



Development of Enceladus ice analogues for *in situ* analysis

Grace Richards, Victoria Pearson, Manish Patel, Geraint Morgan, and Simon Sheridan

AstrobiologyOU, The Open University, Milton Keynes, United Kingdom (grace.richards@open.ac.uk)

Introduction

The surface of Enceladus could provide one of the best places in our Solar System to investigate the potential for life. Material from plumes seen emanating from Enceladus' South Polar Region^[1], which are believed to be sourced directly from the subsurface ocean, is deposited onto the satellite's icy surface^[2]. Rapid resurfacing means that material in this area has not been heavily processed by radiation, so could be an excellent indicator of oceanic composition^[3, 4]. To date, the only surface species detected with certainty are H₂O and CO₂^[5], with NH₃, CH₄ and low molecular weight organics tentatively detected^[6, 7]. More in depth analysis will only come from future missions to the Saturnian system.

The main aim of this work is to develop Enceladus ice analogues of a range of plausible compositions in conditions representative of the surface. The analogues will then be analysed using instrumentation that could be deployed on future missions. A cryogenic vacuum system has been designed in order to replicate the surface environment and grow ices. The analogues grown will be used to test protocols and analytical techniques relevant to future missions. They will then be subjected to simulated space weathering in order to cover all expected possibilities for different surface components and their fate. We will present the preliminary data of the ices grown and the results of testing of the system to ensure it is operating at optimum conditions.

Methods

In order to grow and analyse ices in conditions representative of Enceladus' surface, a vacuum chamber, previously used for analysis of pure H₂O ice for the development of the Lunar Volatiles Mobile Instrumentation (LUVMI) rover^[8], was repurposed.

The chamber has a 35 L capacity and two vacuum pumps that can achieve internal pressures of 10⁻⁷ mbar. The chamber is also fitted with ports to allow it to be connected to analysis equipment such as a GC-MS. The analogues are grown within a sample holder made out of copper piping wrapped around a copper cooling plate. Liquid nitrogen is injected into the chamber and flows through the piping to cool it down to temperatures of -140 °C. Gas mixtures are injected into the chamber, so that they are condensed onto the cold sample holder and form ices. The system is currently undergoing preliminary calibration and testing in order to optimise operating procedures.

H₂O and H₂O-salt mixtures will be inserted into the sample holder as liquids, then cooled and frozen, before the gas mixtures are inserted. A table showing the preliminary ice mixing ratios can be seen in Table 1. These preliminary compositions are based on upper limits estimated for surface components^[5, 7, 9, 10]. The ices grown will be analysed initially using a GC-MS in order to fully characterise both them and the cryogenic system.

Table 1. Expected mixing ratios for ices

Surface Component	Mixing Ratio			
	Ice 1	Ice 2	Ice 3	Ice 4
H ₂ O	99%	98%	98%	96%
CO ₂	1%	1%	1%	1%
NH ₃	-	2%	2%	1.5%
CH ₄	-	-	2%	1%
NaCl	-	-	-	0.5%

Currently, the main system has the capabilities to be connected to a GC-MS, but in order to preserve the ices while in transport to other pieces of equipment for further experiments, an additional system is required. This system is in development, and is designed to replicate a perfect sample oven onboard a spacecraft. A series of valves connects to an external mini chamber, which is capable of being removed from the main system. Within the mini chamber, the sample holder is connected to an external copper bar, which is submerged in liquid nitrogen in order to cool the samples. This allows the ices to be kept in relatively pristine conditions over a longer period of time while being transported. The effects of thermal and vacuum leaks on the ices within the chamber will be determined, in order to mimic potential issues with sample handling onboard a lander.

The preliminary results of ice analogue development, including physical and compositional characterisation, will be presented. In addition, the limitations of the system and how potential instrumentation issues during a mission could affect Enceladus ices will also be presented.

Future work will include investigating the effects of space weathering on the ices and their subsequent analysis. The main focus will be on impacts that are representative of E-ring grains colliding with the surface and will be investigated using a Van de Graaff Dust Accelerator.

References

- [1] Porco, C et al. (2006) *Science* **311** 1393-1401
- [2] Kempf, S et al. (2018) *Enceladus and the icy moons of Saturn* 195-210
- [3] Kempf, S et al. (2008) *Icarus* **193** 420-437
- [4] Howett, C et al. (2018) *Enceladus and the icy moons of Saturn* 342-360
- [5] Brown, R et al. (2006) *Science* **311** 1425-1428
- [6] Brown, R et al. (2004) *Space Science Reviews* **115** 111-168
- [7] Waite, J et al. (2006) *Science* **311** 1419-1422
- [8] Gancet, J et al. (2017) *13th Symposium on Advanced Space Technologies in Robotics and Automation* 1-8
- [9] Emery, J et al. (2005) *Astronomy & Astrophysics* **435** 353-362
- [10] Postberg, F et al. (2009) *Nature* **459** 1098-1101