Institution: Queen's University Belfast

Unit of Assessment: 9 (Physics)

Title of case study: Seagate Technology R&D Investment Strategy

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

University research and expertise in materials and photonics relevant to data storage has influenced strategic investment decision-making within Seagate Technology resulting in the creation of 85 new R&D positions in the UK announced in 2010. These new jobs were part of an £60M investment that saw a re-allocation of corporate budget from the USA and resulted in significant expansion of Seagate Technology's UK based R&D capacity. The investment was made to support their medium-term technology roadmap plans. Seagate Technology is the world-leading manufacturer and supplier of data storage technology in the form of disk drives, employing 53,000 people worldwide.

2. Underpinning research (indicative maximum 500 words)

Since the late 1990's, our research has focused on the processing and physics of nanoscale ferroic materials and in nano-optics and plasmonics aided by the creation of tailored nanostructured materials for various plasmonic implementations. Understanding and controlling the processing and fabrication of nanoscale ferroic materials (e.g. ferroelectrics and ferromagnetics), developing methodologies to explore ferroic domain formation and switching on sub 100-nm lengths are key basic enablers for future hard-disk read/write technology. Plasmonics and near field optical delivery are central to the developments required for heat-assisted magnetic recording (HAMR) that will be the next paradigm in data storage.

By 2009 a culmination and expression of underpinning research was exemplified by:

Meso and Nanoscale Ferroics

We established a globally unique activity in which thin film and nanoscale effects were probed in lamellae, wires and dots cut directly from bulk single crystal material using a Focused Ion Beam (FIB) Microscope [Reference 1]. Thus intrinsic effects of nanoscale patterning geometry on switching behaviour can be studied and related to that being seen in ferromagnetic systems. With our alumina template self-assembly we demonstrated the close integration of ferroic materials and noble metals to make ultra-high density memory demonstrators (at almost 1Tb/inch$^{2)}$ [Reference 2].

Plasmonics and Nanowires

Alumina templates and self–assembly has also seen the realisation of metallic nanowire and nanotube arrays that have been specifically tailored to generate new and exciting plasmon-mediated optical properties [Reference 3]. Of note is the extreme sensitivity of the nanowire absorption properties to the nature of the wire-surface interface and means the arrays show great potential for novel plasmonic transducers [Reference 4] to be exploited via a spinout company, Causeway Sensors, formed in 2013.

This research provided underpinning relevance to Seagate Technology's medium-term technology roadmap plans in three unique ways:

- We (Bowman, Gregg, Pollard) demonstrated the integration of nanoscale noble metals and ferroic materials (magnetic elements and ferroelectric elements layers) into alumina creating electrical and optically functional devices on the sub 100nm length scale [Reference 2 and 4]. This is attractive when considering future integration of photonic elements into conventional ferroic devices such as a read/write head;
- We (Pollard & Zayats (to 2011)) demonstrated how the shape of plasmonic elements leads to particular optical response [Reference 5]. This is attractive when considering realisation of a plasmonic radiating element for HAMR;
- We (Zayats (to 2011)) demonstrated through simulation how material shaping can be used to create plasmonic waveguide elements [Reference 6]. This is attractive in demonstrating a light

delivery system within a read/write head. This work was undertaken in collaboration and co-authored with Seagate Technology and via their financial support of two PhD students on a £80k grant (2005-08) held by Bowman.

This was augmented further because the research programmes undertaken since 2003 had been facilitated by £3M capital infrastructural investment made by Invest NI (see acknowledgements in References 1, 2, 3 and 5) creating an environment commensurate with what is required for high level industrial engagement supporting other relationships e.g. via three Knowledge Transfer Partnerships.

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

For each reference we provide data on the journal ranking within ISI classification area/s by ISI Journal Impact Factor (IF), the actual Journal Impact Factor and the number of cites the article received on the ISI Web of Knowledge to September 2013.

References 1-3 illustrate both quality of the underpinning research and evidence to the impact, while references 4-6 provide the latter.

[1] *"Morphological Control of Polar Orientation in Single Crystal Ferroelectric Nanowires"*, A. Schilling *et al*, *Nano Letters* **7**, 3787 (2007).
http://dx.doi.org/10.1021/nl072260l (7th of 232 in Materials Science – Multidisciplinary (or 5th in 125 Physics – Applied), IF 13.2, 52 cites).
[2] *"Towards self-assembled ferroelectric random access memories: hard-wired switching capacitor arrays with almost Tb / inch^2 densities"*, P. R. Evans *et al*, *Nano Letters* **7**, 1134 (2007).
http://dx.doi.org/10.1021/nl0626028 (7th of 232 in Materials Science – Multidisciplinary (or 5th in 125 Physics – Applied), IF 13.2, 43 cites).
[3] *"Anisotropic optical properties of arrays of gold nanorods embedded in alumina"*, R. Atkinson *et al*, Physical Review B **73**, 235402 (2006).
http://dx.doi.org/10.1103/PhysRevB.73.235402 (13th of 69 in Physics - Condensed Matter, IF 3.7, 59 cites).
[4] *"Plasmonic nanorod metamaterials for biosensing",* A. V. Kabashin *et al*, Nature Materials **8**, 867 (2009).
http://dx.doi.org/10.1038/NMAT2546 (1st of 232 in Materials Science – Multidisciplinary (or 1st in 125 Physics – Applied), IF 32.8, 224 cites).
[5] *"Growth and properties of gold and nickel nanorods in thin film alumina"*, P. Evans *et al*, Nanotechnology **17**, 5746 (2006).
http://dx.doi.org/10.1088/0957-4484/17/23/006 (16th of 125 in Physics – Applied, IF 4.0, 48 cites).
[6] *"Plasmonic waveguide as an efficient transducer for high-density data storage"*, D. O'Connor et al, Applied Physics Letters **95**, 171112 (2009).
http://dx.doi.org/10.1063/1.3257701 (17th of 125 in Physics – Applied IF 3.8, 12 cites).

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

Seagate Technology has two sites for development and manufacture of read/write heads (the micro-scale component that reads and writes information to a hard disk), Bloomington, Minnesota, USA and Springtown (Derry), Northern Ireland. The relentless demand for increased storage density exceeds 20% compound annual growth rate at the same cost/bit: the read/write head is central to delivering the performance gains required. There is also a recognition that advances in existing materials and concepts used in the heads were becoming increasingly incremental. There was corporate realisation of the need to explore new materials, ideas and fabrication methodologies. To this end in 2007-09 Seagate Technology commenced restructuring of R&D activities in tandem with closure of corporate R&D in Pittsburgh, USA.

To be competitive for corporate investment for these new technologies required a set of competences that went significantly beyond that of the R&D activity constituted at Springtown in 2009 and the risk that investment would be made elsewhere was held by the regional development agency, Invest NI *"…*

our initial concern that the investment would be made in USA rather than Northern Ireland." [*Source 1*].

Further, to also address the upcoming paradigm shift of heat assisted magnetic recording (HAMR) whereby a read/write head would integrate a light delivery system to deliver heat to a localised spot on the disk which would necessitate additional expertise in plasmonic design and realisation beyond that of their own early concepts (see W. Challener et al, Nature Photonics **3**, 220 (2009) http://dx.doi.org/10.1038/nphoton.2009.26).

In undertaking the development of the investment business case for the expansion of their R&D activities at Springtown, Seagate Technology developed a strategy that would see the Springtown team focus on Technology Readiness Levels (TRL) 5-9 while simultaneously identifying supporting collaborative basic research in the University [*Source 2*] founded on an *open innovation* model. Following horizon scanning by Seagate Springtown, a due-diligence exercise evaluated our research competence as the suitable supporting element to their strategy [*Source 3*]. Research that made material contribution to the exercise was [*Source 2*]:

- *"A capability to undertake physical creation, examination and measurements on ferroic materials on a sub 100nm dimension*
- *The ability to create novel ferroic and photonic architectures that embody integration of traditional deposition methods such as vapor deposition and electro-deposition and new the nanotechnologies such as template growth and self-assembly.*
- *The fabrication of nanoscale plasmonic elements in geometry and integration akin to that envisaged for medium term realization of HAMR.*
- *The ability to undertake plasmonic design, tailored to preliminary HAMR needs and realization."*

The importance of our role in the Seagate investment case was recognised by Invest NI as *"… a key factor in moving the discussion forward and ultimately enabling the investment to be made in Northern Ireland. Attracting such a large corporate investment to Northern Ireland has had a hugely positive economic impact in the region.*". [*Source 1*].

Management at Seagate Springtown developed their investment business case that secured corporate mandate for the £60M investment package to grow the R&D function, in support of the areas outlined above, by 85 persons and announced in January 2010 [*Source 4*]. Subsequently, in June 2010, a further strand of the business case was an additional investment of around £9M (capital and recurrent) by Seagate to a new open innovation hub at CNM called ANSIN working in TRL 1-4 [*Source 5*]. This is their first such venture globally.

The consequences of this impact have been marked. With the creation of the R&D posts at Springtown, by 2013 the site undertakes 40% of the corporate R&D for read/write heads, a proportion significantly greater than in 2008, and has responsibility for recording heads in notebook products [*Source 2*].

To describe the reach and significance of this impact, Seagate Technology is the world-leading provider of data storage devices. They have the broadest product offering in the industry with the largest customer base, and focus on the vertical integration of the critical technologies: read/write heads and recording media. Seagate has a market capitalisation of $13B and 53,000 employees worldwide. It has some 43% of the storage device market and revenues of $10-12B p.a. (Q2 FY13: 57M drives shipped; revenue of $3.7B).

Of Seagate's two sites for the development and manufacture of the read/write heads, Springtown has a dominant role in manufacture. The operation employs around 1350 staff, with 200 OEM staff on-site, and manufactures some 300-400M read/write heads p.a., supplying 75% of Seagate's needs (equating to some 25-30% of the global supply). The site contributes some £100M p.a. Gross Value Add (GVA) to the UK economy.

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

1. Letter from Technology Executive, Invest Northern Ireland.
2. Letter from Chief Technology Officer, Seagate Technology.
3. Senior Director, Seagate Technology, Springtown.
4. Seagate Technology press release, 28 January 2010, available at

http://www.seagate.com/about/newsroom/press-releases/investment-springtown-60million-pr/
5. BBC News Item, 8 June 2010, available at http://www.bbc.co.uk/news/10267681