World Academy of Science, Engineering and Technology
International Journal of Health and Medical Engineering
Vol:17, No:04, 2023

Fire Safe Medical Oxygen Delivery for Aerospace Environments

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Abstract : Atmospheric pressure and oxygen (O2) concentration are critical life support parameters for human-occupied aerospace vehicles and habitats. Various medical conditions may require medical O2; for example, the American Medical Association has determined that commercial air travel exposes passengers to altitude-related hypoxia and gas expansion. It may cause some passengers to experience significant symptoms and medical complications during the flight, requiring supplemental medical-grade O2 to maintain adequate tissue oxygenation and prevent hypoxemic complications. Although supplemental medical grade O2 is a successful lifesaver for respiratory and cardiac failure, O2-enriched exhaled air can contain more than 95 % O2, increasing the likelihood of a fire. In an aerospace environment, a localized high concentration O2 bubble forms around a patient being treated for hypoxia, increasing the cabin O2 beyond the safe limit. To address this problem, this work describes a medical O2 delivery system that can reduce the O2 concentration from patient-exhaled O2-rich air to safe levels while maintaining the prescribed O2 administration to the patient. The O2 delivery system is designed to be a part of the medical O2 kit. The system uses cationic multimetallic cobalt complexes to reversibly, selectively, and stoichiometrically chemisorb O2 from the exhaled air. An air-release sub-system monitors the exhaled air, and as soon the O2 percentage falls below 21%, the air is released to the room air. The O2-enriched exhaled air is channeled through a layer of porous, thin-film heaters coated with the cobalt complex. The complex absorbs O2, and when saturated, the complex is heated to 100°C using the thin-film heater. Upon heating, the complex desorbs O2 and is once again ready to absorb or remove the excess O2 from exhaled air. The O2 absorption is a sub-second process, and desorption is a multi-second process. While heating at 0.685 °C/sec, the complex desorbs ~90% O2 in 110 sec. These fast reaction times mean that a simultaneous absorb/desorb process in the O2 delivery system will create a continuous absorption of O2. Moreover, the complex can concentrate O2 by a factor of 160 times that in air and desorb over 90% of the O2 at 100°C. Over 12 cycles of thermogravimetry measurement, less than 0.1% decrease in reversibility in O2 uptake was observed. The 1 kg complex can desorb over 20L of O2, so simultaneous O2 desorption by 0.5 kg of complex and absorption by 0.5 kg of complex can potentially continuously remove 9L/min O2 (~90% desorbed at 100°C) from exhaled air. The complex is synthesized and characterized for reversible O2 absorption and efficacy. The complex changes its color from dark brown to light gray after O2 desorption. In addition to thermogravimetric analysis, the O2 absorption/desorption cycle is characterized using optical imaging, showing stable color changes over ten cycles. The complex was also tested at room temperature in a low O2 environment in its O2 desorbed state, and observed to hold the deoxygenated state under these conditions. The results show the feasibility of using the complex for reversible O2 absorption in the proposed fire safe medical O2 delivery system.

Keywords : fire risk, medical oxygen, oxygen removal, reversible absorption
Conference Title : ICAM 2023 : International Conference on Aerospace Medicine
Conference Location : London, United Kingdom
Conference Dates : April 17-18, 2023