Institution: University of Hertfordshire

Unit of Assessment: Panel B (15): General Engineering

Title of case study: Optimising materials interfaces: Supporting the growth of an SME

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

Since the mid-1990s, the Materials and Structures Research Group has been conducting research into materials-joining processes, including metal–ceramic joining for high-temperature applications. The group's research on metal–ceramic interfacial relationships and metal–ceramic joining subsequently assisted Cambridge-based C4 Carbides to optimise metal-to-diamond brazing and develop cutting tools with improved quality and longer lifetimes. Since 2010 the company has also: [text removed for publication] This continuing collaboration has helped C4 Carbides secure a TSB smart award and begin its strategic shift from niche SME to mainstream supplier.

2. Underpinning research (indicative maximum 500 words)

Between 2004 and 2009, the Materials and Structures Research Group undertook novel research on metal–ceramic joining and on the processing and interfacial relationships of metal–ceramic composites. The work was led by Dr Andreas Chrysanthou, who began his research in the field of wear-resistant materials, including carbides, in the 1980s and has continued this since joining the University of Hertfordshire as Senior Lecturer in 1996 (Reader since 2008).

Before 2004, Chrysanthou's focus was on metal-matrix composites where titanium carbide was used as the ceramic reinforcement (see Section 3, Ref. 1). The investigation aimed to develop metal-ceramic composites with improved high-temperature capability or for applications such as cutting tools that required high wear resistance.

From 2004, Chrysanthou worked in collaboration with researchers at the Polytechnic of Torino (Italy) and the Advanced Materials and Processes Research Institute of Bhopal in two EU-funded projects (see section 3, Research Awards 1 and 2), to investigate 1) new materials for applications under extreme conditions and environments, such as high temperatures, abrasive or wearing conditions; and 2) the development of nanostructured materials for high-temperature applications, including applications where wear resistance was required (Ref. 2). Chrysanthou built on his earlier research on titanium carbide by using additions of vanadium, which led to synthesis of compositionally-graded titanium-vanadium carbide in a ferrous matrix. This was accompanied with a carbide particle size reduction from an average 5µm to 1µm and an improvement in hardness. This was attributed to the lower surface energy between vanadium carbide and iron than for titanium carbide and iron, leading to improved interfacial wetting when vanadium carbide was present. The research used chemical thermodynamics analysis to confirm that the synthesised carbide composition would be graded, and also established the mechanism of the process.

Chrysanthou also investigated methods of improving the wetting between metal matrices and ceramics to strengthen metal-ceramic bonding. Techniques such as self-propagating high-

temperature synthesis (SHS) were used to generate carbide dispersions in metal matrices. The SHS technique was subsequently adapted by injecting mixed titanium and carbon pressed powders into molten metals like copper (Ref. 4). Small elemental additions of aluminium to the copper matrix led to the refinement of titanium carbide dispersions and to improvement in hardness, again due to lowering of the interfacial energy between the matrix and the reinforcement.

As a result of these investigations, C4 Carbides, a Cambridge-based manufacturer of cutting tools for the global market, approached Dr Chrysanthou to help resolve a quality issue concerning their diamond-brazed product range, which was suffering premature failure. [text removed for publication]

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

Bold type indicates University of Hertfordshire authorship; other authors are collaborators based at the Regional National Laboratory of Bhopal and Polytechnic of Torino

1. **A. Chrysanthou**, **Y.K. Chen**, **A. Vijayan** and **J.M. O'Sullivan**, 'Combustion synthesis and subsequent sintering of titanium-matrix composites', *Journal of Materials Science* 38 (9), 2003, 2073–2077. DOI: 10.1023/A:1023562126927

2. **A. Chrysanthou**, O.P. Modi, **L. Han**, N. Ramakrishnan and **J.M. O'Sullivan**, 'Formation and microstructure of (Ti,V)C-reinforced iron-matrix composites using self-propagating high-temperature synthesis', *International Journal of Materials Research* 99 (3), 2008, 281–6. DOI: 10.3139/146.101635.

3. D. Vallauri, I.C. Atias Adrian and **A. Chrysanthou**, 'TiC-TiB_2 composites: A review of phase relationships, processing and properties', *Journal of the European Ceramic Society* 28 (8), 2008, 1697–1713. DOI: 10.1016/j.jeurceramsoc.2007.11.011

4. S. Rathod, O.P. Modi, B.K. Prasad, **A. Chrysanthou**, D. Vallauri, V.P. Deshmukh and A.K. Shah, 'Cast in-situ Cu-TiC composites; Synthesis by SHS route and characterisation'. *Materials Science and Engineering*: A 502 (1–2), 2009, 91–8. DOI: 10.1016/j.msea.2008.10.002.

– *This output is listed in REF2*

Key Research Awards

1. 2004–9: EU Network of Excellence in 'Knowledge-based Multi-component Materials for Durable and Safe Performance'. **€250,000**.
2. 2004–8: EU STRP in 'Processing of Nanostructured Materials through Metastable Transformations'. **€62,500**.

[text removed for publication]

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

The Materials and Structures Research Group's research into the synthesis of carbides of

graded composition in metal matrices paid dividends when the university was approached by Cambridge-based C4 Carbides in 2010. C4 is an SME that trades internationally, primarily serving the power tool accessory and industrial band saw blade industries, with interests also in oil and gas, security, aerospace and motor sports. Initially, C4 Carbides wanted the research group to help solve quality issues related to the brazing of diamond, and subsequently to enhance the braze–diamond bond in several of their drill products. The work by Dr Chrysanthou and his research team that ultimately benefited this company was initially funded by a short Knowledge Transfer Partnership (sKTP) in 2010, and followed by a full KTP the following year.

The 2010 sKTP research showed that the bond between a metal matrix (or braze) and carbides could be strengthened by chemically grading the carbide composition so that there was a gradual decrease in the value of the linear coefficient of thermal expansion when moving from the metal into the carbide. This is particularly helpful in brazed diamond tools: a graded interfacial carbide will reduce stresses and cracks during heating–cooling cycles when the drill is performing, and increase tool life.[text removed for publication]

With this knowledge, C4 Carbides was able to rectify the problem and cease losing revenue on faulty products: the discovery of the reasons for the quality issue immediately led to tighter controls of the tempering process within both temperature and time limits, ensuring that in the future there would be no complete separation of the carbide phases. According to Mr Peter Nicolson, CEO of C4 Carbides, [text removed for publication]

The sKTP led on to a full KTP (2011–13). This is still in progress, and is focusing on strengthening the braze-to-diamond bond to create tools with improved life and cutting capability. In order to achieve this, Dr Chrysanthou and his research team are looking into the development of alternative brazes and pre-brazing diamond coatings. The investigation, which is nearing completion, has already resulted in several early benefits to C4 Carbides; for example, the thickness of the pre-brazing diamond coating has been optimised for a bond for better cutting performance.

First, the KTP has brought about improved performance and greater consistency [text removed for publication]

Second, the KTP contributed materially to C4 Carbides' success in winning a £250,000 TSB smart award in 2012. This is a strategically important award for the company as it repositions itself to address the shift away from tungsten carbide towards diamond products, and from a niche to a mainstream market. Mr Nicolson states that it has already fundamentally altered the profile of the business, and he has accordingly put in place a strategic five-year plan for C4 Carbides to build on this change as his company continues to benefit from the research expertise of the Materials and Structures Research Group, and Dr Andreas Chrysanthou in particular, in facing the technical challenge of developing better ceramic-to-steel bonding for new products.

Finally, the KTP is helping to establish a new strip line product in the high-performance band saw sector; development is currently well underway and on target for its scheduled launch in June 2014. [text removed for publication]

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

Report

'Investigation of EN8DM tools through SEM & EDS ', Internal (sKTP) Report for C4 Carbides by Ozan Osman and Andreas Chrysanthou, 24 December 2010.

– A copy of this report can be supplied on request

Website

C4 Carbides website, 'Technology' page: <http://www.c4carbides.com/technologies.aspx>

C4 Carbides, Cambridge

The CEO of this organisation has agreed to corroborate the impact on his company as reported in this case study; contact details are supplied separately.