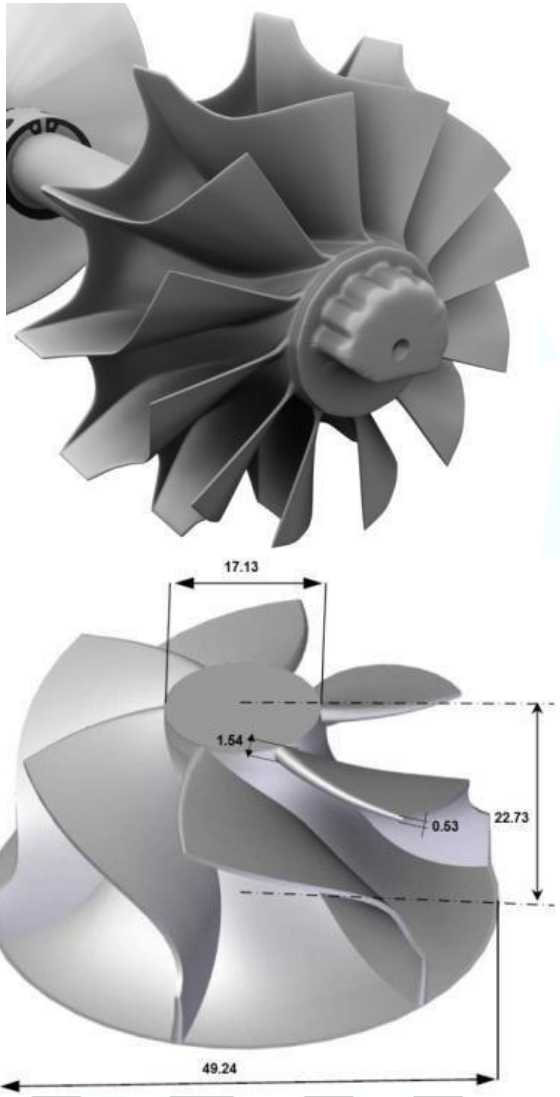
High-priority product: Micro gas turbines

Designation of multi-material multi-functional product:	*Turbochargers and micro gas turbine engines that include ceramic turbines and turbine nozzles*
General description of product (3 – 4 sentences):	*Microturbines are expected to become widespread in distributed power and combined heat and power applications. They are one of the most promising technologies for powering hybrid electric vehicles. They range from hand held units producing less than a kilowatt, to commercial sized systems that produce tens or hundreds of kilowatts. Basic principles of microturbine are based on micro combustion. Micro gas turbines are key components for widely used turbochargers and microgas turbine engines.*
Multi-materials needed/required:	*The material combinations that are considered promising to improve the performance of turbochargers and micro gas turbine engines is the use of ceramic turbines, e.g. silicon nitrides, in combination with metal shafts, e.g. stainless steel. In particular, the multi-material aspects are associated with the design and manufacturing issues in combining ceramic and metal components in turbochargers and micro gas turbine engines, e.g. joining the ceramic turbine and a metal shaft by using invar and thus to avoid the overstress in the contact area.*
Multi-functionality needed/required:	*Substantial improvements in thermal mechanical properties of ceramic turbines and turbine nozzles can be achieve by producing them from silicon nitrides. In particular, the turbines and turbine nozzles will be able to resist impacts and shocks due to their extremely high strength, wear resistance and fracture toughness.*
Expected improvement:	*Microturbine systems have many advantages, such as higher power-to-weight ratio, low emissions and few, or just one, moving part. Other advantages are that microturbines may be designed with foil bearings and air-cooling operating without lubricating oil, coolants or other hazardous materials. Microturbines also have a further advantage of having the majority of the waste heat contained in the relatively high temperature exhaust making it simpler to capture, whereas the waste heat of reciprocating engines is split between its exhaust and cooling system. Ceramic turbines can offer more efficient conversion of heat to mechanical energy. A ceramic turbine can improve turbocharger performance by cutting turbo lag by 1/3[48]. It also helps in increasing speed, allowing temperature to increase up to 1200^{o}C and improve efficiency of related engines. Ceramic turbines are particularly suitable for petrol engines which start-stop frequently and emit too high temperature for Inconel turbines to last.*

Bottlenecks to overcome for reaching the expected improvement	*In spite of the outstanding mechanical and thermal properties, micro silicon nitrides components have not been used as much as they should largely due to the highly demanding fabrication processes. The serial production of silicon nitrides components requires shaping of silicon nitrides powders into green bodies using hard micro moulds by powder injection moulding (PIM) and then compacting the green bodies at a high pressure (10 MPa), high temperature (over 1800^{o}C) and nitrogen protected environment employing gas pressure sintering and hot isostatic pressing sintering processes. The process from design and fabrication of hard micro moulds to producing a green body is both time consuming and expensive, which greatly limit the applications of silicon nitride components. In addition, complex silicon nitride micro components such as microturbines with features sizes down to 100 microns increase even further difficulties in designing and implementing suitable micro tool-making processing chains and also in achieving the necessary accuracy, repeatability and reproducibility in producing serially PIM micro components. Another alternative and promising way to produce serially micro silicon nitrides components is the use of lithography and 3D printing technologies but there are many bottlenecks, the available*

	feedstocks and process capabilities.
Significant Functional requirements:	*Ceramic micro components integrated in turbochargers and micro gas turbine engines should provide extremely high strength, very low thermal expansion, wear and corrosion resistance and fracture toughness and thus make them resistant to impacts and shocks.*
Technical sketch of product (if applicable):	 *A ceramic microturbine wheel*

Name: Organisation: Responsible 4M2020 partner: UoB