Liquid Nanoparticle Ion Source (LNIS)

Boubakar Diallo, Sean McInnis, Jatin Mukerji
Mentor: Alex Hagen

Meet the Team

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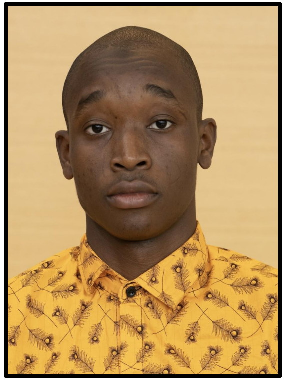

Boubakar Diallo
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ECE

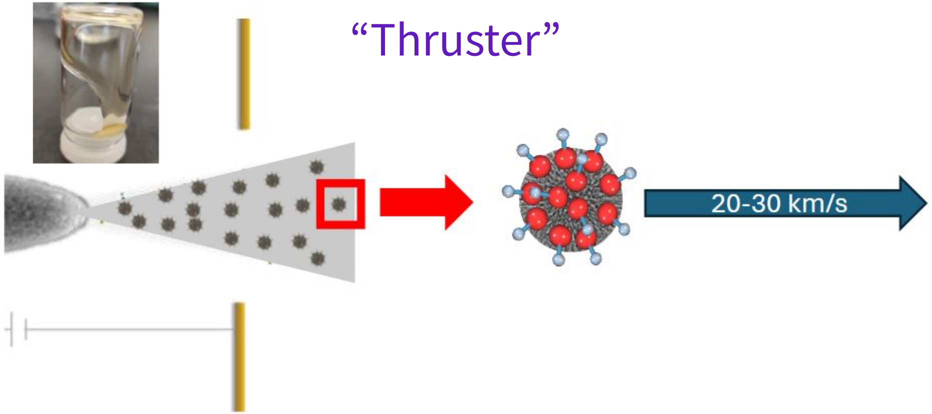
Alex Hagen
Team Mentor

Stefan Bell
Primary Inventor

Useful Acronyms

- LNIS: **L**iquid **N**anoparticle **I**on **S**ource.
- NIM: **N**ano**I**onic **M**aterial
- EMI-BF4: *1-**E**thyl-3-**m**ethyl**i**midazolium tetrafluoroborate*, a room temperature ionic liquid widely used as an electrolyte in electrochemical studies.

Technology Overview



- Creating a better liquid “fuel” for microthrusters and electrospray analysis.
- Charged NIMs are extruded through a charged nozzle.
- Each satellite would have hundreds or thousands of these microthrusters.

Inventiveness Analysis

Invention Description

The Liquid Nanoparticle Ion Source (LNIS) provides an ion beam consisting of inherently charged nanoparticles emitted from a neat fluid, similar to an ionic liquid, released via electrostatic evaporation. This fluid exhibits low vapor pressure and room-temperature fluidity while maintaining a stable, high mass-to-charge species. The efficacy of this fluid is characterized by exposed surfaces and secondary species created as a result of the impacts from nanoparticles. In-situ current measurements of the nanoparticle beam identified multiple emission sites with narrow divergence. The NIMs fluid has vastly lower ionic conductivity than ionic liquids, but broadly has similar properties to ionic liquids. Diameters for both the trenches and craters indicate impacts that are highly energetic in nature. The detection of secondary species also demonstrates the ability of the nanoparticle ion beam to ionize ionic liquid material on the surface of a substrate. The NIMs class provides an easily-tunable mass-to- charge ratio which enables engineers to directly tune thruster performance characteristics for mission demands or adjust parameters for microscopy applications.

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Prior Art Search

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Analysis of Technical Articles

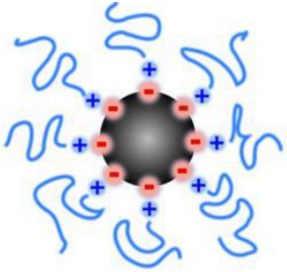
Conferred Advantages

More stable

Property	NIMs, 15 nm	$EMI\text{-}BF_4$
Surface Tension (N/m)	24	45
Ionic Conductivity (mS/m)	1	1200
Viscosity at 25°C (Pa·s)	0.2	0.0346
Storage Modulus (Pa)	0.07	~0.01
Loss Modulus (Pa)	1.3	~0.218
Dissipation Factor	20	>200
Vapor Pressure (Pa)	0.1	1.4

Lower conductivity → higher stability

Analysis of Technical Articles



Conferred Advantages

More stable

Species	Voltage (kV)	Average Exposure Current (pA)	Exposed Charge (pA-hr)	Energy Dose (nA-eV-hr)
NIM	-3, -3, -3	19, 29, 36	86, 120, 72	300, 420, 250
Jeffamine	3, 3, 3	34, 54, 65	85, 94, 170	8.5×10^{-2}, 9.4×10^{-2}, 0.17
EMI^+, BF_4^-	3, -3	1.4×10^5, 2.6×10^5	3.4×10^5, 3.9×10^5	340, 390

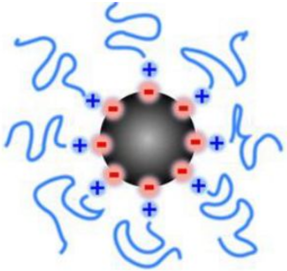
More modular

"Solute" "Solvent"

Property	NIMs, 15 nm (negative)	Jeffamine M600 (positive)	EMI^+	BF_4^-
Average mass (Da)	2.5×10^6	600	111	87
Average charge per ion (e)	3500	1	1	1
q/m (C/kg)	1.4×10^5	1.6×10^5	8.6×10^5	1.1×10^6
Ideal I_sp (s)	2900	3100	7300	8300

Easier-to-adjust ratio of "solute" to "solvent" to modulate beam strength.

Analysis of Technical Articles

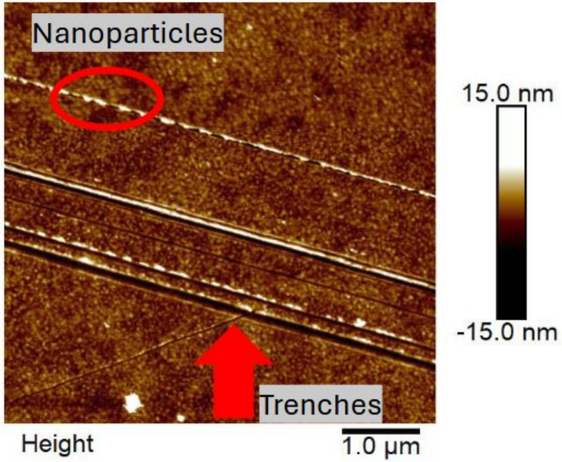


Conferred Advantages

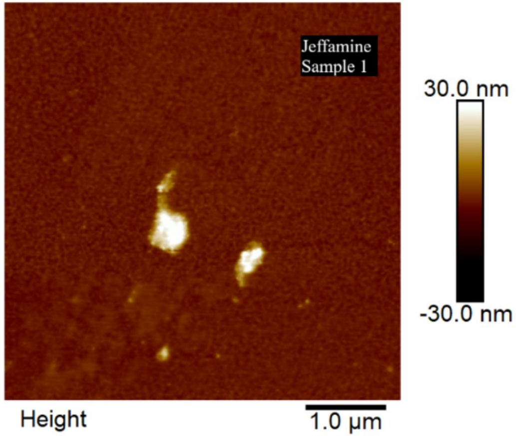
More stable

More modular

“Solute”



“Solvent”



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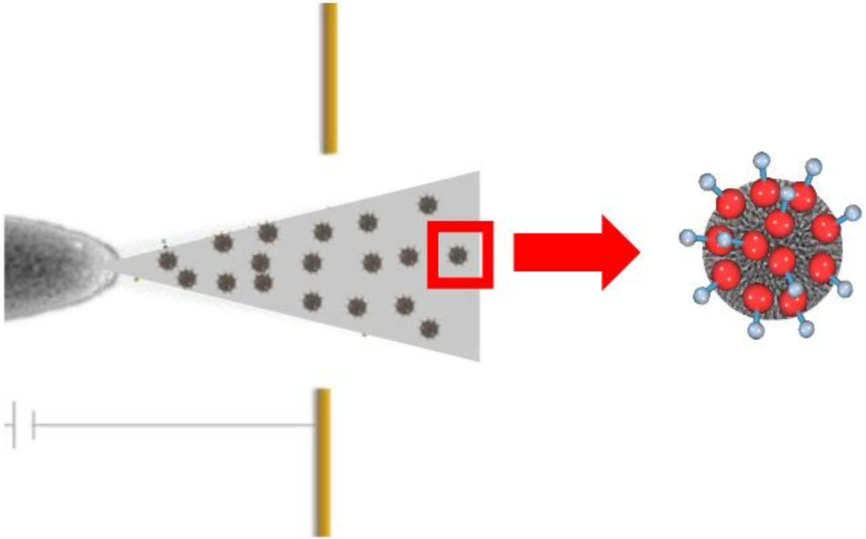
Analysis of Technical Article Excerpts

Conferred Advantages

More stable

More modular

Novel



Emitting charged nanoparticles rather than ions produced by them.

Property Control Position

Property Control Position

Patent: Use NIMs as the working fluid in electrospray, and on the LNIS method of emitting and accelerating multiply charged nanoparticles for thrust and beams.

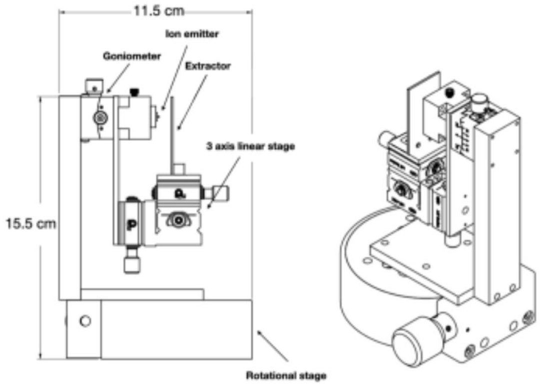


Fig. 3 Experimental setup of the externally wetted LNIS

Copyright:

- Nanoparticle beam used for material deposition & propulsion.

Current IP: No patent application files and no electrospray sources using NIMs as the working fluid

- Electrospray Emitter Geometry
- Multiply charged nanoparticles extracted from liquid phase using strong electric fields

Market Application & Value Proposition

Market Application & Value Proposition

Space Propulsion

- High Thrust: Massive and multi charge nanoparticle
- Design for small satellite (CubeSats) and Scalable to large spacecraft
- Tunable Thrust by changing nanoparticle size and chemistry
- Reduce short circuit and lifetime
- Cost → Cheaper and more Scalable

Nanoparticle Bean Tools (Future Work)

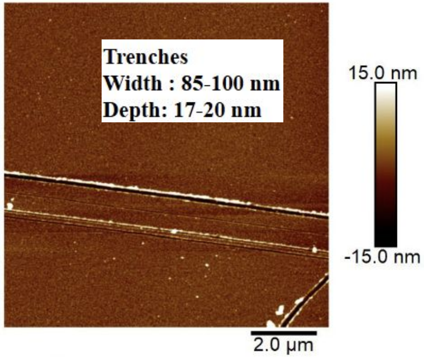
- Surface modification and milling: Directly write nano milling, and patterns
- Material deposition: Control nanoparticle deposition for thin film
- Mass to charge ratio
- Research Lab and Semiconductor

Tech Readiness Level

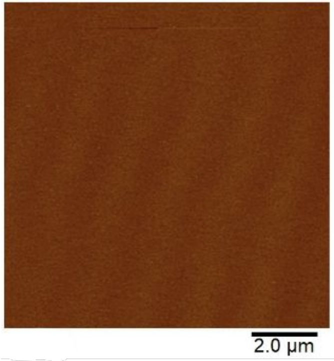
Tech Readiness Level

- Established reproducible synthesis of NIMs
- Basic validation in laboratory environment
- **Surface Erosion tests:** Demonstrate controlled, narrow electrospray of ions
    - Low fidelity system (nm scale)
    - Emission precision → Propulsion precision

Nanoparticle Ionic Materials



Ionic Liquids



Ten-Point Tech Scoring

Ten Point Scoring Tool

	Categories	Score
1.	Detailed description of Invention and its Inventive features	5
2.	Potential/existing Quality of Property Control Position	3
3.	Market Relevance (solves economic/meaningful problem)	4
4.	Market Size & Characteristics	4
5.	Value Proposition/ Potential for Reasonable Business Model	5
6.	Potential for Significant Revenue Generation	4
7.	Stage of Development/ Technology Readiness	3
8.	Scale-up Feasibility	4
9.	Support, Funding & Resources	4
10.	Existing or Potential for Commercialization Partnerships	5
Total score:		41

- **Clear inventive features:** Nanoparticle ionic materials working fluid with greater charge density results in greater propulsion velocity
- Clear ties to satellite market
    - Expected to grow to $108 billion by 2035
- ~$100/kg for NIMs and ~$1000/kg for ionic liquids
- 1-10pL/s fluid per emitter, 1000s of emitters per CubeSat
- Future work with Naval Research Lab
- Early stages of prototyping, low fidelity
- Overall Score: **41/50**

Tech Brief

Tech Brief, Distilled

- Summary of Invention:

  A liquid nanoparticle solution is used as an ion source for microthrusters and ion microscopy.

- Features and benefits:

  The LNIS system is more stable than contemporary ion sources, highly adjustable, and novel in its means of ion beam production.

- Opportunity presented:

  The LNIS system represents a broadly applicable and novel ion beam generation method that possesses significant advantages over current methods.

Tech Brief, Distilled

- Stage of development:

  Still experimental; tied to development of novel extruder trials in January.

- Business arrangements sought:

  Already funded by DARPA / NSF, seeking partnerships with propulsion manufacturers (e.g. Busek, Ion-X, Revolution Space), propulsion customers (e.g. NASA JPL, DoD), and analytical companies (e.g. Hiden Analytical, Zeiss, Ionoptika).

- Contact information:

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  Jatin Mukerji, jam834@cornell.edu

Questions?

References