TEACUP ROCKET EXPERIMENT

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INTRODUCTION

• Objective
  – To investigate effectiveness of ‘electric tempest in a teacup’ method for microfluidic separation in microgravity

• Team
  – 5 SpaceMaster students at LTU, Kiruna: Mark Fittouck, Samuel Webster, Martin Siegl, Fan Chunman, Pooja Mahapatra

INTRODUCTION

• Einstein’s tea leaves: circular stirring in a teacup
  – Friction at cup base
  – Reduction in centrifugal force towards cup bottom

MOTIVATION

- Efficient separation difficult in microfluidic devices
- Some methods:
  - **Strong centrifugation**: difficult to achieve in nanoscale, cumbersome machinery
  - **Microfabricated filters**: complex membranes and fabrication techniques, deformation and denaturing of cells in case of blood
  - **Dielectrophoresis (DEP)**: ineffective below 10µm particle diameter

PRINCIPLE

- **Ionic wind**
  - $V >$ threshold air ionization voltage
  - **Corona discharge** around sharp electrode tip
  - Plasma counterions collide with electroneutral air molecules, transfer momentum
PRINCIPLE

- Orientation effects
  \[ \varphi = \text{angle between probe and fluid surface} \]

VERTICAL INCIDENCE

OBLIQUE INCIDENCE

OBLIQUE, OFFSET INCIDENCE

\( \varphi = 90^\circ \)  \( 0 < \varphi < 90^\circ \)  \( 0 < \varphi < 90^\circ \)

SETUP
REQUIREMENTS

• Microfluidic chamber (8 mm diameter, 4 mm depth)
• Separation medium: Diluted sheep’s blood (enables easy visualization)
• ~3 min microgravity time, 1 bar pressure and 23° C to be maintained in rocket chamber
• High voltage supply and sharp probe
• On-board image acquisition and data storage hardware

ADVANTAGES

• No mechanically moving parts
• Small sample size
• No electrode-sample contact: mechanical failure, sample contamination prevented
• Little field penetration into fluid: no adverse effects on biomolecules
• Minimal current, low power
• Particle aggregates undisturbed after removal of electric field
• Miniaturization possible: piggybacking for rocket launch
DRAWBACKS

- Risk due to high voltage: adequate safety precautions necessary while implementing and testing
- High cost
- Piggybacking, hence no data transfer back to ground: post-launch experiment recovery is crucial

APPLICATIONS

- Miniature, low-power replacement for centrifuge (for experiments in physics, biology, materials)
- Portable medical diagnostic kits for astronauts, especially in long-duration spaceflights
- Microarray chips in high-throughput drug screening
CONCLUSION

- Ion-jet induced vortex separation holds promise for miniature implementation on board spacecraft
- The project is currently in the design phase
- Launch options are being explored
- After implementation, rigorous ground testing is important to validate results of microgravity experiment

REFERENCES

THANK YOU