Institution: University of Durham

Unit of Assessment: 9/Physics

Title of case study: Unique materials signature identified from nanotechnology research leads to spinout company to combat forgery **(Ingenia)**

1. Summary of the impact

Fundamental research in Durham Physics Department in 2002-4 demonstrated that the nanoscale structure of materials gives a unique signature from its effect on the diffuse scattering of laser light. Paper has a large scale stochastic pattern from the wood fibres which is distinctive enough to allow identification of the manufacturer, while small scale random variations can uniquely identify an individual sheet. This technique can be used to combat forgery by 'fingerprinting' documents, packaging and even gold bullion. The impact from this intellectual property is exploited through a spinout company, *Ingenia technology*, which has won multiple awards.

2. Underpinning research

The magnetism group in Durham Physics Department focuses on thin film materials for spintronic devices. Such devices can provide a non-volatile alternative to standard silicon memory chips, but the polarity of the magnetic domains is difficult to switch reliably due to stochastic fluctuations in the size of the domains. Russell Cowburn joined this group as a lecturer in October 2000, and worked on characterising these fluctuations in magnetic structures as a prerequisite to controlling them [e.g. 1]. He used laser speckle imaging to determine the characteristic size scale of the magnetic domains, where each point on the illuminated surface acts as a secondary source of diffuse spherical waves which interfere to produce a speckle pattern whose properties are determined by the surface roughness over the entire illuminated surface (Fig 1). One day the memory chip being tested fell off its paper backing, and the laser hit the paper instead. Prof Cowburn realised that the speckle pattern (Fig 2) that resulted from the paper fibres (Fig 3) had all the right characteristics for a security device as it depended on the random, and hence unique, alignment of nanoscale structures over the macroscopic size of the sample.

Cowburn's team at this time consisted of Atkinson (staff member in Durham Physics 2001-present), Allwood (postdoc in Durham Physics 2001-2005, then moving to Sheffield), Petit and Xiong (postdocs in Durham Physics 2001-2005, then moved to Imperial), Buchanan (PhD student and postdoc in Durham 2000-2005, then moving to Imperial), Jausovec (PhD student in Durham 2003-2005, then moving to Imperial), and two undergraduate project students, Kate Fenton (Durham MSci Physics 2001-2005), and Peter Seem (summer student from Cornell BSc Engineering Physics 2001-2005). They were able to show that the overall properties of the speckle pattern could be used to identify the generic type of paper and its manufacturer, and that the specific details of the speckle pattern were unique to each piece of paper. An individual sheet of

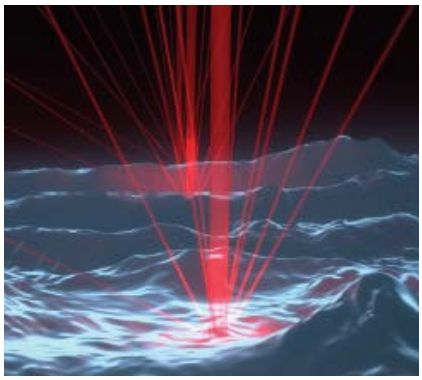

Fig 1: Surface roughness giving rise to diffuse light

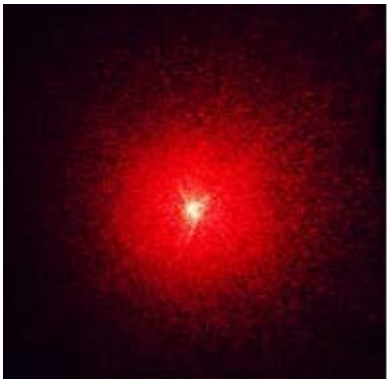

Fig 2: Laser speckle pattern from surface roughness

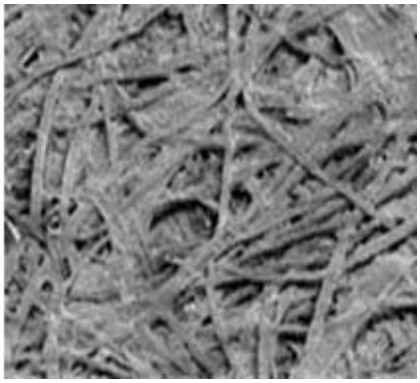

Fig 3: Electron microscope image of paper fibres

paper could be identified by its speckle pattern after being mixed back into the full ream from which it was taken. This pattern is also very stable as it depends solely on the topography of the fibres (Fig 3). This meant that the paper could still be identified even after being charred black by heat or soaked in water [2].

Cowburn's nanomagnetism research programme in Durham was supported to a total of about £4M by Ingenia Holdings, a venture capital company then operating under the name of Eastgate Investments Ltd. Initial patents including both the process itself and technical aspects of pattern matching via Fourier transforms were filed in March and August 2004 [P1-3] and assigned to Ingenia Holdings under the terms of the research funding agreement. In January 2005, Prof Cowburn moved to Imperial College, London to take up a Chair in Nanotechnology, together with several of his research group. The article describing the application of the technique to the detection of forgery in documents and packaging appeared in Nature in July 2005 [2]. Hence the majority of this underpinning research, described in the paper, was performed in Durham, Prof Cowburn's Durham team (including the undergraduate project students) being co-authors of the paper.

3. References to the research

[1] Allwood D.A., Xiong, G, Cooke M.D. Cowburn R.P., 2003, *Magneto-optical Kerr effect analysis of magnetic nanostructures*. *J. Phys D.* **36**, 2175 (all authors with Durham affiliation)
Quality of this research evidenced by 101 citations
[2] Buchanan, J.D.R., Cowburn, R.P., Jausovec, A-V, Petit, D., Seem, P., Xiong, G., Atkinson, D., Fenton, K., Allwood, D.A. and Bryan, M.T. 2005. *Forgery: `Fingerprinting' documents and packaging Nature* **436**: 475 (all authors were in Durham for the majority of their contribution to the research) 78 citations

[P1] Cowburn, R.P. *Determining a signature from an article to determine its authenticity*, UK patent GB2411954B. Assignee Ingenia Technology, Application date 12th March 2004, Publication date 14th September 2005
[P2] Cowburn R.P., *Authenticity verification methods, products and apparatuses*, UK patent GB2417074, Application date 13th August 2004, Publication date 15th February 2006
[P3] Cowburn R.P., *Verification of articles utilizing fourier transform thumbnails*, UK patent GB 2417592, Application date 13th August 2004, Publication date 1st March 2006

4. Details of the impact

A recent report from the UN's Office on Drugs and Crime (UNODC) on organised crime across the Asia-Pacific region estimated that the market in counterfeit goods is worth $24.4 billion i.e. about 2% of world trade, and that it is as profitable for criminal gangs as the trade in illegal drugs [C1]. This highlights the scale of the problem, and also the scale of the potential impact of successfully combating forgery.

Ingenia Technology (UK) Ltd was incorporated in October 2006 to commercialise the technique, now known as Laser Surface Authentification (LSA). There followed much more research and development after Prof Cowburn's move to Imperial College in order to turn the process into a feasible, practical and robust technique to counter forgery and counterfeiting, resulting in a whole series of subsequent patents which cite the original work [e.g. P4-6].

LSA has major advantages over previous methods of authentication such as watermarks or holograms in that the surface is an inherent rather than an additional feature of the document so does not require additional manufacturing. The speckle pattern depends on the nanoscale fluctuations over the entire illuminated surface, and there is no known method to fraudulently reproduce this, unlike watermarks/holograms which are difficult but not impossible to replicate (if you can make it, you can fake it). Ingenia Technology claims that it "*has been described as being like a fingerprint or DNA sequence for the item, is unique for every document, card and carton and can be used to uniquely and unambiguously identify the item.*" [C2]

Much of the business is in designing bespoke implementations, with applications in security (Fig 4, from C2), customs, and law enforcement. These are highly sensitive, so the company will not release details. However, several applications are public, including authenticating packaging of

luxury goods and pharmaceutical products. The packaging is scanned on the production line and the speckle pattern stored on a secure custom database (LSANet). A mobile LSA field unit (Fig 5) can scan the package anywhere in the world and authenticate it against the database [C3]. This application was developed in partnership with Bayer Technology Services GmbH, a subsidiary of Bayer GmbH which offers fully integrated solutions for chemical/pharmaceutical plants [C4]. It is also used by Cartondruck, a German based folding carton manufacturer, who installed an LSA system on one of its production lines for packaging high-end perfumes, cosmetics and other luxury products. Cartondruck Head of Sales and Marketing says: "*The LSA system is simple and 100% reliable, and it works with different materials. Our customers don't have to come to us or to send the product to us to have a scan made. We are happy to have this market advantage*." [C5]. The newest scanners, released in April 2013, are capable of processing 50 items per second, and the LSANet database can now hold up to 100 billion items [C6].

The technology is not limited to paper but can be used on other systems which exhibit stochastic fluctuations. Ingenia Technolgy has developed a complete authentication system for precious metals with leading Swiss refiner PAMP. This Veriscan™ system uses Ingenia's Laser Surface Authentication system to scan and code every gold and silver bar produced by PAMP and then enables authentication by multiple users across the world. Ingenia hosts the secure database for PAMP and has developed a customised version of their hardware and software for them [C7-8].

In 2010 Ingenia Technology signed a partnership agreement with IDT Systems Ltd, a leading 2D and 3D in-surface decoration systems provider. IDT will include LSA as part of its in-surface decoration and personalisation offerings, specifically targeting the consumer electronics sector. "*Working with Ingenia Technology will allow us to offer a much more comprehensive authentication and identification package for our customers*," commented the CEO of IDT Systems. "*Ingenia's LSA technology is the most robust and sophisticated solution for product tracing and anti-counterfeiting that we have seen in the marketplace*" [C9].

Ingenia Technology (UK) Limited has its headquarters in London with satellite offices in Vienna and Zurich. At 31st December 2011, it had shareholder funds of just over £5M on its balance sheet [C10]. The Ingenia team consists of 15 people, with a mix of business and security experts. It includes three members who were originally part of the university research team as well as specialist engineers and physicists with many years of experience in electronic and product engineering [C11]. The company have won multiple awards including the prestigious 2006 Global Security Challenge Award for the most promising Security Start-Up of the year, with subsequent awards in 2007 from Hermes for Best Technology (together with Bayer Technology Services), and two awards for Emerging Technology Companies (Red Herring Europe 100 and Red Herring Global 100) [C12].

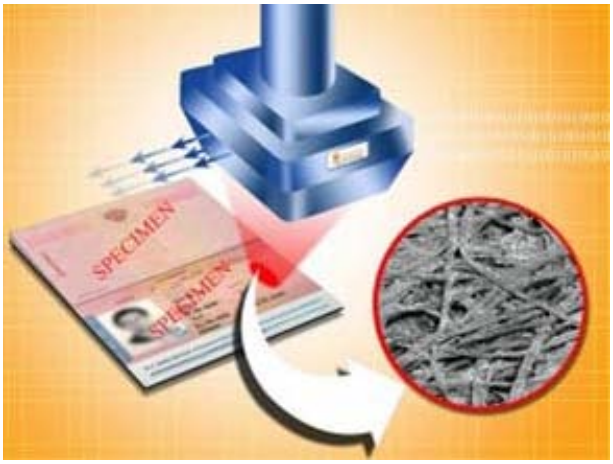

Fig 4: securities application of LSA technology

Fig 5: LSA portable unit designed for use in the field

5. Sources to corroborate the impact

[C1] UN report on transnational organised crime in East Asia and the Pacific
http://www.unodc.org/documents/data-and-analysis/Studies/TOCTA_EAP_web.pdf

[C2] Ingenia web site securities application
http://www.ingeniatechnology.com/the-lsa-technology/

[C3] Ingenia web site – mobile field scanner
http://www.ingeniatechnology.com/product/

[C4] Ingenia presentation – Bayer Technology Services pharmaceutical production line
http://www.who.int/impact/activities/McGlade.pdf

[C5] *Packaging Today* 2nd April 2012.
www.packagingtoday.co.uk/features/featurelooking-the-part

[C6] Ingenia high speed scanner launch
http://www.ingeniatechnology.com/wp-content/uploads/2013/04/ING130408_HighSpeedScannerLaunch.pdf

[C7] PAMP press release on Veriscan (not available on the web)
Filed with corroborating documents, also referenced in the PAMP news item 01/29/2013
http://www.pamp.ch/allnews

[C8] Andrew Gilbert, Business Development Director and Deputy Managing Director of Ingenia
Email filed with corroborating documents

[C9] Ingenia and IDT sign partnership agreement
http://www.businesswire.com/news/home/20101029005385/en/Ingenia-Technology-IDT-Systems-Sign-Partnership-Agreement

[C10] Ingenia accounts from FAME database
filed with corroborating documents

[C11] Ingenia about us
http://www.ingeniatechnology.com/about-us/

[C12] Wikipedia entry for Ingenia
http://en.wikipedia.org/wiki/Ingenia_Technology#Awards