UNIVERSITY OF MANITOBA

13-5

CANADA FOUNDATION FOR INNOVATION
Innovation Fund

Notice of Intent

1. Completed NOIs must be submitted by the Associate Dean (Research)/Research Liaison Officer of the "Lead" Unit to the Office of Research Services to: Birtukan.Gebretsadik@umanitoba.ca by May 15, 2018.

Proposed name of project: Additive Manufacturing of Advanced Materials	**Estimated Total Project Costs: $3 Million**
Designated Project Leader/Faculty/Dept: O. A. Ojo, Faculty of Engineering, Department of Mechanical Engineering **CV:** x **List Principal Users/Faculty/Dept:** **1.** O. A. Ojo CV: x **2.** N. Sepehri CV: x **3.** C. Deng CV: x **4.** N. Wu CV: x **5.** G-Z Zhu CV: x **6.** M. Khoshdarregi CV: x	
'Lead' Unit ADR/RLO: Associate Dean of Research, Faculty of Engineering **Name: C. Shafai**	

Briefly describe (max 1 page, 12 pt. font size, 2 cm margins):

- The proposed research and how it is world-class, innovative and demonstrates clear benefits to Canada.
- The infrastructure and how it will enhance the University's existing research capacity.
- The excellence of the team, including expertise and existing collaborations necessary to conduct the proposed research.
- Plans to secure matching funds and the potential funding sources for the operation and maintenance of the infrastructure.

Additive Manufacturing of Advanced Materials

Proposed Research: Additive manufacturing (AM), commonly known as 3D printing, which uses sequential addition of ultra-thin layers of material to fabricate solid components, has been recognized and predicted as a key technology that could revolutionize manufacturing process for many industries. AM has become popular for producing parts from plastics, but will have a much greater commercial impact when it can be used to produce advanced metallic and ceramic components for innovative applications in the aerospace, biomedical, automotive and energy industries. Ultimately, microstructure of materials controls their performance. Notwithstanding the inherent capabilities and potential benefits of the new manufacturing technique, advanced materials, such as superalloys, heat resistant nanostructured alloys, functionally graded materials, intermetallics and metal-ceramic composite materials with capabilities for innovative industrial applications are extremely difficult to produce by AM. These materials are highly susceptible to defects formation such as cracking, porosity, and more importantly, formation of deleterious micro-constituents that degrade their properties. Accordingly, while AM has rapidly evolved, globally, into a world-class research topic of interest, a major area that urgently needs adequate attention to drive innovative use of this emerging technology is material microstructure engineering to induce the required microstructure, prevent deleterious micro-constituents and impart desired properties in difficult-to-process advanced materials during fabrication. Therefore, the main target of this proposed research is to perform systematic collaborative research to address this key challenge through a combination of an in-depth understanding of how various AM process parameters influence microstructure of various advanced materials and precise in-process monitoring and intelligent process control.

Benefits to Canada: AM of advanced materials have the potential to contribute many innovative commercial applications that represent significant economic growth opportunities for both existing and emerging start-up Canadian companies. Presently, the manufacturing sector comprises 10.6% of Canada's entire Gross Domestic Product (GDP) and it has the largest multiplier effect of any industry in Canada, as it generates over $3 in economic activity for every $1 of output. Active support for research on this emerging technology is, therefore, an economically strategic opportunity for Canada due to its vast potential to directly impact Canada's economy. The aerospace, biomedical, automotive and energy sectors have the greatest capacity to adopt and profit from the outcomes of the proposed research. As such, the research will address key issues that currently limit the innovative use of advanced materials in these sectors. AM is poised to revolutionize aerospace, healthcare, custom-fit safety equipment and bio-engineering, and is well suited to produce significant societal impacts. Moreover, AM can help to mitigate environmental impacts by replacing conventional manufacturing processes like casting that consume significant amounts of energy and produce large volumes of hazardous waste. It has been reported that AM can reduce the environmental impact of manufacturing by 70% over conventional processes. Therefore, this proposal offers the potential for beneficial impacts on Canadian society, the economy, and the environment.

Required Equipment and Enhancement of University of Manitoba Existing Research Capacity: To perform the proposed research, an electron beam (EB) melting powder-bed based AM equipment is required for producing various advanced materials; superalloys, heat resistant nanostructured alloys, functionally graded materials, intermetallics and metal-ceramic composite materials, along with accessories needed to perform in-process monitoring and process control. In addition to the EB AM system, an upgrade to a Gleeble thermo-mechanical simulation system at the University of Manitoba is needed to perform physical simulation of the thermo-mechanical conditions involved during the AM process in order to gain insights into the underlying mechanisms of various microstructural phase changes that occur during fabrication. Furthermore, to enable advanced microstructural characterization of the AM materials, an upgrade to the aging electron microscopy and spectroscopy sample preparation facility at the University of Manitoba is also required. AM of advanced materials is a high profile area of study that will attract considerable attention, including new research grants, new students and visiting scientists from other institutions. This increased activity will have direct positive impacts on the Manitoba Institute of Materials at the University of Manitoba, because the research will require the use of their state-of-the-art electron microscopy and spectroscopy facilities for microstructural analyses of the simulated microstructures produced by AM.

Excellence of the Research Team and Existing Collaborations: The research team consists of researchers with prior experience and expertise in the key areas of study involved in the proposed research; influence of processing technique on material microstructure and properties (Drs. Ojo, Deng, Zhu and Wu) and in-process monitoring and intelligent process control (Drs. Sepehri and Khoshdarregi). Dr. Ojo is an international leader in research on laser and electron beam processing of advanced aerospace superalloys. He used physical simulation by Gleeble thermo-mechanical simulator to simulate the rapid thermal cycling of single-pass laser and electron beam joining of aerospace superalloys and was the first to discover and report an underlying non-equilibrium phase reaction responsible for cracking in these alloys during joining. His work is now frequently referenced in the literature on AM manufacturing of difficult-to-process aerospace superalloys. Dr. Ojo has had successful industrial research collaborations with various Canadian and International aerospace companies on processing of aerospace materials including Standard Aero Ltd, Magellan Aerospace, Haynes International in the US and GKN Aerospace (formerly Volvo Aerospace) in Sweden, where he still visits annually to deliver lecture on processing of aerospace superalloys. Internationally, Dr. Ojo collaborates with Dr. Joel Andersson of the University West in Sweden, via co-supervision of 4 PhD student on AM by laser and electron beam based AM systems.With regard to nanomaterials, Dr. Deng has rapidly established his expertise by using theoretical atomistic simulation methods to develop computational models for understanding structural evolution in nanostructured materials during processing. Internationally, Dr. Deng collaborates with Dr. C. Schuh at MIT, USA on the thermal stability of nanocrystalline metals. Dr. Zhu is a Tier II CRC in the design and characterization of structural and functional nanostructured materials. She has developed a new electron microscopy technique for the characterization of advanced materials, which is reported in the prestigious top rank journal, Nature. Dr. Nan Wu expertise is in the development of innovative structural health monitoring schemes for automotive and aerospace structures. He has developed crucial structural health monitoring theoretical models for damage detection and analysis, including the use of functionally graded materials. Dr. Khoshdarregi has extensive past experience and well-cited papers on in-process monitoring and closed loop control of open-architecture machine tools. Dr. Sepehri is an internationally recognised leader in the area of advanced process robotics monitoring and control, who aside from his over 150 journal publications has several Patents in advanced manufacturing systems. Furthermore, the National Research Council (NRC) of Canada, which is establishing a $60 million advanced manufacturing research and development and demonstration facility in Winnipeg, has indicated interest to collaborate with the University of Manitoba on AM of aerospace materials. Members of this proposed research team will be going to Montreal on May 25th 2017 discuss details of the research collaboration, which is envisaged to commence in August 2017, with the NRC research team.

Potential Funding Partners: The research proposed in this application consists of fundamental concepts that are necessary to enable industrial applications of an emerging advanced technology. The work is well suited to attract research funding from both government and industry, such as from the NSERC Discovery, Strategic Partnership and CRD grant programs. Potential industry partners include Magellan Aerospace, Standard Aero Ltd in Winnipeg and Pratt and Whitney Canada in Montreal and GKN Aerospace in Sweden. Dr. Ojo had prior collaborations with Magellan aerospace, Standard Aero Ltd, GKN Aerospace and is pursuing partnership with Pratt and Whiney Canada on processing of aerospace superalloys. The matching funds for the purchase of the equipment requested in this CFI application will be obtained from the Province of Manitoba, possibly also from the NRC and Arcam, the manufacturer of the EB melting AM system. The applicants will negotiate with Arcam to obtain a CFI discount.