OPERATION OF PNEUMATICALLY-ACTUATED MEMBRANE-BASED MICRODEVICES DESIGNED FOR *IN SITU* ANALYSIS OF EXTRATERRESTRIAL ORGANIC MOLECULES AFTER PROLONGED STORAGE AND AT NEGATIVE GRAVITY. Z. Duca[a], G. Tan[a], T. Cantrell[a], M. Van Enige[a], M. Dorn[a], M. Cato[a], N. Speller[a], A. Pital[a], R. Mathies[b], and A. Stockton[a†]. [a]Georgia Institute of Technology, Atlanta, GA. [b]University of California, Berkeley, CA 94720. †Corresponding author: amanda.stockton@chemistry.gatech.edu; 901 Atlantic Dr., Atlanta, GA 30332, Rm. 1102G.

Introduction: Programmable microfluidic architectures (PMAs) are powerful arrays of normally-closed, pneumatically-actuated monolithic membrane microvalves capable of conducting complex fluid manipulation on the microscale, including dilutions, mixing, transfer, reactions, etc…. These microvalve systems lie at the heart of lab-on-a-chip organic analyzers, specifically those using microcapillary electrophoresis (μCE) with laser-induced fluorescence (LIF) like the Mars Organic Analyzer (MOA) and Enceladus Organic Analyzer (EOA) concepts under development by Berkeley Space Science Laboratory.

Despite having superb resolution and ultra-low sub-parts-per-trillion limits of detection for compound classes including amines, amino acids, aldehydes, ketones, carboxylic acids, polycyclic aromatic hydrocarbons, and thiols,[1] these systems have not seen wide-scale deployment in spaceflight due in part to a misperception that the microvalves have a limited shelf-life due to irreversible bonding of the PDMS elastomer to the glass substrate. A further criticism has centered around a misplaced concern about operational dependence on a specific orientation in a gravitational field.

Results: We tested a MOA prototype microdevice fabricated in 2005 and demonstrated that it retained full functionality after 10 years of storage in ambient conditions. All pneumatically-actuated valves opened after vacuum cycling using 500 ms pulses at -950 mbar from STP.[2] Figure 1 depicts a valve opening at -750 mbar from STP. An open valve is indicated when the shadow of the valve appears more bubble-like with a stronger reflection.

With these valves, we transferred fluid through the microdevice by operating multiple valves in series sequentially to form a peristaltic pump. Pumping rates for each were determined by measuring the required amount of time for transfer of 50 μL of fluid. Maximum rates were calculated to be 122 ± 8 μL/min when right-side up and 114 ± 14 μL/min when upside down (Fig. 2), indicating successful future operation both after prolonged storage and in multiple orientations with respect to a g-field.

Conclusions: Automated microfluidic systems are ideal for assays requiring miniaturized set-ups, like those designed for field portability or space flight. These devices for both terrestrial and extraterrestrial applications need to be robust to prolonged storage, and this work shows that Mathies/Grover-style normally-closed monolithic membrane microvalves have this capability. A further requirement for space flight, especially microgravity applications, is that microfluidic manipulation must be independent of device orientation within a gravitational field. The ability of these microvalves to transfer fluid both right-side up and upside down demonstrates the capability of fluidic manipulation independent of orientation with these systems. Further work to ready the system for space flight must demonstrate microdevice functionality after extreme swings in temperature and vibrational conditions. The completion of these further objectives will confirm the value of PMA-based microdevices for fluidic manipulation in planetary missions.

References: [1] Kim J. et al. (2016) *LOC*, 16: 812-819. [2] Duca Z. et al. (2015) *EPSC*, Abstract # 416.

Figures:

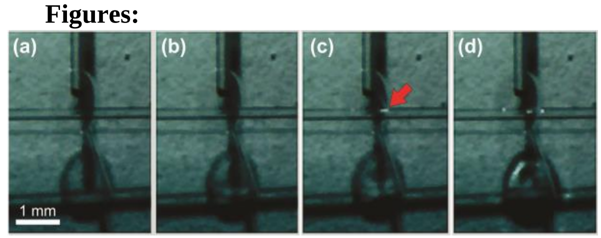

Fig. 1: Still images of a video capturing a microvalve open after 5 hours of vacuum cycling at -750 mbar from STP. (a) Closed valve under no vacuum (t = 0). (b) Closed valve under vacuum (t = 4:00:00). (c) Valve beginning to open under vacuum (t = 4:54:03). (d) Opened valve under vacuum (t = 5:00:00).

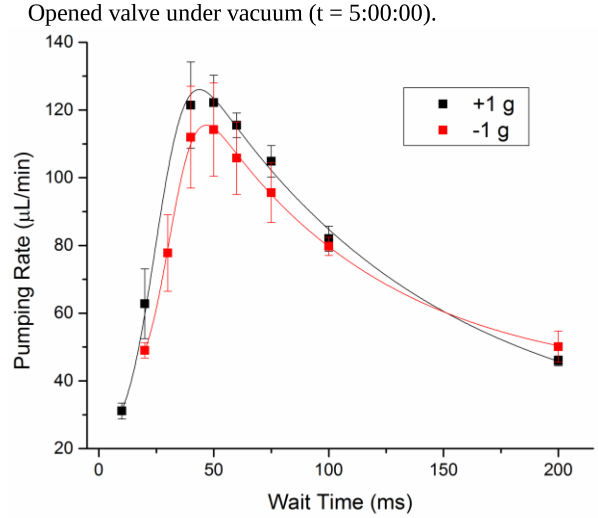

Fig. 2: Characterization of the pumping rate dependence on valve actuation wait times. (Black) Right-side up actuation. (Red) Upside down actuation.