Project Introduction

Ionic liquid ion sources (ILIS) have numerous applications in spacecraft propulsion and focused ion beam technologies. The Space Propulsion Lab at the Massachusetts Institute of Technology is developing electrospray ion thrusters for small satellites. Current work is focused on the characterization of ion beams produced by various ionic liquids. Determining the best electrospray propellants and what properties drive their performance is the focus of the proposed work. Additional areas of research include fully characterizing ILIS, increasing the predictability of ion beam properties based on ionic liquid composition, and determining the limitations of ILIS for focused ion beam and spacecraft propulsion applications. Understanding and predicting ILIS beam properties allows for its application to small satellites requiring precise position control as well as ion beam lithography. Ionic liquids, or molten salts, are liquids at room temperature composed of positive and negative ions. ILIS works by using an electric field to stress the liquid surface, extract ions from the liquid, and accelerate the ions to high velocities. A single ion source consists of a sharp tip coated with ionic liquid, placed close to a metal extraction plate with a hole in it to let the ions pass through. An array of ILIS tips can be used as an electrospray thruster. Electrospray thrusters have many advantages over plasma thrusters. The most significant advantage is that electrospray thrusters are very compact and can be used on small satellites. Plasma thrusters are difficult to scale down for use on small spacecraft because the plasma density must be increased, which greatly decreases the lifetime of the thruster. Because of this, electrospray propulsion has the potential to revolutionize the attitude and position control of small spacecraft. Less than ten ionic liquids, out of thousands, have been tested as propellants for electrospray thrusters. It is very likely that the best ionic liquids for electrospray propulsion have not been tested in ILIS or have not yet been synthesized. For example, a major source of inefficiency comes from non-uniform beam composition. Determining how liquid composition affects this is the focus of current work. However, beam composition is only a small part of finding the best propellants. Determining how bulk liquid properties like conductivity, surface tension, and viscosity affect performance is another area of study. Additionally, it is critical to investigate how liquid properties affect fundamental ILIS processes: ion evaporation, microfluidics, and interface interactions. A complete understanding of how liquid properties control performance will enable the development of highly efficient, variable thrust electrospray thrusters that can be used as a multipurpose propulsion system. It also will enable the use of electrospray thrusters for precision drag-free spaceflight, possibly like that required by the Laser Interferometer Space Antenna (LISA). Electrospray thrusters and ILIS have the potential to improve small spacecraft propulsion capabilities and focused ion beam technologies. Electrospray thrusters could enable low-cost, small spacecraft to accomplish the scientific goals of large, costly platforms, which is undoubtedly valuable to society. ILIS focused ion beam deposition and etching could vastly improve and expand the possible applications of these technologies by offering thousands of new options for ion beam constituents. Determining
the best propellants for electrospray thrusters, investigating the limitations of ILIS, and evaluating the feasibility of a small scale LISA mission is the focus of the proposed work and would be a part of making these electrospray technologies possible.

**Anticipated Benefits**

Electrospray thrusters and ionic liquid ion sources (ILIS) have the potential to improve small spacecraft propulsive capabilities and focused ion beam technologies. Electrospray thrusters could enable low-cost, small spacecraft to accomplish the scientific goals of large, costly platforms, which is undoubtedly valuable to society. ILIS focused ion beam deposition and etching could vastly improve and expand the possible applications of these technologies by offering thousands of new options for ion beam constituents. Determining the best propellants for electrospray thrusters, investigating the limitations of ILIS, and evaluating the feasibility of a small scale LISA mission is the focus of the proposed work and would be a part of making these electrospray technologies possible.

**Primary U.S. Work Locations and Key Partners**

<table>
<thead>
<tr>
<th>Organizations Performing Work</th>
<th>Role</th>
<th>Type</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Massachusetts Institute of Technology (MIT)</td>
<td>Lead Organization</td>
<td>Academic</td>
<td>Lexington, MA</td>
</tr>
</tbody>
</table>
Space Technology Research Grants

Advanced Propellants for Scalable, Multipurpose Electrospray Ion Thrusters

Completed Technology Project (2015 - 2019)

Primary U.S. Work Locations

Massachusetts

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Maturity (TRL)

Start: 2
Current: 2
Estimated End: 3

Technology Areas

Primary:

- TA2 In-Space Propulsion Technologies
  - TA2.2 Non-Chemical Propulsion
    - TA2.2.1 Electric Propulsion

Target Destinations

Foundational Knowledge, Earth, Others Inside the Solar System