Institution:
The University of Manchester

Unit of Assessment:
UoA08 Chemistry

Title of case study:
Nanoco Grp Ltd

1. Summary of the impact

Nanoco, is a University of Manchester spin out company having a current market capitalisation of £384m (31/7/2013). Nanoco's proprietary processes enable, for the first time, commercial quantities of high-quality quantum dot nanoparticles, free of toxic heavy-metals, to be manufactured economically – for incorporation into next-generation displays & solar-cells."

As a result of its world-leading disruptive technology, Nanoco has, in the REF period, forged down-stream global business partnerships that have generated around £11m revenue, creating 95 jobs with Nanoco (at a cost of over £3m/year), substantial secondary employment in the supply chain, and underpinning technology to enable the delivery of more energy-efficient electronic devices.

2. Underpinning research

Research conducted at the University of Manchester developed novel processes to prepare, reproducibly, bulk quantities of high-quality quantum dot nanoparticles from non-heavy metal precursors. [4,5]

The research was carried out by key Manchester researchers:

- Paul O'Brien – Professor of Materials Chemistry (1999-present);
- Nigel Picket - PDRA (2000-2004);
- Steve Daniels – PhD student (2001-2004).

Most often, quantum dots have been prepared by 'hot-injection methods' rapidly introducing solutions of often hazardous precursor compounds into a vast excess of hot solvent, resulting in nucleation and subsequent growth of the quantum dot nanoparticles by 'heating-up' methodologies. The approach can be severely limited by being non-reproducible in terms of the stability, size and colour of the quantum dot nanoparticles produced.

The molecular seeding process developed at Manchester circumvented these limitations. In this approach, the precursor compounds are heated in the presence of a molecular-cluster in a single-pot reaction. The molecular cluster serves as a prefabricated template to nucleate nanoparticle growth, offering more accurate control over the size and associated emission wavelength of the resulting quantum dots. [3]

This seeding process was then further developed at Manchester, coating the quantum dot nanoparticles with a wide band-gap inorganic shell in order to confine the exciton generated within the quantum dot, upon irradiation, from the external environment. This improved both the stability and brightness of the quantum dot nanoparticles. [1,2,6]

3. References to the research

All of the papers appear in peer-reviewed international journals that led to Professor O'Brien being invited to present his research internationally. The patents capture the underpinning research that forms the basis of Nanoco Technologies. Professor O'Brien was made FRS in 2013 largely for his contributions to the development of the chemistry described in this Impact Case.

Key references

1. Investigation of the internal heterostructure of highly luminescent quantum dot-quantum well nanocrystals, Santra, P. K. Viswanatha, R. Daniels, S. M. Pickett, N. L. Smith, J. M. O'Brien, P., Sarma, D. D., J. Am. Chem. Soc., 2009, 131, 470-7 DOI: 10.1021/ja8033075

2. Power law carrier dynamics in semiconductor nanocrystals at nanosecond timescales. Sher, P. H., Smith, J. M., Dalgarno, P. A., Warburton, R. J., Chen, X., Dobson, P. J., Daniels, S. M., Pickett, N. L., O'Brien, P., Appl. Phys. Lett., 2008, 92, 101111, DOI: 10.1063/1.2894193

3. New synthetic routes for quantum dots, Crouch, D., Norager, S., O'Brien, P., Park, J-H., Pickett, N. L., Phil. Trans. R. Soc. Lond. A., 2003, 361, 297-310. DOI: 10.1098/rsta.2002.1129

Other references

4. Preparation of nanoparticle materials, O'Brien, P.,Pickett, N., PCT Int. Appl. (2005), WO 2005106082 A1 20051110.

5. Nanoparticles, Pickett, N., Daniels, S., O'Brien, P., PCT Int. Appl. (2007), WO 2007020416 A1 20070222

6. Synthesis and characterization of CdS quantum dots in polystyrene microbeads, Li, Y., Liu, E. C. Y., Pickett, N., Skabara, P. J., Cummins, S. S., Ryley, S., Sutherland, A., O'Brien, P., J. Mat. Chem., 2005, 15, 1238-1243. DOI: 10.1039/b412317d.

4. Details of the impact

Context

Despite the advantageous electroluminescent and photoluminescent properties of quantum dot nanoparticles, their incorporation into next-generation consumer electronics has been precluded by the absence of a means to manufacture both sufficient quantities and materials that are free of toxic heavy metals in-order to comply with 'Restriction of Hazardous Substances' (RoHS) legislation.

Pathways to impact

The research conducted at the University of Manchester enabled the preparation of bulk quantities of quantum dots free of toxic heavy metals, which led to the spinout of Nanoco Technologies in 2001-2 from the School of Chemistry based on its proprietary technology covered, by 19 patents [4,5].

Whilst located within the School of Chemistry building, Nanoco grew to 10-12 workers before moving to dedicated premises where it experienced extraordinary growth between 2004-2013. Currently, Nanoco operates from the company's headquarters and R&D facility in Manchester, a production plant in Runcorn and sales offices located in Japan and the United States.[A]

Impact.

During the period 1st January 2008 to 31st July 2013, Nanoco Technologies established itself as the world's leading manufacturer and supplier of commercial quantities of RoHS compliant (RoHS 2002/95/EC) quantum dots, employing approximately 95 staff at a total cost of over £3m per year and generating over £10.5m revenue since 1st August 2008 [B].

On the 1st May 2009 Nanoco Group plc began trading on the Alternative Investment Market of the London Stock Exchange and since this time has grown its market capitalisation to £384m (31/7/2013).

Nanoco's strategic partnerships have generated significant secondary impact through job creation throughout its associated supply chain and within its partner companies. Currently, Nanoco's quantum dot's are being developed with its strategic partners in several areas including displays and photovoltaic solar cells as follows:-

1. Displays

Display technology has progressed from bulky cathode ray tubes to plasma screens, liquid crystal displays and more recently to energy efficient organic light emitting diodes (OLED). OLED technology has provided low power, lightweight, thinner displays of improved user experience through wider viewing angles and improved contrast. However, OLED display technology is limited to the fabrication of small displays employing wasteful and energy inefficient evaporation procedures with a high discard rates.

Quantum dot electroluminescent display technology (QD TV™) offers a tremendous advantage over existing OLED-technology. Quantum dots have been printed using facile low cost techniques into various sizes of lightweight flexible displays. High photoluminescence quantum yields render the displays energy efficient, narrow emission band-width provides displays of superior optical resolution, whilst the high stability of inorganic quantum dots provides displays with improved lifetimes.

Since 2011, Nanoco has delivered 1kg batches of both red and green coloured quantum dots worth £2.5m and achieved performance milestones that have generated an additional £1.1M. In January 2013 Nanoco entered into an exclusive licensing agreement with Dow Electronic Materials' who are opening a production facility in the far-east to manufacture quantum dots and have exclusive worldwide rights for the sale, marketing and manufacture of Nanoco's quantum dots for use in electronic displays [C].

2. Photovoltaic solar cells

The world's growing demand for power is met predominantly by the combustion of fossil fuels (13TW, 87%). As fossil fuels become depleted and the demand for cleaner, greener energy increases it is imperative that renewable energy becomes a more significant proportion of our energy mix. Currently, solar power contributes a negligible 0.03% toward the global energy mix despite the earth receiving sufficient energy from the sun to meet its current and future energy demand (>120,000 TW). The widespread adoption of solar power has been impeded by the high cost of cells, principally of silicon fabricated by expensive methods.

In partnership with a Japanese automotive firm that has invested approximately £1m and 'Tokyo Electron' who have invested an undisclosed amount, Nanoco has exploited its proprietary intellectual property and expertise to prepare a range of novel copper indium gallium diselenide and copper indium diselenide quantum dot inks that have been fabricated into solar cell devices of good efficiencies using conventional low cost printing techniques [D].

5. Sources to corroborate the impact

A) Corroboration of Nanoco startup timeline and individual involvement. Letter of support (CEO Nanoco)

B) Nanoco 2013 Interim Report.

C) Press Release re Dow use for LCD displays.

D) Press Release re Tokyo Electron use of solar ink