

Impact case study (REF3b)

Institution: University of Leicester
Unit of Assessment: 8 Chemistry
Title of case study: New crime detection technologies for law enforcement agencies
1. Summary of the impact <p>Fingerprints remain the most conclusive means of linking an offender to a crime scene. Conventional visualization techniques require the sweat deposit to be largely retained and thus have low success rates. We have developed technologies to visualize fingerprints on metals after the sweat deposit has been substantively lost, deliberately removed or environmentally degraded. One technology uses microscale corrosion caused by the sweat deposit; it has been used in solving gun crimes. A second technology uses trace residual sweat deposit as a template to direct electrochromic polymer deposition to bare metal between the ridge deposits. These have been adopted in the new Home Office Fingerprinting Manual and licensed to UK forensic providers.</p>
2. Underpinning research <p>Fingerprint recovery rates on ballistics are extremely low due to vaporisation of sweat deposits during the firing process. Motivated by this, Dr John Bond (then working at Northamptonshire Police but also an Honorary Fellow of the University since 2007) and Professor Robert Hillman undertook collaborative research blending interfacial science and forensic expertise (2008-13). Their shared interests in interfacial chemistry and surface analysis were focused on characterization of thin films generated by and/or directed by fingerprint deposition. Fundamentally, this presents materials imaging challenges in terms of 3D control of surface composition and properties at micro- and nano-scales. With adequate control of the spatial resolution of these processes, the uniqueness of the fingerprint can be preserved and captured via permanent surface structures attributable to contact between the finger and the substrate. This strategy was explored and exploited in two ways: (i) using <i>localised corrosion under</i> the fingerprint ridges to generate surface oxides with semiconducting properties and (ii) using the fingerprint deposit as an insulating (inert) template to direct electrochemically-driven deposition of <i>electrochromic polymers</i> to regions of bare metal <i>between</i> the fingerprint ridges.</p> <p><i>Localized corrosion strategy:</i> Bond and Hillman showed that fingerprint deposits on metals could, on relatively short timescales, generate sufficient corrosion for the fingermark to be visualized long after the fingerprint residue was removed or lost. Exploitation required understanding and optimization of the underlying interfacial processes. Topological and compositional imaging (from micro- to nano-scales) by Hillman provided morphological insights into fingermark development, veracity and sharpness [1,2]. Application to brass surfaces (representative of bullet casings) revealed that oxide corrosion products formed Schottky barrier diodes [1], whose electronic properties could be exploited to bind coloured particulates electrostatically. Materials property studies [3] revealed that Schottky barrier formation requires dominance of one corrosion product (copper oxide or zinc oxide); chloride concentration is a key determinant. Where neither oxide dominates, optical interference effects attributable to the oxide layer permit non-invasive visualization by colour mapping.</p> <p><i>Electrochromic polymers:</i> Hillman exploited the insulating nature of the fingerprint deposit as a “mask” to direct the electrochemical deposition of coloured electroactive polymers onto the bare metal between the ridge deposits. The key fundamental feature is that minute (nanometre) amounts of insulating material can (locally) prevent the electron transfer required for electropolymerization, contrasting favourably with the larger amounts of residual deposit required for the physical /chemical binding strategies of conventional latent fingerprint enhancement methods (e.g. powders and cyanoacrylate polymerization). In a totally novel extension, the use of electrochromic polymers (from thiophene-, aniline- or pyrrole-based monomers) permits subsequent manipulation of optical density and colour via applied potential [4,5], providing excellent contrast on metals (Au, Pt, Pb, Ni, steel, brass) with diverse surface chemistries, optical</p>

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properties and operational significance (precious objects, weapons, tools, metal theft). The performance of the electrochromic technology has been explored for fingerprint sweat deposits on metal subjected to diverse environmental conditions (heat, immersion in water, soap and solvent treatment) and in operationally significant scenarios found to be favourable over conventional methodologies. *(Image right shows a fingerprint on stainless steel, left for 7 days under ambient conditions before treatment involving electrodeposition of an electrochromic polypyrrole film).*



3. References to the research

- 1) Imaging fingerprint corrosion of fired brass shell casings, J.W. Bond, Rev. Sci. Instrum., 80(7), 2009, 075108 DOI: 10.1063/1.3183578
- 2) On the electrical characteristics of latent finger mark corrosion of brass, J.W. Bond, J. Phys. D, 41(12), 2008, 125502. DOI: 10.1088/0022-3727/41/12/125502
- 3) High resolution imaging of latent fingerprints by localized corrosion on brass surfaces, A.J. Goddard, A.R. Hillman, J.W. Bond, J. For. Sci., 55(1), 2010, 58-65. DOI: 10.1111/j.1556-4029.2009.01217.x
- 4) Electrochromic enhancement of latent fingerprints on stainless steel surfaces, A.L. Beresford, A.R. Hillman, Anal. Chem., 82(2), 2010, 483-486. DOI: 10.1021/ac9025434
- 5) Electrochromic enhancement of latent fingerprints by poly(3,4-ethylenedioxythiophene), R.M. Brown, A.R. Hillman, Phys. Chem. Chem. Phys., 14(24), 2012, 8653-8661. DOI: 10.1039/c2cp40733g
- 6) Physical characterization and recovery of corroded fingerprint impressions from post-blast copper pipe bomb fragments, J.W. Bond, J. Forensic Sci. 58, 2013, 776-781.

4. Details of the impact

Gun crime is on the increase across the world. Conventional technology to visualise fingerprints on spent shell casings produced poor results because of vaporisation of the sweat deposits during the firing process. Fingerprint recovery rates were traditionally low (<10%). The UoA's new technology solves this problem, revealing previously undetectable fingerprints on metal objects.

These technologies have economic and societal impact of substantive reach and significance:

- improved fingerprint recovery rates which have helped police forensic departments worldwide solve recent homicide investigations and re-open previously closed "cold" cases.
- development of new forensic products by commercial partners, now being sold to forensic practitioners worldwide, stimulating the economy.
- new policies and processes for forensic practitioners, which are now standard operational procedure for police forces across the UK.

1. Helping to tackle gun crime and further homicide investigations

The **corrosion** enhancement technology has been used in many homicide investigations including Kingsland, GA; Killeen, TX; North Richland Hills, TX; Tinley Park, IL; Marin County, CA [1,2]. It has been used to examine evidence in more than 100 criminal cases in the US, UK and Europe, including re-examination of evidence in a number of "cold" cases. In 2012, evidence from the corrosion enhancement technique was heard [**Bond**] and accepted by the Superior Court of the State of California, setting a precedent in the US legal system [1,2].

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2. Development of new forensic products

a) Consolite Forensics

The *localised corrosion* enhancement technology has been patented [3] and commercialised with UK industrial partner Consolite Forensics [4] through consultancy (**Bond** and **Hillman**; 2011-2013). The research helped the company develop the CERA LT, a new optical system to recover fingerprints from gun cartridges, offering a quick and simple to use product with a fully integrated high resolution camera. The product is now commercially available for £50,000 per unit. The company launched the product in the summer of 2013, making its first sale to the Granite Falls Police Department, Michigan USA. The product is currently being trialled in other crime labs worldwide.

b) Foster and Freeman

Following patent filing [5], a similar commercialisation partnership has been adopted to transfer the *electrochromic polymer* film technology, with one of the world's foremost forensic science equipment suppliers, Foster and Freeman [6]. A prototype instrument developed via this partnership was undergoing testing as of July 2013. The immediate target is to improve fingerprint detection on stainless steel, a common material for knives; knife crime is a major area of concern in the UK where guns are less readily available.

3. New processes, procedures and training for forensic practitioners

Historically, gun crime has been less prevalent in the UK than the US, but a range of terrorist, drugs and organized crime threats make this a key target for UK policing. Widespread uptake of the *electrochromic polymer* fingerprint enhancement technology in the UK will benefit from interactions with the Home Office (formerly HOSDB, now CAST). As a result, both the corrosion and the electrochromic technologies have now been incorporated as standard operational practice for police forces across the UK through inclusion in the Home Office Fingerprint Manual [7,8]. The research has given forensic practitioners new options for the investigation of crime. The substantive impact of the *localized corrosion* technology has been underpinned by **Bond** providing consultancy training on the technology for practitioner organisations (2009-2013) at: Home Office Biometrics Group; European Network of Forensic Science Institutes; National Forensic Academy (Knoxville, TN); Southern Californian Association of Fingerprint Examiners, Californian Department of Justice; Santa Clara County Crime Laboratory, California; American Association of Crime Scene Reconstruction; No. 1 Forensic Institute, Beijing, China, with approximately 150 practitioners trained at each of the seven events, reaching more than 1,000 in total.

Additional technology transfer activity and widening impact

Collaboration with the US Naval Criminal Investigative Service (NCIS) (2012-13) by **Bond** involved pseudo-operational trials of pipe bomb fragments being sent to the University for fingerprint analysis and the identification of fingerprints using these techniques. This represents a natural expansion of the *localised corrosion* technology from shell casings to other metals that have been subject to environmental extremes, such as bomb fragments.

Dissemination has included Regional Development Agency Awards (Innovation Fellowship and Follow-on Fund), practitioner-based conferences (International Fingerprint Research Group: Sweden (2011) and Israel (2013); Home Office meetings (2010-13)), extensive media coverage [9,10] (including America's Most Wanted and CrimeWatch) and briefings to Police Forces (invited events at the University 2011, 2012 and 2013, involving the Forensic Science Special Interest Group of the Technology Strategy Board).

Fingerprint corrosion on metal was recognised by Time Magazine as one of the 50 best inventions of 2008 [9] and by BBC Focus Magazine (2009) as one of the inventions most likely to change the world in 2009 and its description by a detective from the North Richland Hills Police Department as "The new DNA" [1].

The interdisciplinary nature of this field has been recognized via the establishment (2012) of the Alec Jeffreys Forensic Science Institute (AJFSI), led by Chemistry. This Institute has been created to fulfil the need to bring together academics across diverse disciplines to tackle current and

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emerging problems in forensic science.

5. Sources to corroborate the impact

1. Contact details for Detective at North Richland Hills Police, Texas, USA
2. Contact details for Inspector at Marin County District Attorney's Office, San Rafael, CA. USA
3. Patents: GB2008/001261 Fingerprint detection method and apparatus (2008). GB 0819445.8 Fingerprint detection (2008)
4. Contact details for Managing Director of Consolite Forensics and also <http://www.consolite.co.uk/Forensics/CERALTmachine.html>
5. Electrochromic latent fingerprint enhancement patent: PCT application number: PCT/GB2010/050479 (filing date 22 March 2010).
6. Contact details for Managing Director of Foster and Freeman (Evesham, Worcs)
7. Contact details for Home Office Scientific Development Branch, UK Home Office
8. Fingerprint Manual: <https://www.gov.uk/government/publications/fingermark-visualisation-manual-notice-of-publication>
9. http://www.time.com/time/specials/packages/article/0,28804,1852747_1854195_1854178,00.html:
10. <http://www.bbc.co.uk/news/science-environment-23136589>