1. Bioceramics – Paper, Ash and Resin (Bioceramics)

Paper mill wastes, fly ash and resins can be combined to provide a range of materials for the construction and ceramics sectors in the UK. We are looking to develop and manufacture improved, low carbon, sustainable, products, in particular, fire resistant boards for construction and decorative panels and tiles with ceramic-type finishes. We will turn environmental problems into valuable commercial opportunities producing large reductions in the carbon footprint of UK manufacturing and a materials technology which embodies circular economy principles.

Inventor: **Dr Gareth W Roberts**, Business Development, Cambond Ltd

Provide background to the invention and how it came about.

This is an Innovate UK project 50840 Valorisation of Foundation Industry Waste Streams. UK industry produces large volumes of by-products or wastes e.g. – paper making (1.4MT sludge) and ceramics, energy generation and metals -10MT of ash. Some of these material is used for energy generation or cement manufacture but most goes to landfill.

Applying technology developments could make use of these materials, replacing the use of virgin materials and producing significant commercial AND environmental benefits.

The biggest barrier to more effective use of waste resources is cost. The cost of transforming or processing waste streams into useful materials and up the value chain is often too high compared to the cost of existing methods of use or disposal. This leads to a failure of innovative change and the maintenance of existing environmentally damaging and high carbon manufacturing processes.

Cambond have been developing ways of using waste streams to make 'bioceramic' composites which have excellent technical properties but do not require firing at high temperature (>250^{0}C). South African Associated Paper Industries (SAAPI) is a global corporation and has developed expertise in cost effective processing of waste streams and transformation of by-products into commercial products. The Biocomposites Center at University of Wales has expertise in the evaluation of sustainability and environmentally advantageous manufacturing.

This project brings together these strands of expertise and focusses them in a robust plan to drive the commercial development of a new low carbon materials technology which up-cycles waste streams and could provide a significant development in materials manufacturing in the UK. Paper sludge, fly ash and resins can be combined to provide a range of materials for the construction and ceramics sectors in the UK. These materials offer commercially attractive opportunities to develop and manufacture improved, low carbon, sustainable, products such as: Fire resistant boards for construction (market £125M a year in UK); Decorative panels and tiles with ceramic-type finishes; Ceramic type materials which can be moulded into many types of product

Describe how you view the novelty of the invention in the context of similar inventions.

SAAPI has developed a scaleable low cost method of extracting lignin from PMS (paper mill sludge). This provides a firm basis for feedstock. Cambond has a suite of patents covering the manufacture of sustainable resins from agricultural by-products, chemistry of the biopolymer crosslinking process, uses of biomass based adhesives for products and 3D printing/molding and extrusion and straw/biomass based materials.

SAAPI is making a significant effort to develop new applications for this PMS, especially for magnesium lignosulfonate, MLS. The large majority of this product is currently incinerated, and while this allows for the partial recovery of inorganic cooking chemicals and for the generation of steam, it is symptomatic of the global paper and pulp industries in that the most widely available natural biopolymer is used as a fuel rather than for high value biomaterials.

Cambond and SAAPI have extensive technical know- how and preliminary data concerning the utility of PMS and bioresins to produce biocomposites and bioceramics. A patent application has been filed by Cambond to cover the utility of manufacturing low temperature bioceramics.

Initial studies have shown that PMS, lignin components and Cambond resin can be utilised to manufacture boards and panels which can be used in construction. In addition Cambond resin, ash and fibrous biomass can be used to produce ceramic type products.

By extending the life cycle of PMS is for manufacturing composite panels that can be used as building, furniture and construction materials. Composites panels range from medium density fibre (MDF) boards, particle boards, mineral boards, hardboard, plasterboard etc. Such products are embedded into buildings and can last up to 20 years. This could reduce the embodied energy or carbon footprint of paper mill and combustion industries if their by-product can be integrated in long lasting products.

This project will facilitate the development of a circular bio-economy in the UK and drive the valorisation of low/no value waste by-products into valuable biocomposite materials which can reduce manufacturing costs, lower carbon emissions and solve environmental problems.

If appropriate, what are the potential applications you would like to explore for your invention?

The consortium are interested in exploring the application of the technology to manufacture fireproof claddings and flame retardant construction products. These products attract a premium price in the market place and already account for a >£250M a year market in the UK (boards, claddings, panels etc.)

Are you already aware of potential markets? If so, please elaborate.

There is an existing – mature- market for flame retardant products in the UK.

Do you have a feel for the challenges in addressing this market?

Many of these products are associated with high carbon manufacturing techniques, toxicity of fireproofing additives and issues surrounding end of life disposal and safe handling and poor environmental outcomes. Post Grenfell there is renewed industrial and commercial interest in the sector and a better appreciation of the limitations and environmental liabilities of current fire-retardant materials. Particular issues are around costs of these products.

We would like to have a clear idea around:

- The classes of products in the market (what are different products made off, do they have chemical additives)?
- What technical strength, water resistance, fire resistance) do these classes have?
- Do these classes relate to pricing premiums?
- Is there a growing market awareness around the environmental issues around these products?
- Are there particular environmental attributes, certifications, public relations strategies that would be beneficial in positioning these products.
- Would there be issues that might arise in using waste streams to make these products and how could we address them?

How does the invention compare with competing technologies? And what are these, if you know.

Low temperature bioceramics made from waste could be a huge opportunity to compete in the market with cost AND environmental benefits. Most other competitors have no IP and scale of manufacture to reduce cost or access to specific feedstocks is key to commercial positioning.

Have you a clear idea about the IP position?

Yes. We believe the position for low temperature manufacturing of bioceramics is strong. The key issue for commercial exploitation is to find the correct product offering and technical attributes to challenge current competitors in the market.

Dr Gareth W Roberts (Inventor)
Business Development, Cambond Ltd

Gareth started with a PhD in Neuropathology and a teaching post in Imperial School of Medicine, London. He grew a successful research group and became an expert in the molecular mechanisms of neuropsychiatric diseases such as Alzheimer's disease, schizophrenia and epilepsy. He raised £million's in research funding and published over 200 academic papers and 5 books. Gareth moved into the pharmaceutical industry as a research head for SmithKline Beecham and as a Group Director led its Neuroscience research programme.

His strategy project for his MBA became the business plan for a biotech start up in pharmacogenetics. Several other biotech start-ups followed and he has worked in the areas of genetics, informatics, medical devices and stem cells. One of the big lessons Gareth learned from this activity was the value of intellectual property for creating valuable assets within small companies. He has filed over 230 patents during his career.

Cambond Ltd is his latest adventure and a significant step into the unknown. Cleantech and manufacturing – two new disciplines have meant a very steep learning curve over the last 6 years. Cambond has won numerous technology and business awards. Gareth is excited that the company is scaling up product manufacture and enjoying (mostly!!) the challenge of bringing these to market.

Peter Howarth (Supervisor)
Technology Business Development

Peter founded the Cambridge-based business growth consultancy Technology Business Development (TBD) over ten years ago. He has an MA in Marketing and a career background as a marketing/business development manager and director in both international engineering corporations and early-stage technology start-ups, in industries ranging from materials-handling and office equipment, to building products, computer security and high-speed digital printing systems.

Focusing on business-to-business products and services, TBD's projects aid market entry, business expansion and diversification. Most client organisations have been founded by highly-qualified technical specialists - scientists, engineers or therapists for example and include Cambridge's best-known technology development consultancies, with projects designed to evaluate market opportunities, target and engage with business partners and support the commercialisation of new ideas.

Julius Bock
Institute for Manufacturing, University of Cambridge

I was very excited to get the opportunity to join Prof. Leifer's and Dr. Velu's research groups in Stanford and Cambridge as part of my Mechanical Engineering as well as Management master. Combining Business Model Innovation and digital manufacturing technologies under their supervision, perfectly aligned my professional and personal interests as an entrepreneurial- as well as business-minded engineer. I have shown this interest on different levels during my studies, gathering hands-on, practical experience in international engineering internships at Airbus and BMW or within my startup Honeycrush for automated bee keeping (failed greatly). Continuously learning, though, with the PhD I want to become an expert in the field of Business Model Innovation and value creation. As such it is my dream to successfully build my own company with a particular management focus on Business Model Innovation and digital transformation.

To gain more perspectives and leverage my academic skillset I decided to spend the last term of my M.Sc as a research assistant under the guidance of Prof. Leifer from Stanford University. Quickly caught by the productivity crisis in the manufacturing industry and inspired by the value enhancing capabilities of Business Model Innovations I applied for a PhD in Engineering at the University of Cambridge. For the next three years I will analyse how Business Model Innovations can be paired with radical digital innovations in order to unlock their economic potential.

Elena Gelzinyte
Department of Engineering, University of Cambridge

In 2019 I joined Gábor Csányi's group at the Department of Engineering as part of the SynTech CDT, after completing a BA/MSci degree in Natural Sciences (Chemistry) at the University of Cambridge. The focus of my research is on development of ab initio accurate force fields for small molecule radical reactions, with an application to Cytochrome P450 modelling in mind. This involves atomistic simulations to obtain reference data, systematic exploration of fitting (ML) algorithms and careful testing and evaluation of the resulting interatomic potentials. I hope to continue exploring this field of research.

Spyros Ploussiou
Department of Chemical Engineering and Biotechnology, University of Cambridge

Spyros Ploussiou is a master's student in Chemical Engineering at Cambridge University. As an undergraduate, he was awarded the Jennings Prize for outstanding academic excellence twice by Wolfson College. For two years, Spyros served as a sergeant major in the infantry division of the Cyprus National Guard, where he managed a force of 27 personnel and the logistical network for camp resources. In 2019, Spyros was part of the Silicon Valley Innovation Academy at Stanford University, where his team developed an algorithm for predicting concussion recovery time. His experience at Stanford concluded with an innovation showcase, where his team presented their innovative solution for the healthcare industry to the Silicon Valley community. Spyros made the most out of his time at Stanford,

by extending his social network and developing an entrepreneurial attitude. He aspires to develop a novel business idea that will add value to modern-day society.

My chemical engineering studies encompass a wide range of areas including the pharmaceutical industry and the energy sector. Topics such as fluid dynamics and reaction kinetics lie at the core of processes that define these areas. Optimising such processes from an economic perspective without jeopardising the environment is the criterion that defines a chemical engineer. My undergraduate degree's design group project involved the preliminary design and optimisation of a biochemical plant processing renewable feedstock and outputting biofuels. The project exposed me to a plethora of market and process parameters that had to be accounted for, and I was responsible for its techno-economic analysis. As the co-ordinator in the team, I ensured that our project was progressing through constructive arguments and coherence between the team members. During my time at Stanford University in 2019, I was involved in two different group projects. The first that was based on the field of additive manufacturing, equipped me with the knowledge required to design complex equipment ranging from shoe soles to microfluidic devices. The second which was part of Silicon Valley Innovation Academy, involved the development of an algorithm using Machine Learning with the purpose of predicting concussion recovery time. This algorithm was targeted as an innovative solution for the health care industry. From this experience I developed a deeper understanding of business, innovation, entrepreneurship, and teamwork. I tactfully spoke with different people, assessing preferences and adjusting my own communication style accordingly. In the end, the team achieved a good prediction with a validation error of 15 %, earned the attention of Stanford Medical School heath community and paved the way for further project development. Most recently, in the summer of 2020 I spent 2 months as a Deal Advisory intern at PwC and KPMG, in Cyprus. While at PwC, I was involved in a project concerning the technological transformation of a department store during the COVID-19 pandemic, in Nicosia, Cyprus.

Omar Darwish
Department of Applied Mathematics and Theoretical Physics, University of Cambridge

I studied Physics at the University of Padua, Italy, and its college of excellence, the Galilean School of Higher Education. I had a full scholarship, extra multidisciplinary courses, and other benefits. I am now a Ph.D. student at the Centre for Theoretical Cosmology, approaching my last year. My research is focused on cosmological data analysis and techniques to improve our ability to extract information from the Universe. During my second year of Ph.D., I did an internship at a small start-up, Cambridge Cancer Genomics, exploring a new type of deep learning. In the future, I imagine myself involved heavily in technological advancement (e.g., tinyML). I see this by building my own company and working with other people to reach our goals.

Cosmology is the study of the history of the Universe to reach a deeper understanding of the fundamental laws of nature. Today, cosmologists are stuck: many things work great, and a few others do not work very well. We know that our theories are incomplete. Despite this, they are so good that we are unsure about the right direction that would lead to better ideas. From here, the importance of analyzing more precisely data and extract cleaner

information to understand the Universe. Indeed, better data analysis means it is easier to distinguish models. To help the community reach this goal, others and I measured the cosmic mass by studying the oldest light in the Universe and extracted the information from it by minimizing systematic measurements. In another major project, with another group, we developed a technique to extract faster cosmological information from galaxy surveys. During my internship, I helped the small startup explore a type of neural network (NN), called Bayesian neural network (BNN). They needed this, as standard NNs give predictions (usually) without any uncertainty, while BNNs do.

Akhila Kadgathur Jayaram
Cavendish Laboratory, Department of Physics University of Cambridge

I am an interdisciplinary nanoscientist, currently working in biophysics. My future aspirations are to influence policy, either as a consultant or a policymaker. Previously, I have undertaken research internships in India, UK and Canada which allowed me to gain exposure to a wide variety of scientific problems. I also spent a year in industry as a Materials Science Analyst at GSK, where I worked with an international team dealing with highly business critical projects across manufacturing and R&D. I am also passionate about youth-led entrepreneurial movements. My first experience was with AIESEC Leeds where I was the Vice President for International Exchanges and delivered 20+ exchange experiences during my term. More recently, I was involved in organising Shaping Horizons, a science policy and innovation summit, as a Co-Director.

I also currently lead Polygeia, a global health think-tank comprising of 180+ students lobbying senior leaders on health policy issues. My current research focuses on elucidating the role of lipid membranes in the progression and causation of neurodegenerative disorders. Currently, models that are used in literature are not representative of mammalian membranes and are often too simplistic. My research will aim to improve these models but also develop new techniques which will enable improved fundamental understanding of the role of lipid membranes in disease progression. This in turn, would enable better early diagnosis tools to be adopted. I am also developing a bioelectronic device that would enable high-throughput lipidomics to be conducted in a lab setting, which would be instrumental in enabling the screening of various lipid compositions in a parallel fashion and therefore, act as a diagnostic assay.

Cambridge Judge Business School
Entrepreneurship Centre

EnterpriseTECH PG 1 December 2 2020 – March 5 2021

Project details and team biographies

Email addresses

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Supervision 1	Date:
Supervision 2	Date:
Supervision 3	Date:
Inventor Meeting 1	Date:
Inventor Meeting 2	Date:
Inventor Meeting 2	Date:

Supervisions

We recommend students and supervisor sketch out provisional dates for the three early on. Students should also include at least two further meetings with the inventors to discuss direction and progress.

Length	Supervisions usually last around 2-hours *i.e.* 7- 9 pm.
Evening work	Use evenings whenever possible.
Frequency	The first supervision should happen close to the start of the programme, after the students have defined the project scope using a project initiation document (PID). Supervisors should comment and work with their team to understand the goals. The remaining two supervisions can be midway then towards the end of the programme. The *team communicator* will coordinate the three dates with the supervisor so workflow targets can be met.
Attendees	All students in the team are expected be present (in person or online) for the supervision. Inventors are not present.
Supervision venues	At present, supervisions are a hybrid of in-person (with facemasks) and online. There is restricted access to the CJBS building for the moment, although we hope the situation will improve considerably in the new year. We will not be able to arrange room bookings for the time being.

Supervision 1: technology and opportunity evaluation

Post PID	Review and agree on the content shared in the PID.
Opportunity evaluation	Evaluate the business opportunity by looking at the potential market for the application. What is the actual business opportunity? What is the problem the idea will address and for whom? Who are the customers? What do they really need? Do we know this or are we making assumptions? What other problems do these customers face that could be addressed? What needs to happen for these customers? What questions are you planning for starting primary and/or secondary market research? Who are your KOLs?

Supervision 2: developing the business proposition

Review progress	Review how the team has defined the business opportunity and value proposition, routes to market, market research and potential customers.
First draft of report	The team should share an early draft of their report. S*WOT analysis* - what are the strengths, weaknesses, opportunities and threats to the application of the technology? *Competition* - what competitor technologies exist that do the same thing or substitute technologies? How much do we know? What do you need to find out and how? *Customers* - what are customers doing now to address this problem? How likely are they to change to another solution? What factors will impact on their decision to adopt your product? *Suppliers* - how does the supply chain look? What could create a bottleneck in delivering the product on time and scale? *Replication* - how easy it is for someone else to copy? IP protection, know-how, complexity of integration, cost of setting up etc. What else is in your favour or is a threat? What is the optimal business model? Can you disrupt anything on those models? What advantages are you going to bring? Who are the potential partners that can help take the application to market? Manufacturers, R&D partners, corporations, NGOs, governments, Angels, VCs etc. Who are the early adopters that can validate the market need?

Supervision 3: refining the research and analysis

Tidy-up	Review the team's research, look for gaps in the work and help them refine the analysis. • What is the missing information? • What is the picture for commercialisation in short, mid and long term? • Is the customer VP clear and does it fit the business model? If not what is missing? • What are the most important issues the inventor should be aware of?
Report	Discuss a late stage draft of the report.
Pitch	Discuss content for the team pitch and review pitch deck.
Video	Review and guide the team's storyboard ideas.

Project Initiation Document (PID)

The PID is should be completed by the students only, after discussions with the inventors and supervisor. A PID ensures everyone is on the same page and has a good idea where the team's efforts will be going and in what direction, and that everyone is on board with the plan (as brief and possibly changeable as that may be at this early stage).

IMPORTANT: have your inventor and supervisor agree to its contents then return it along with your provisionally agreed dates foe supervisions and inventor meetings to enterprisetech@jbs.cam.ac.uk by Friday 11 December with the email subject *Project Name: PID*. The questions on the PID will be as follows:

Project Name:

Names of student team members:

Project Brief (*this is a short statement of what your team intends to research and deliver for the project).*

Project Scope *(succinctly explain what you consider to be in scope and out of scope for the project in the given research spell i.e. between the lectures and Pitch Night).*

Project Deliverables *(after reading the student handbook check your team's understanding of the project deliverables. Explain what you hope to deliver.).*

Project Methodology *(explain how the team intends to go about the project work including work streams and deadlines. You may provide a Gantt chart or similar).*

Time Allocation *(agree how much of each team members personal time can be spent on the project. This is so everyone is clear on what other demands there are on their time. Add each team member's name and a line of explanation).*

Team Lead *(who will be your team lead? How did you settle on this person? The task for the team lead is to press through the project methodology and keep everyone to schedule. The lead is not there to influence or control the direction of the project. They are providing a team service).*

Team Communicator (w*ho will be your team communicator? How did you settle on this person? Describe how you plan to communicate within your team, with your supervisor and your inventor).*