* have positively impacted on Foster & Freeman's business, with orders for the device having been taken since the start of 2019. Clients worldwide, comprising a disparate range of police forces and government agencies from a dozen countries, have purchased the unit (which is priced at circa £40k/$60k) reflecting both the effectiveness and the ease of use of the system. Added commercial return has stemmed from extra production of imaging systems to be used alongside the units. Deployment of *Recover* not only hinges on the instrument itself but also on the chemical precursor employed, which is custom made by Foster & Freeman in labs on the Loughborough University Science and Enterprise Park, a dedicated site for industrial collaboration and spin-outs. This has allowed the company access to chemical capabilities previously unavailable to them. As noted by CEO Bob Dartnell:

> "As a result, the company expect sales of *Recover* and the *Recover* precursor chemical (now being produced on-site at Loughborough), to make a significant contribution to its economic growth, following a strong uptake to the technique and the capabilities it offers." [S6]

Overall, our work has seen serendipitous observations being built on, developed, and refined at Loughborough into a commercial end-product that provides law-enforcement agencies worldwide with a unique capability.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[S1] www.gov.uk press release: '"New fingerprint chemical to make it much harder for criminals to escape justice", Defence Minister announces'. (2017)
[S2] Royal Canadian Mounted Police study published in Journal of Forensic Identification. (2020)
[S3] Testimonial letter from Toronto Police Service, Forensic Identification Services. (2020)
[S4] Orange County Sheriff's Dept video release showing a description of *Recover's* capabilities. (2020)
[S5] Foster & Freeman Ltd *Recover* brochure demonstrating *Recover's* design and capabilities. (2018)
[S6] Testimonial letter from Foster & Freeman Ltd. (2020)