Institution: University of Strathclyde

Unit of Assessment: 12

Title of case study: Economic impact through improved product and process development within Carron Phoenix

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

Initial research into polymer nanocomposites and their formation took place at Strathclyde from 2000 – 2010. This was followed by a collaboration with the world's largest manufacturer of composite kitchen sinks, Carron Phoenix Limited, through a 6-year Knowledge Transfer Partnership (KTP) which resulted in a successful new production process of its high-end synthetic granite kitchen sinks. This led to £4 million of capital investment in new production facilities at their Falkirk site, enabling the company to sustain its leading position in the designer kitchen sink market and retain its workforce of over 400 employees in central Scotland, including the 170 workers in the composite sink division in Falkirk. Within the REF period, the research has led to the manufacture and sale of in excess of one million kitchen sinks, generating sales revenue in excess of over £50M and supporting the UK economy.

2. Underpinning research (indicative maximum 500 words)

Context:

Following initial research into the development of so-called polymer-clay nanocomposite materials [1,2], chemical engineering research and development has led to the successful commercial manufacture of kitchen sinks with enhanced durability, mechanical and chemical properties, including impact strength, gas and liquid impermeability, and fire retardancy, compared to existing products.

Prior to the research, the manufacturing process was energy and labour intensive, and the product quality frequently unreliable with a net cost to the company in terms of lost production time, material wastage and disposal costs. Together with licencing and significant royalty costs, the company sought expertise to develop new alternative quality products. Through £268k of KTP funding between 2004 and 2010, the research involved initially carrying out a full evaluation of the chemical processing practices, as well as material and energy audits. Detailed understanding of the mixing of materials, reaction characterization, and heat and flow properties was also achieved. This led to a radically new approach to processing, which influenced how the workforce was deployed, with the changes fully implemented by the company in 2009.

Key findings:

The research outputs [3,4] detail how information was obtained on the cure rates and viscosity of polymer-clay nanocomposites that are formed through *in-situ* polymerisation. The nature of the dispersion of clay platelets in a resin composite plays an important role in the process of enhancement of the physical properties of that material. Reference 3 examines how different modifiers and the quantity of surface treatment for the Cloisite® range of organically modified clays affect properties in *in situ* polymerised poly(methyl methacrylate). Another clay, which is a mixture of rod- and platelet-like minerals, was also investigated to understand how the shape of the clay particles can affect the polymer properties. Five different clays, including Cloisite 30B and Cloisite 15A, were dispersed using ultrasound and the cure of the samples was monitored using the Strathclyde Rheometer. Rheology, transmission electron microscopy and X-ray diffraction were used to determine that a good level of clay dispersion was achieved. The mixed mineral formed the most stable dispersion seen from settling tests. The cure accelerated in the presence of organoclay, although the affect was less pronounced at higher temperatures. The glass transition temperature was increased by 20 °C with only a few weight percent of clay, and water uptake was not adversely affected.

This research was crucial in allowing the team to fully characterise and optimise the new production process and to identify suitable nanoclay fillers and rheology modifiers to allow control of the main processing and materials characteristics that influenced the manufacturing process: i) the mixing and distribution of materials, ii) effective flow properties, and iii) heating and curing

rates. Understanding and control of these properties was crucial for the production of synthetic sinks free from warpage and surface blemishes, and so was central to improvements in the efficiency of manufacture and in the reduction of wastage from spoiled products.

To meet the company's overall objective of achieving a 25% reduction in production costs, the research project was presented with significant technological challenges. The trilateral research partnership between the company and Strathclyde's Chemists and Chemical Engineers was central to the successful design of the new production process leading to the new materials being extensively trialled for two years before becoming part of the company's standard production process in 2009.

Key Researchers:
The research in process and product development of polymer-based synthetic granite kitchen sinks was based on the complementary expertise of chemical engineers and chemists at the University of Strathclyde together with engineers and chemists at Carron Phoenix Limited, based in Falkirk, Scotland.
Department of Chemical & Process Engineering (CPE): Prof Carl Schaschke (August 1990 to present). Department of Pure & Applied Chemistry (PAC): Prof Richard Pethrick (lecturer from 1969, then retired and currently Research Professor), Dr John Liggat, (Reader 1994 to present).

3. References to the research (indicative maximum of six references)
References 3 and 4 best indicate the quality of this research.

1. Study of the factors influencing the exfoliation of an organically modified montmorillonite in methyl methacrylate/poly(methyl methacrylate) mixtures. M. McAlpine, N. E. Hudson, J. J. Liggat. R.A. Pethrick, D. Pugh, I. Rhoney, Journal of Applied Polymer Science, 2006, 99, 2614-2626.
2. Effects of organically modified clay loading on rate and extent of cure in an epoxy nanocomposite system, S.E. Ingram, R.A. Pethrick, J.J. Liggat, Polymer International, 2008, 57, 1206 - 1214.
3. Influence of clay type on the enhancement in physical properties of in situ polymerised poly(methyl methacrylate) nanocomposites, S. Ingram, H. Dennis, I. Hunter, J.J. Liggat, C. McAdam, R.A. Pethrick, C. Schaschke, D. Thomson, Polymer International, 2008, 57, 1118-1127 DOI: 10.1002/pi.2453
4. Use of sonication and influence of clay type on the enhancement in physical properties of poly(methyl methacrylate) nanocomposites, S. Ingram, H. Dennis, I. Hunter, J.J. Liggat, C. McAdam, R.A. Pethrick, C. Schaschke, D. Thomson, Proceedings of the Materials Research Society, Fall National Meeting, Boston, November 2007. http://www.mrs.org/f07-abstract-hh/ Session HH10.5

Other evidence for quality of research.
In view of the highly competitive and financially lucrative market for high-end kitchen products and the propensity to replicate the product by other manufacturers, Carron Phoenix and Strathclyde took the mutual decision **not** to protect IP through patenting, instead choosing to retain key knowledge in-house but publicising the relevant technological development by way of a conference presentation and refereed journal publication [3,4] to prevent other manufacturers patenting the process. The work was funded by:

- KTP Programme with Carron Phoenix Ltd. Pethrick R.A., Liggat J.J., Schaschke C.J. (2005) £234,490. For the development of a new process and product.
- Shorter KTP with Carron Phoenix ltd. Liggat J.J., Schaschke C.J., Pethrick R.A. (2009) £20,850 funded by Momenta. To extend the above project.
- KTP Composite Sink Manufacture - R&D Support Liggat J.J., Schaschke C.J., Pethrick R.A. (2009) £9,500 funded by Carron Phoenix Ltd. To extend the above project.

Upon completion, the KTP programme (Knowledge Transfer Partnership 0596 with Carron Phoenix) was formally assessed by the Programme Managers, Momenta, as Very Good.

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

Process/Events from Research to Impact:
Carron Phoenix Limited based in Falkirk, Scotland, is the world's largest manufacturer of composite 'granite' kitchen sinks employing over 400 workers, and is part of the Swiss Franke Group. Through a partnership of complementary expertise between the departments of Chemical & Process Engineering (CPE) and Pure & Applied Chemistry (PAC) within the University of Strathclyde, a major collaborative Knowledge Transfer Partnership (KTP) with Carron Phoenix was established. The specific aim was to create a new range of synthetic granite kitchen sinks, enabling the company to sustain its position in the higher-end designer kitchen sink market across Europe and compete in markets worldwide. The initial work was undertaken by the company through an EPSRC CASE studentship with PAC which operated from 2002-2005 and led to the development of novel polymer nanocomposite formulations with mechanical, thermal and barrier properties superior to the base polymers. Such innovative formulations offered the potential of significant benefits to Carron Phoenix Ltd in terms of process flexibility, enhanced product performance and reduced wastage.

Following promising results in establishing the underlying polymer chemistry, a wider and considerably more major expansion of the project via a KTP programme (Source A) was established in January 2005 involving specialists in chemical and process engineering in CPE as well as chemists in PAC, which was followed by a Short KTP (sKTP) collaboration between the company and the University, over the period 2009 – 2010. These knowledge transfer programmes brought together the complementary expertise of the Strathclyde chemists (Pethrick, Liggat) and chemical engineers (Schaschke) with technologists at Carron Phoenix Ltd (Dennis, Hunter, Mackintosh). The main engineering focus was to ensure that the prior chemistry findings could be fully translated and scaled-up as an industrial production process that delivered a consistent high quality product.

Nature of the Impact:
Improved manufacturing process
The KTP projects consolidated the findings of the preliminary research by providing a full evaluation of the chemical processing practices as well as material and energy audits. From a detailed understanding of the mixing, reaction characterization, heat and flow properties, a radically new approach was devised for all aspects of the process operation, including the reallocation of labour, reduced process times, increased mould tool usage and major capital investment in automation (Source A).

Process acceleration and automation created new challenges in terms of control of the flow behaviour of the composite sink formulation during the final curing step. In particular, more rapid heating rates led to greater sedimentation of the fillers resulting in product defects. Detailed and extensive chemical and processing studies were required in terms of formulation, cure characteristics, flow and thermal properties of the nanoclay materials. This provided the necessary platform for the development of a completely new process with the successful commercial production of high-end designer synthetic kitchen sinks sold worldwide. The research enabled the team to identify a suitable type and concentration of nanoclay filler and rheology modifier to allow control of a) the mixing and distribution of materials, b) the effective transfer of the mix, and c) heating and curing rate, to produce synthetic sinks free from warpage and surface blemishes and thus reduce wastage from spoiled products. Prior to this project, it had been necessary to re-work moulded kitchen sinks in such a way as to avoid warpage and product spoilage. The company is forthright in its acknowledgement of the criticality of the new formulation: "*The nanoclay influenced the processability significantly and enabled us to introduce the new process technology with its significant savings. No nanoclay - no new process at that time, it is as "simple" as that*", (Source B, Head of R&D, Carron Phoenix/Franke PL Colour).

Production efficiency and cost savings
The implementation of the changes to the process enabled by the new nanocomposite formulation resulted directly in considerable production efficiency gains through the reduction of raw materials wastage, the reduction in manufacturing time and the significant reduction of landfill costs of failed and out-of-spec products. These savings alone amounted to in excess of £1 M annually,

significantly in excess of the 25% target defined for the project. Franke's Sustainability Report 2011 notes that:
"*Our production processes mainly use electricity and natural gas. We have experienced that the combination of process and technological improvements result in major energy savings….In Falkirk, United Kingdom, the energy required for the moulding of granite composite could be reduced by 20 % per annum with an innovative process called "Rapid Energy Distribution*" (Source C p.19).

Competitive advantage to the company
By creating superior, high quality products and reducing production costs, the research outcomes from this project have enabled the company to maintain its international business and market share in the higher-end designer kitchen sinks. The company has been able to use these efficiency savings to sustain its drive to maintain the economic viability of the Falkirk site relative to other competitive options. In 2010, Franke the parent company, subsequently established Carron Phoenix in Falkirk as the Group Competence Centre for composite sink technology, due in part to the strong research and development brought about by the incorporation of nano-composite technology. This has secured both major employment for 170 workers in the composite sink division at the Falkirk site and retained the associated supply chain infrastructure supporting further employment locally and nationally (Source D).

Investment
The successful research outcomes from this project were further supported by internal company investments securing significant investment in new automated production facilities with a capital investment of approximately £4 million. These were installed in 2008 and 2009 to incorporate the new nanocomposite technology with the production and sale of over one million kitchen sinks by Carron Phoenix. This resulted in generating income in excess of £50M for the company as well as generating support for the associated supply chain involved and contributing to the UK economy generally.

Ongoing collaboration
The Carron Phoenix company remains in regular contact with researchers at Strathclyde, using facilities such as the Advanced Materials Research Laboratory. Schaschke and Liggat provide training courses on polymer chemistry and process technology for company staff. Skilled researchers from the University have transferred to posts in the industry; a PhD graduate from the Liggat research group, and an MEng graduate from Chemical & Process Engineering have been employed by Carron Phoenix since 2012.

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

A. The KTP programme was assessed on a quarterly basis by and minutes of these meeting are held by the West of Scotland KTP Centre, www.ktpws.org.uk

B. Statement from Head of R&D, Carron Phoenix/Franke PL Colour, confirms the impact of the research on new processes.

C.http://www.franke.com/content/dam/frankegroup/pdf/publications/Sustainability_Report_2011.pdf provides evidence of increased efficiency and cost savings at the Falkirk site

D. Commercial & Product Support Manager, Carron Phoenix/Franke PL Colour, can be contacted to confirm company perspective on the impact of the research, including quantitative estimates of the benefits.