Pulsed Plasma Discharge Drilling: Enabling Deep Subsurface Access to Mars' Polar Layered Deposits

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Program: Spontaneous

Project Objective:

The objectives of this Spontaneous R&TD were:

1. To assess the fundamental feasibility of using electrical breakdown between two ice-embedded electrodes to promote fragmentation.
2. To demonstrate the utility of glow-discharge plasma in inducing phase change.
3. To approximate the energetics of plasma drilling and perform comparisons against mechanical and hot-tip melt probe methods.

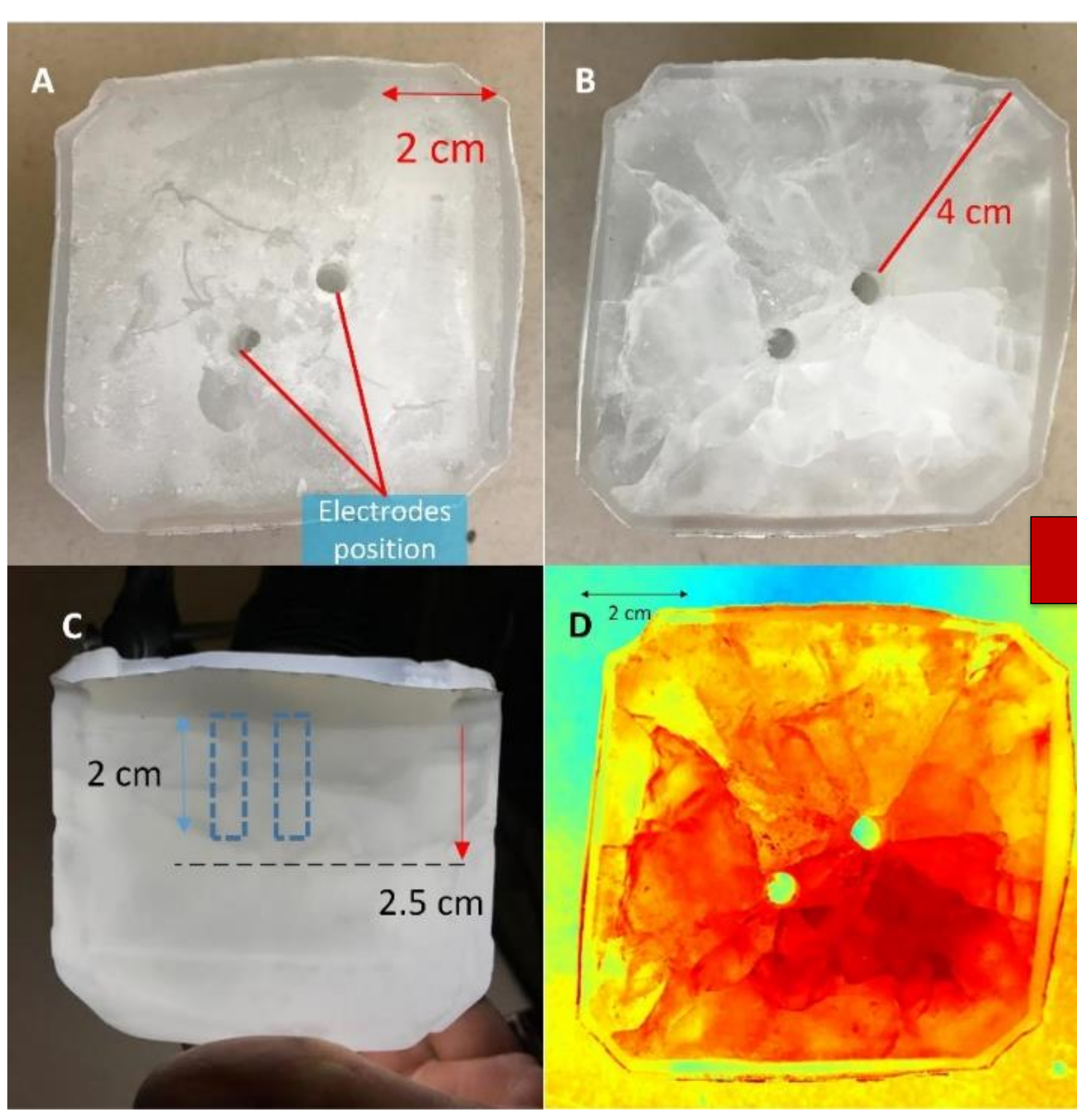
FY18/19 Results:

Can ice be fractured by low-energy plasma pulses?
Yes! Despite early skepticism, a single 20 – 100 J pulse is capable of liberating several cubic centimeters of ice.

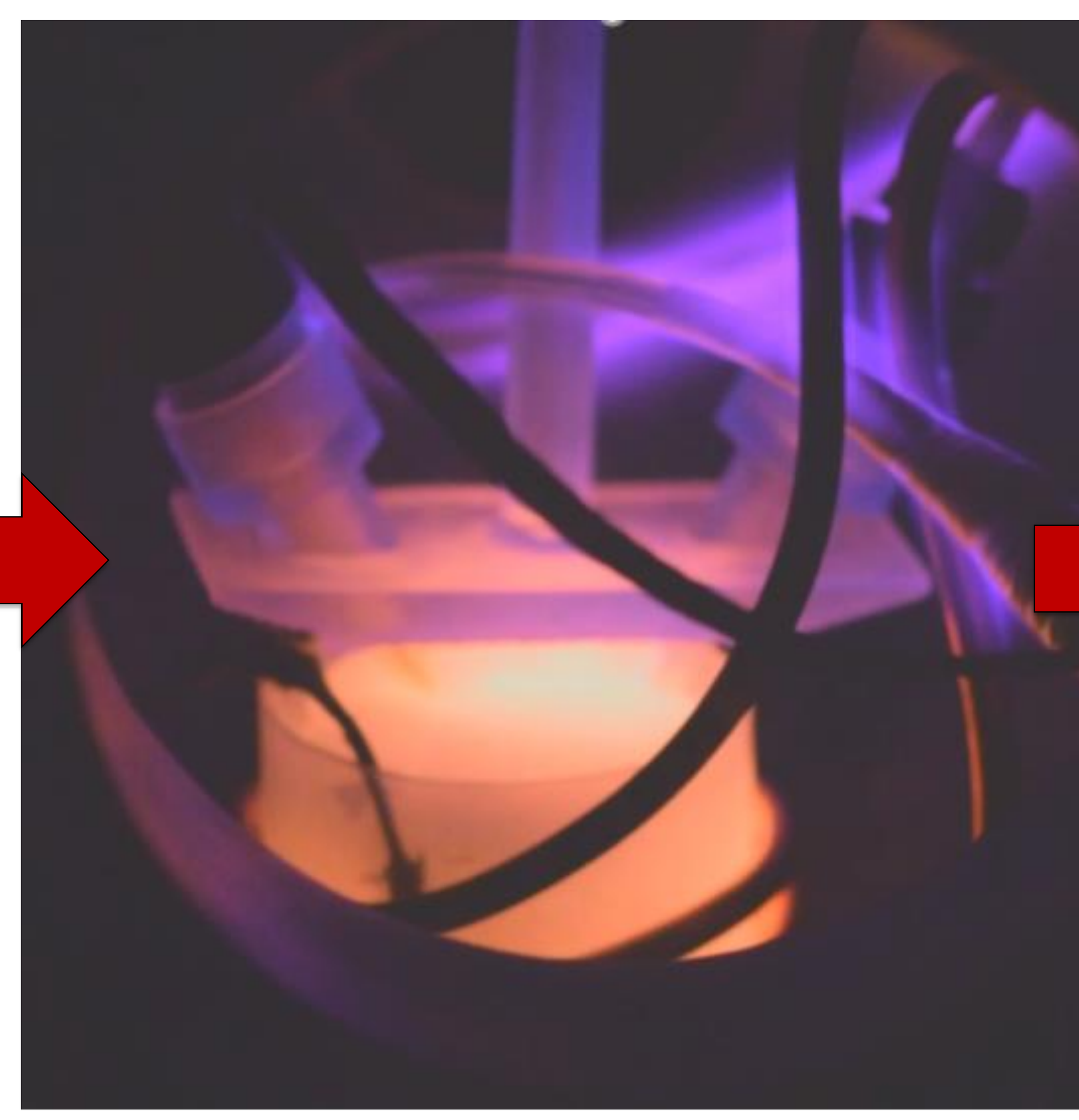
Does this fractured ice have significantly greater surface area and reduced thermal conductivity?
Yes. Based on COMSOL simulations and experiments performed in a Mars chamber, fractured ice can undergo partial or full phase change using significantly less energy.

Does it work under Mars' ambient conditions (temperature, pressure, chemistry)?
Yes – in fact, Mars' rarefied CO_2 atmosphere is ideal for plasma generation.

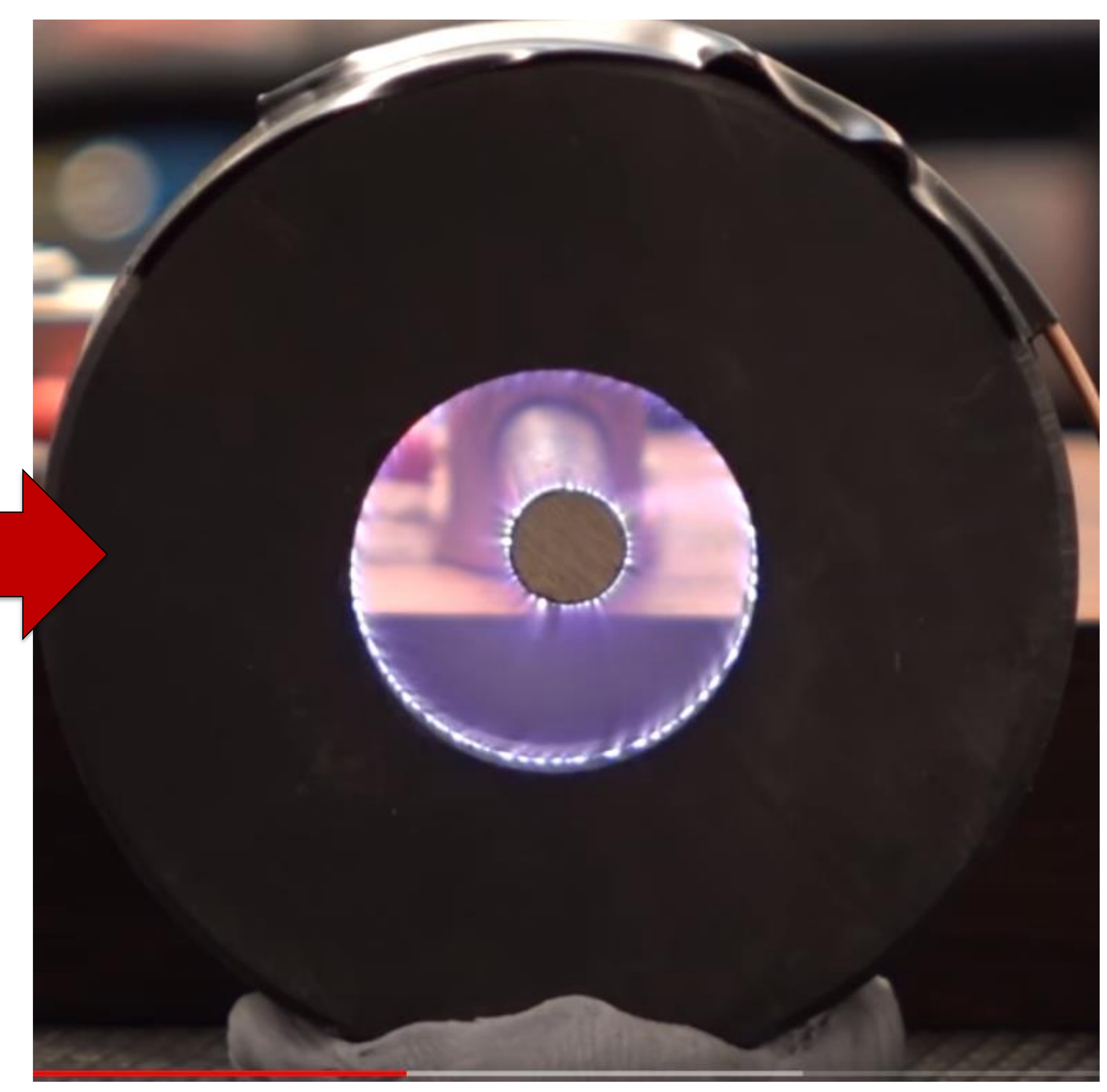
How do the energetics of glow-discharge compare to a hot-tip melt probe?
During glow-discharge induced phase change, initial tests suggest a thermal efficiency of 78%; this is a marked advantage over traditional melt probes.



Fracture down-hole ice using a 25 J pulse discharge



Generate a 25 W plasma glow-discharge



Evenly distribute the glow using Lorentz force

Benefits to NASA and JPL (or significance of results):

Background

Mars' polar layered deposits contain the best historical record of the Amazonian time period. Key questions include the isotopic ratios (D/H, $\delta^{18}O$ and $\delta^{17}O$) found within layered ice deposits and the composition of non-ice species (CO_2 and dust). While the rate of deposition is ~0.5 mm/yr, changes in obliquity, and thus climate, occur ~hundreds of thousands of years apart precipitating a desire for measurements at depths in the tens to hundreds of meters.

Challenge

Enabling deep-subsurface access to Mars' poles is challenging. Traditional drilling methods have limitations. Melt probes are thermally inefficient and slow (ROP). Mechanical drilling (rotary percussive etc) requires cuttings removal via a fluid. Neither H_2O nor CO_2 are phase-stable at the poles.

Benefits of proposed solution

Plasma-induced fracturing of ice is a low-energy method with which to increase the surface area of the ice and reduce thermal losses during phase change. Further, the drilling system requires zero active degrees of freedom; the probe moves with gravity and evenly distributes heat from the glow discharge using the Lorenz force.

Future work

This spontaneous R&TD was recently selected to advance as a Topical R&TD. During that study we aim to refine our methodology, optimize electrode spacing/pattern, produce a functional probe-prototype at JPL and demonstrate its capabilities. Other questions that should be addressed are: is there a compelling Ocean Worlds application? Can we perform science on the ionized particles, i.e. can they be fed to a mass spectrometer?

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