REMADE Institute – Request For Information

ADMINISTRATION

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INTRODUCTION

IperionX Limited's (formerly 'Hyperion Metals Limited') (ASX: IPX) mission is to be the leading developer of low carbon, sustainable, critical material supply chains focused on advanced industries including space, aerospace, electric vehicles and 3D printing. IperionX's breakthrough titanium technologies have demonstrated the potential to produce titanium products which are sustainable, 100% recyclable, low carbon intensity and at product qualities which exceed current industry standards. The Company also holds a 100% interest in the Titan Project, covering approximately 11,100 acres of titanium, rare earth minerals, high grade silica sand and zircon rich mineral sands properties in Tennessee, United States.

IperionX believes that its breakthrough technologies in combination with its Titan Project will allow the US to re-shore domestic critical material supply chain, which will directly assist the REMADE Institute to achieve its four primary goals:

1. Develop technologies capable of reducing energy and emissions through a reduction in primary material consumption and an increase in secondary feedstock use in energy-intensive industries,
2. Develop technologies capable of achieving "better than cost and energy parity" for key secondary materials,
3. Promote widespread application of new enabling technologies across multiple industries, and
4. Educate, train, and develop the incumbent and future workforce to support deployment of REMADE technologies.

IPERIONX'S ABILITY TO ACHIEVE THE REMADE INSTITUTE'S PRIMARY GOALS

1. **Develop technologies capable of reducing energy and emissions through a reduction in primary material consumption and an increase in secondary feedstock use in energy-intensive industries**

IperionX's breakthrough technologies have established it as a clear market leader in advanced titanium processing methods that offer low cost, low carbon titanium metal and powders from sustainable all-American recycled metal and critical mineral supply chains.

A technical challenge in titanium metal production is the difficulty in removing oxygen from titanium feedstocks, including scrap metal and titanium ores, and the subsequent propensity of purified titanium metal to rapidly pick-up oxygen and other impurities.

The current standard technology, the Kroll process, addresses these challenges via converting titanium ore (an oxide) into titanium tetrachloride ($TiCl_4$), and then reducing the chloride to titanium metal with magnesium. ***Unfortunately, the incumbent Kroll process is both capital, energy, and carbon intensive*.**

IperionX's breakthrough hydrogen assisted magnesiothermic reduction ("HAMR") technology is a low cost, low-to-zero carbon titanium powder production process invented by Dr. Z. Zak Fang and his team at Blacksand Technology, LLC in collaboration with the University of Utah in conjunction with Boeing and Arconic as industrial partners, and with funding from the DOE's ARPA-E program.

The HAMR technology utilizes hydrogen to destabilize Ti-O, making it possible to turn the reduction of TiO_2 with magnesium from thermodynamically impossible to thermodynamically favored. This allows TiO_2 to be reduced and deoxygenated directly by magnesium to form TiH_2, with low oxygen levels that can meet the needs of the industry. TiH_2 can be further processed to titanium metal through standard industry methods.

IperionX's breakthrough HAMR process reduces the energy intensity and resulting carbon emissions and cost of producing titanium metals. Importantly, with this technology the source material can be 100% recycled titanium scrap material.

The manufacturing of titanium components and structures can generate a large amount of titanium machining chips (this 'scrap' can be over 90% for complex traditionally milled parts). ***This scrap titanium can be sorted, cleaned, and prepared for processing as the source material for the HAMR process.*** This recycling pathway for the can reduce costs and significantly improve the sustainability of titanium metal manufacturing.

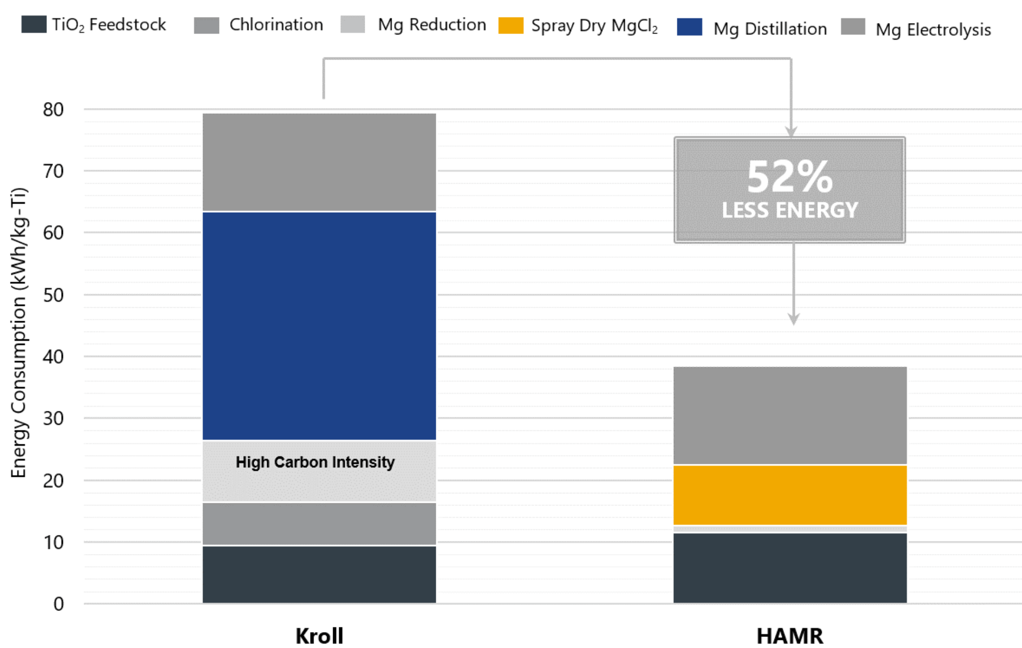
2. Develop technologies capable of achieving "better than cost and energy parity" for key secondary materials

Titanium is not 100% recyclable with the current industry process, as titanium scrap readily absorbs oxygen and therefore remelting requires a mix of new titanium sponge (from the Kroll process) and recycled titanium to maintain homogeneity.

Titanium scrap has a <50% recirculation rate, with most scrap being sold into the Ferrotitanium market. Additionally, 10-20% of new titanium sponge production is typically "off-grade" and sold as Ferrotitanium as current technology does not allow for the iron impurities to be removed from titanium.

The HAMR technology breakthrough of the was the discovery that hydrogen destabilizes the Ti-O bonds making it thermodynamically favorable to reduce Ti-O with Mg and allows for reduction and de-oxygenation of titanium oxides from titanium concentrate and scrap metals and revolutionizes the primary / virgin mineral to metal production and enables 100% recycling of scrap titanium recycling to new titanium metal.

Over US$10m has been invested through the DOE's ARPA-E program and others to develop the HAMR technology from lab scale to pilot scale, and ***IperionX is operating a pilot scale titanium metal and powder plant in Salt Lake City, producing titanium metal from 100% scrap titanium feedstock.***



Given both the absolute reduction in energy consumption of the HAMR process over the Kroll process, and the ability to use 100% recycled scrap as a feedstock, the HAMR technology clearly achieves better than cost and energy parity for the production of titanium metal.

Further information on the research can be found on the University of Utah's website (https://powder.metallurgy.utah.edu/research/hamr.php) and on ARPA-E's website (https://arpa-e.energy.gov/impact-sheet/university-utah-metals).

3. Promote widespread application of new enabling technologies across multiple industries

Titanium is desired by industry for its light weight, high strength to weight ratio, stiffness, fatigue strength and fracture toughness, excellent corrosion resistance, and the retention of mechanical properties at elevated temperatures.

Titanium and titanium alloys are used in diverse areas such as high-performance space, aerospace, defense, automotive components, chemical processing equipment and medical implants. However, a barrier for the widespread use of titanium is the cost associated with manufacturing a finished part, with approximately half of the cost historically associated with fabrication.

Additionally, the use of titanium powder to print 3D parts has been a recent technological breakthrough, allowing the production of parts, including automobiles and aerospace frames and engines, with minimal waste and material loss, resulting in significantly less energy consumption and emissions.

The U.S. market is one of the largest and highest value titanium markets globally due to the significant use of titanium in the high-performance space, aerospace and defense sectors. There is no current titanium sponge production capacity in the U.S. – titanium sponge is the first metal product in the process of converting TiO_2 minerals to titanium metal.

Titanium competes with metals such as aluminum and stainless steel for strength, and corrosion resistance, and while there are several other metals with excellent properties in these applications, none have the same combined superior properties of strength, weight and corrosive resistance as titanium.

IperionX's technologies have the potential to provide a step change in the titanium supply chain process through eliminating process stages, reducing energy consumption, reducing carbon emissions and significantly cutting costs.

IperionX believes these breakthrough technologies offer a pathway to create the lowest cost, lowest carbon titanium components globally, with the ability to be applied across many high value industries, including as a substitute for inferior metals such as stainless steel and aluminum.

4. Educate, train, and develop the incumbent and future workforce to support deployment of REMADE technologies.

In developing its titanium metal technologies and Titan Project, IperionX is actively educating, training, and developing its workforce to support deployment of a technology that achieves the institute's primary goals. In 2021/2022 alone, IperionX employed over 15 full time staff, as well as 2 interns at its Pilot Plant in Utah, and is supporting 2 post-doctorate graduates from the University of Utah and has established the IperionX Scholarship Fund at the University of Utah, issuing 5 scholarships in metallurgical engineering, process engineering and materials science to date.

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SELECT RFI RESPONSES

Category 1.3: Partnerships

2. How might coordination of research efforts with other DOE initiatives help REMADE reduce energy and emissions associated with industrial-scale materials production, processing, and end-of-life (EOL) disposition and advance specific research directions REMADE is pursuing?

A common challenge in the development of new technologies is moving beyond R&D and proof of concept, through to scale up, commercialization and widespread application of the new technology. This can be for various reasons, including:

1) Lack of capital for private organizations to commercialize a technology beyond R&D stage
2) Sunk capital in incumbent technology & associated manufacturing facilities means manufacturers are resistant to the high capital cost of implementing new technologies at industrial scale
3) The unit cost of product produced via new technologies may only be attractive at industrial scale application, yet industry may not choose to apply new technologies at industrial scale until unit costs are attractive (a "chicken and egg" scenario)

Coordination efforts with other DOE initiatives have the potential to significantly help REMADE reduce energy and emissions associated with industrial-scale materials production, processing, and end-of-life disposition and advance specific research directions REMADE is pursuing through mitigation any of the above challenges.

A direct example of this would be a collaboration between REMADE and the DOE Loan Program Office's Advanced Technology Vehicles Manufacturing (ATVM) program. The ATVM program includes a focus on manufacturers of components or materials that support eligible vehicles' fuel economy performance, including materials for light-weighting, such as titanium.

A collaboration with the ATVM program regarding the early identification of technologies that will help reduce energy and emissions in vehicles, and collectively assisting to overcome the challenges of commercialization, will significantly increase the likelihood of transformational materials technologies reaching industrial-scale production.

Category 2.1: Strategy

1. Are there other key performance indicators REMADE should consider besides emissions, material consumption, and energy reduction (see Appendix B for a full list of the TPMs)? For other metrics, please briefly describe how these metrics would be quantified.

IperionX believes that the REMADE key performance indicators are suitable to help measure progress towards the institute goals and the overall goals of the Manufacturing USA Institutes. Notably, IperionX believes that its titanium metal technologies have the ability to meet or exceed all listed KPIs.

Given that the goals of the REMADE and Manufacturing USA Institutes are focused upon domestic manufacturing and supporting the U.S. manufacturing ecosystem, IperionX recommends that additional KPIs are included that assess the current state of a particular U.S. manufacturing supply chain, and that supply chain's ability to withstand shock from foreign impacts outside the U.S.'s control.

An example KPI may be ***"Demonstrate that no more that 50% of Primary Feedstock and no more than 33% of Secondary Feedstock is reliant on supply from foreign nations."***

If this KPI threshold is not met, then additional resources should be allocated to ensure that particular domestic source of feedstock can be established in order to insulate the individual U.S. manufacturing chain from external shocks. A clear example of this is titanium; the U.S. is the largest global manufacturer of titanium metal products, but currently has no Primary Feedstock production capability (in the form of titanium sponge), and limited supply of suitable quality Secondary Feedstocks, typically in the form of titanium scrap.

2. One of REMADE's Technical Performance Metrics (TPMs), to lower greenhouse gas emissions, is aligned to the administration's focus on industrial decarbonization. Are their technology development opportunities related to industrial decarbonization that REMADE should consider pursuing? If so, please identify these technology development topics and explain why REMADE should consider them.

As detailed on pages 1-3 of this submission, IperionX's technologies are a proven method of reducing the energy intensity and resulting carbon emissions of producing titanium metal. Importantly, with these technologies the source material can be 100% recycled titanium scrap material.

The technologies have been developed by Dr. Z. Zak Fang and his team at Blacksand Technology, LLC in collaboration with the University of Utah with Boeing and Arconic as industrial partners and with significant funding from the DOE's ARPA-E program.

IperionX would be pleased to work with REMADE regarding accelerating the development, scale up and commercialization of the technologies.

3. Based on REMADE's mission space, are there other pressing national needs and challenges not yet represented in REMADE's mission, goals, and Focus Areas (see background section)?

A critical national need / challenge not yet represented in REMADE's mission, goals, and Focus Areas is the security of domestic supply of feedstocks to meet REMADE's four primary goals.

Titanium is a clear example: the U.S. now has minimal commercial titanium sponge production capacity, which is the primary feedstock for the production of titanium metal products. Titanium is a critical material for many advanced U.S. manufacturing industries such as defense systems, including fighter jets, bombers, attack aircraft, transports and helicopters, with newer aircraft using increased amounts of titanium.

Further, absent new technologies such as IperionX's HAMR process, titanium is not 100% recyclable as titanium scrap readily absorbs oxygen and therefore remelting requires a mix of new titanium sponge (from the Kroll process) and recycled titanium to maintain homogeneity. Titanium scrap has a <50% recirculation rate, with most scrap being sold into the ferrotitanium market. Additionally, 10-20% of new titanium sponge production is typically "off-grade" and sold as ferrotitanium as current technology does not allow for the iron impurities to be removed from titanium.

In 1988, U.S. titanium sponge production could fulfill all domestic consumption. By 2018, production at the last operational sponge facility fulfilled just 28% of domestic consumption and by 2021 the U.S. had no meaningful production capacity. In an emergency scenario where imports were disrupted, U.S. downstream producers may not be able to continue normal melting and fabrication operations without access to titanium sponge and scrap imports. Absent domestic titanium sponge production capacity, the U.S. titanium manufacturing is completely dependent on imports of these feedstocks.

Category 2.2: Technology

3. Where should REMADE focus its efforts relative to electric vehicles and solar power, which will both see increased domestic adoption in the next 10 years? What new remanufacturing or recycling opportunities and challenges will these products create?

Given REMADE's primary goals, it should focus on technologies with a meaningful ability to deliver a step change in reduction in emissions, including both the absolute light weighting of electric vehicles, but also the substitute of high carbon materials in vehicles for lower carbon materials.

Titanium offers excellent strength to weight ratio, high performance in corrosive, high temperature and high stress environments, but has been historically limited in use due to high costs. Today, stainless steel and aluminum are the primary metals used in place of titanium, but their production remains a substantial source of emissions.

- Steel production accounts for approximately 8.5% of global CO_2 emissions while aluminum accounts for as much as 2%
- 2.9 tonnes of CO_2 are produced per tonne of stainless steel and approximately 12 tonnes of CO_2 are produced per tonne of aluminum

IperionX's titanium metal technologies provide a pathway to low cost, low-to-zero carbon, recyclable, and traceable titanium product in many vehicle applications, including battery packs for EVs as well as widespread applications in heavy haulage. Based on studies by the NACFE, titanium used for light-weighting in the largest, Class 8 trucks has the potential for the significant weight reductions and the ability to massively increase their haul capacity compared to current largely steel-based trucks, which in turn requires less truck-miles on the road to deliver the same payload, with a huge potential reduction on CO_2 emissions as a result.

4. What megatrends, such as climate change, resource scarcity, and technological breakthroughs, should REMADE proactively incorporate in its research agenda as it transitions toward self-sustainment?

As highlighted in the responses to questions 2.1.2 and 2.1.3, REMADE's ability to transition toward self-sustainment and encourage long-term involvement by U.S. manufacturers will be limited by U.S. manufacturer's confidence in their ability to securely and consistently source key feedstocks.

Given current geopolitical tensions with Russia and the rise of China, IperionX recommends REMADE proactively incorporate the ability to domestically source feedstocks (primary and secondary) in its research agenda and prioritization of new technologies.