

<b>Fiscal Year:</b>	FY 2021	<b>Task Last Updated:</b>	FY 09/22/2022
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<b>Project Title:</b>	Medical Oxygen Delivery System in Exploration Atmosphere Minimizing the Risk of Fire		
<b>Division Name:</b>	Human Research		
<b>Program/Discipline:</b>			
<b>Program/Discipline--Element/Subdiscipline:</b>	TRISH--TRISH		
<b>Joint Agency Name:</b>		<b>TechPort:</b>	Yes
<b>Human Research Program Elements:</b>	None		
<b>Human Research Program Risks:</b>	None		
<b>Space Biology Element:</b>	None		
<b>Space Biology Cross-Element Discipline:</b>	None		
<b>Space Biology Special Category:</b>	None		
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<b>Zip Code:</b>	96822	<b>Congressional District:</b>	1
<b>Comments:</b>			
<b>Project Type:</b>	Ground	<b>Solicitation / Funding Source:</b>	2020 TRISH-RFA-2001-PD: Translational Research Institute for Space Health (TRISH) Postdoctoral Fellowships
<b>Start Date:</b>	09/01/2020	<b>End Date:</b>	08/31/2022
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<b>No. of PhD Candidates:</b>		<b>No. of Master' Degrees:</b>	
<b>No. of Master's Candidates:</b>		<b>No. of Bachelor's Degrees:</b>	
<b>No. of Bachelor's Candidates:</b>		<b>Monitoring Center:</b>	TRISH
<b>Contact Monitor:</b>		<b>Contact Phone:</b>	
<b>Contact Email:</b>			
<b>Flight Program:</b>			
<b>Flight Assignment:</b>			
<b>Key Personnel Changes/Previous PI:</b>			
<b>COI Name (Institution):</b>	Ohta, Aaron Ph.D. ( MENTOR: University of Hawaii, Honolulu )		
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	<p><b>POSTDOCTORAL FELLOWSHIP</b></p> <p>Astronaut's health is critical to the success of space exploration missions. Hence, onboard medical interventions may require addressing planned and unplanned health issues. NASA's recent change in Exploration Atmosphere to 8.2 psia and 34% Oxygen (O<sub>2</sub>) increased the risk of mild hypobaric hypoxia. The primary treatment for hypoxia is the administration of supplementary medical-grade oxygen, most commonly through the means of an oxygen mask. Currently, NASA uses a portable oxygen ventilator to supply medical-grade oxygen which increases the oxygen concentration of the closed vehicle due to oxygen-enriched exhalation by the patient, which increases the likelihood of fire. This research effort aims to design an oxygen delivery system that is able to reversibly absorb the oxygen from the exhaled air of the patient through a chemical reaction. The system is comprising of an airtight, soft-cushioned, transparent, and low breathing resistance mask. The air inlet of the mask is connected to the ventilator, and the outlet is connected to a reservoir bag through a valve which allows the air to flow unidirectional out from the mask. The other end of the reservoir bag is fitted with an electric valve controlled by the signal from an embedded Zirconium oxygen sensor. The valve remains closed when the oxygen concentration inside the bag is higher than room air restricting the oxygen-enriched air to mix with room air. In addition, the inner surface of the reservoir bag is coated with cationic multimetallic crystalline cobalt complexes ([{CO<sub>2</sub>(bpdp)(O<sub>2</sub>)}<sub>2</sub>(bdc)](BF<sub>4</sub>)<sub>4</sub>·5H<sub>2</sub>O·MeOH(2a(BF<sub>4</sub>)<sub>4</sub>·5H<sub>2</sub>O·MeOH)) which reversibly, selectively, and stoichiometrically chemisorb dioxygen from the air exhaled by the patient. Dioxygen absorption by BF<sub>4</sub><sup>-</sup> salt is a reversible process where complete desorption takes place when the salt is heated to 120°C. An indium tin oxide (ITO) coated transparent heater fabricated over the reservoir facilitates the oxygen desorption in case the BF<sub>4</sub><sup>-</sup> salt is saturated.</p>
<p><b>Task Description:</b></p>	
<p><b>Rationale for HRP Directed Research:</b></p>	<p>According to NASA's Human Research Program evidence report titled, "Risk of Hypobaric Hypoxia from the Exploration Atmosphere," published in November 2015, the future human exploration missions will require a robust, flexible Extravehicular Activity (EVA) architecture not provided with existing approved operational pre-breath protocols. Therefore, it may be met using a reduced-pressure cabin atmosphere, which could result in compromised health and performance to the crewmembers due to exposure to mild hypobaric hypoxia. The primary treatment for hypoxia is the administration of supplementary medical-grade oxygen, most commonly through the means of an oxygen mask. The current medical oxygen requirement aboard the International Space Station (ISS) is met using 100% oxygen from high pressure oxygen tanks. Using 100% oxygen can increase the risk of fire. The addition of oxygen from the oxygen-enriched exhalation into the close vehicle environment quickly violates NASA Flight Rules to not exceed greater than 30% oxygen (or Exploration Atmosphere 34% O<sub>2</sub>) concentration, increasing the likelihood of a fire on NASA vehicles. Specifically, within 20-30 minutes on the ISS, a localized high-percentage oxygen bubble forms around the patient, and within 12 hours, the entire cabin exceeds NASA Flight Rules regarding oxygen concentration. The proposed technology, if successful, would enable the delivery of medical oxygen to a sick or injured astronaut and simultaneously reduce the spaceflight cabin fire hazard risk, improving NASA's Human Research Program Exploration Medical Capabilities, the ISS Health Maintenance System, and the Commercial Crew Program.</p>
<p><b>Research Impact/Earth Benefits:</b></p>	<p>Astronaut's health is critical to the success of space exploration missions. Hence, onboard medical interventions may require addressing planned and unplanned health issues. NASA's recent change in Exploration Atmosphere to 8.2 psia and 34% oxygen (O<sub>2</sub>) increased the risk of mild hypobaric hypoxia. The primary treatment for hypoxia is the administration of supplementary medical-grade oxygen, most commonly through the means of an oxygen mask. Currently, NASA uses a portable oxygen ventilator to supply medical grade oxygen, which increases the oxygen concentration of the closed vehicle due to oxygen-enriched exhalation by the patient, which increases the likelihood of fire. This research effort aims to design an oxygen delivery system that is able to reversibly absorb the oxygen from the exhaled air of the patient through a chemical reaction. The system is comprised of an airtight, soft-cushioned, transparent, and low-breathing resistance mask. The air inlet of the mask is connected to the ventilator, and the outlet is connected to a reservoir bag through a valve which allows the air to flow unidirectionally out from the mask. The other end of the reservoir bag is fitted with an electric valve controlled by the signal from an embedded Zirconium oxygen sensor. The valve remains closed when the oxygen concentration inside the bag is higher than room air, restricting the oxygen-enriched air to mix with room air. In addition, the inner surface of the reservoir bag is coated with cationic multimetallic crystalline cobalt complexes ([{CO<sub>2</sub>(bpdp)(O<sub>2</sub>)}<sub>2</sub>(bdc)](BF<sub>4</sub>)<sub>4</sub>·5H<sub>2</sub>O·MeOH(2a(BF<sub>4</sub>)<sub>4</sub>·5H<sub>2</sub>O·MeOH)) which reversibly, selectively, and stoichiometrically chemisorb dioxygen from the air exhaled by the patient. Dioxygen absorption by BF<sub>4</sub><sup>-</sup> salt is a reversible process where complete desorption takes place when the salt is heated to 120°C. An indium tin oxide (ITO)-coated transparent heater fabricated over the reservoir facilitates the oxygen desorption in case the BF<sub>4</sub><sup>-</sup> salt is saturated.</p> <p>Key findings: Most other efforts to address the above problem use an oxygen concentrator that pulls and concentrates oxygen out of the ambient environment, instead of compressed oxygen, to supply medical-grade oxygen to a patient. In contrast to the oxygen concentration approach, this research effort uses an oxygen absorber to remove excess oxygen from the patient's exhaled air. Year-1 of this project focused on the feasibility of the approach. In Year-1, a reversible oxygen absorber has been synthesized, and its oxygen absorption/desorption is characterized.</p>
<p><b>Task Progress:</b></p>	<ol style="list-style-type: none"> <li>1. The cobalt complex (cobalt tetrafluoroborate) is synthesized as the oxygen absorber. It absorbs oxygen at room temperature and pressure in less than a second upon exposure to the air.</li> <li>2. The complex desorbs over 85% of the absorbed oxygen at 100°C.</li> <li>3. In over nine cycles of reversible oxygen absorption and desorption (thermogravimetric analysis), only a marginal decrease in reversibility in oxygen uptake was observed. The weight loss and gain on the final cycles amount to a 99% yield, demonstrating stoichiometric oxygenation and deoxygenation.</li> </ol> <p>Impact of the key findings on hypotheses: In order to remove the excess oxygen from the patient's exhaled air, the oxygen absorber needs to absorb oxygen in real-time in a subsecond. Preliminary results show that the complex can absorb oxygen in less than a second. Also, the feasibility of the proposed system depends on the low-power oxygen desorption capability and oxygen sorption/desorption process, over many cycles, without any loss of activity. The experiment results show that the cobalt complexes desorb over 85% oxygen at 100°C, 1 atm pressure. In contrast, the lowest reported temperature for a reversible oxygen uptake material is in the range of 200-300°C, or at high pressure. The complex demonstrates stoichiometric oxygenation and deoxygenation over nine consecutive cycles. The key findings show that the complex is a potential material for the proposed oxygen delivery system. However, further</p>

<p>experiments are required to quantify the oxygen absorption parameters and characterize and optimize the mass/power/volume of the absorption/desorption cycles.</p> <p>Proposed research plan for the coming year: We plan to synthesize other cationic multimetallic cobalt complexes (cobalt hexafluorophosphate) and characterize reversible sorption cycle, oxygen selectively, and stoichiometric activities. Next, the performance of the tetrafluoroborate and hexafluorophosphate salt will be compared to select the best material. Then, we plan to study and select the best methods of immobilization of these complexes in membranes and polymers. Also, we will prototype the oxygen delivery system consisting of a mask and a reservoir bag coated with the oxygen absorber. The reservoir bag will hold the exhaled air momentarily for oxygen absorption, and facilitate desorption by heating when the absorber is saturated.</p>	
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