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Molecular sieve vacuum swing adsorption purification and radon reduction system for gaseous dark matter and rare-event detectors

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SF6 has become of interest as a negative ion drift gas for use in directional dark matter searches. However, as for other gas targets in such searches, it is important that contamination gases can be removed. This includes radon gas contamination that can decay, producing unwanted background events able to mimic genuine signals, but also outgassing and leaking introduce contaminants such as water, oxygen and nitrogen, which can capture interaction-produced electrons, thus suppressing signals. We present here a novel molecular sieve (MS) based gas recycling system that offers a solution for the simultaneous removal of both radon and common impurities from SF6. The apparatus has the additional benefit of minimising the total amount of gas required in experiments and utilises a Vacuum Swing Adsorption (VSA) technique for continuous, long-term operation. The gas system's capabilities were tested with a 100 L low-pressure SF6 Time Projection Chamber (TPC) detector. For the first time, we present a newly developed low-radioactive MS type 5A, specifically engineered for this study. This material was found to emanate up to 98% less radon per radon captured compared to commercial counterparts, representing the lowest known emanation at the time of writing. Coupled with this new MS, the gas system reduced the intrinsic radon activity in the detector to 0.8 +/- 6.4 mBq, within error of the radon measurement apparatus background. MS types 3A and 4A further mitigated gain deterioration, sustaining signal for 340 hours until detector operation was terminated, compared to 50 hours without the system. These results demonstrate that a VSA gas recycling system coupled with suitable MSs can reduce intrinsic radon activity and extend detector operation in an SF6 gas-based directional dark matter detector.

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