# Space Applications of MEMS
# Activities in Astronautics Research Group, School of Engineering Sciences, University of Southampton

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# Summary

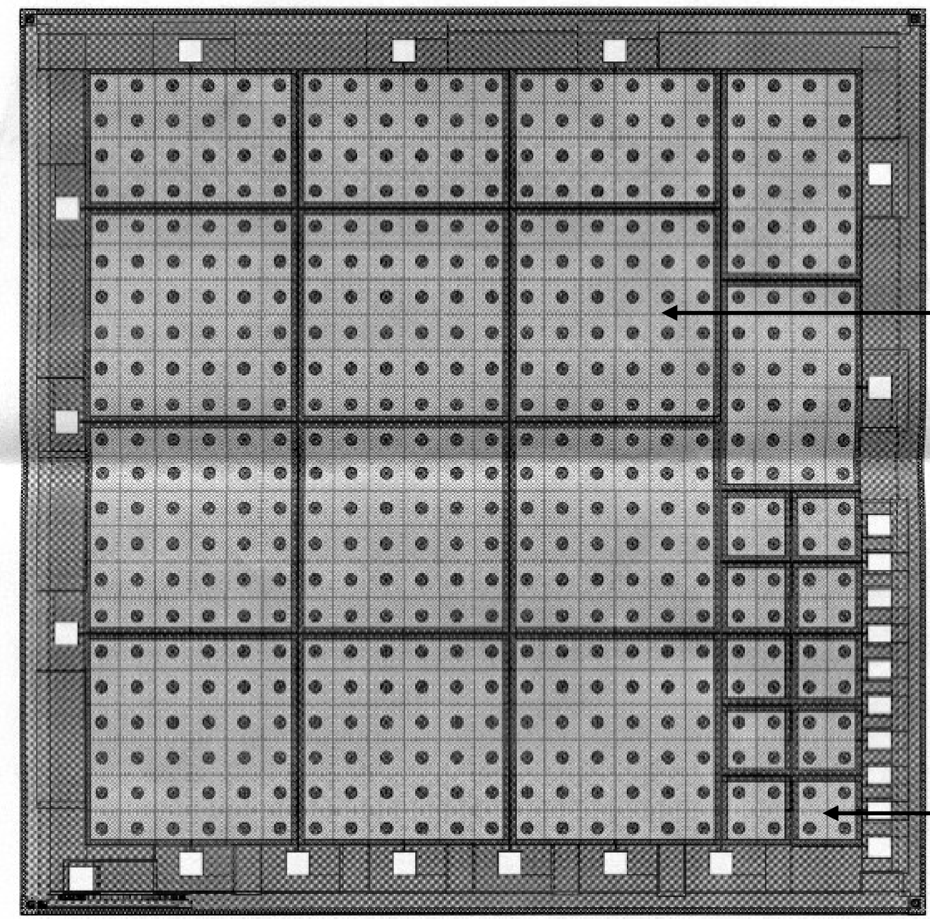
- Micro-colloid thruster on a chip
- 2 ESA funded Ariadna studies on
  - Inkjet printing technology applied to injectors for chemical rockets
  - Hollow cathode micro-thrusters on a chip inspired by plasma TV displays

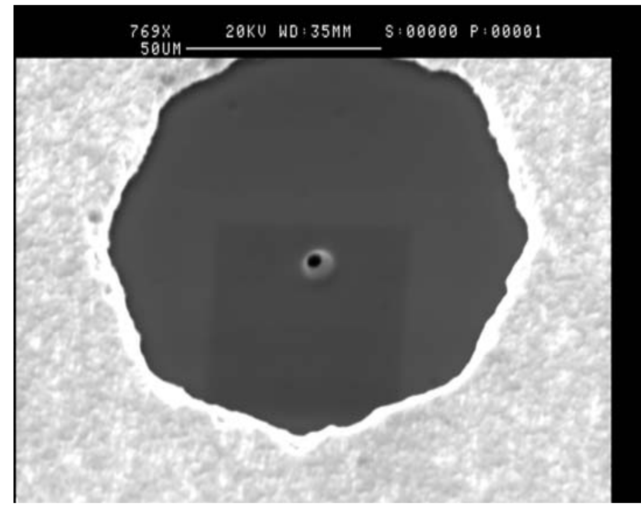
# MEMS colloid thruster

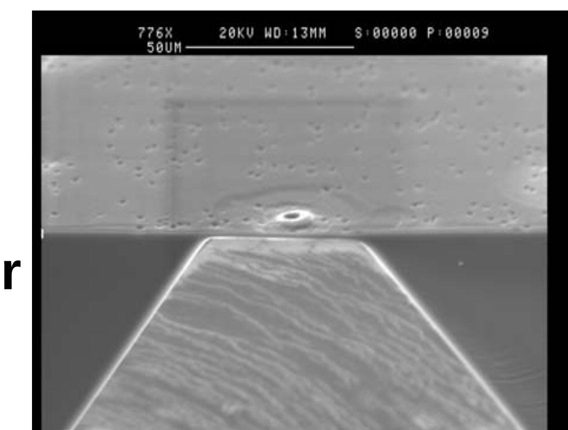
- Conventional colloid thrusters need high voltages(~10kV) to achieve the extremely strong electric fields( ~ $10^8$V/m) to get electrospraying
- MEMS can help reduce the required voltages by reducing the dimensions and has other advantages such as reduced mass and volume, mass production ( lower cost) and digital control. ( see M D Paine et al, 'Realisation of very high voltage electrode-nozzle systems for MEMS', Sensors and Actuators A 114(2004), 112-117)

# MEMS colloid thruster : results

- Design fabricated which consists of nozzles with 3-5μm exit diameter. The nozzles are situated in the centre of an electrode with an aperture of 100-200μm and are in arrays of several hundreds on a $3cm^2$ chip.

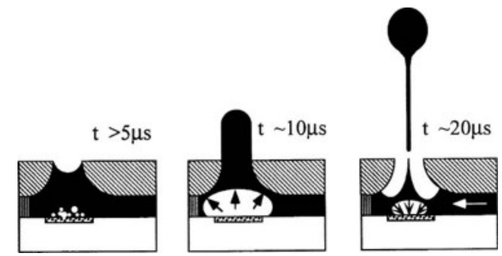


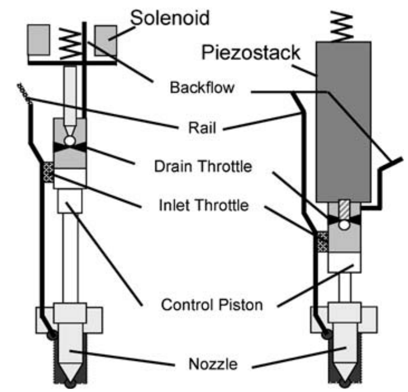



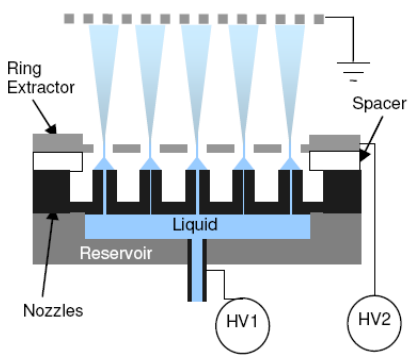



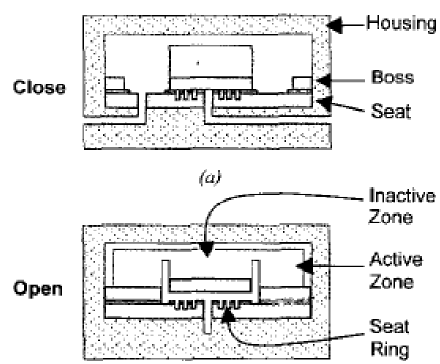
# Ariadna 1 – inkjet printer technology applied to chemical rocket injectors

- Small study ( 25keuros); 4 months
- Looked at
  - Inkjets
  - Diesel type fuel Injectors
  - Membrane atomizer
  - Electrospray injectors



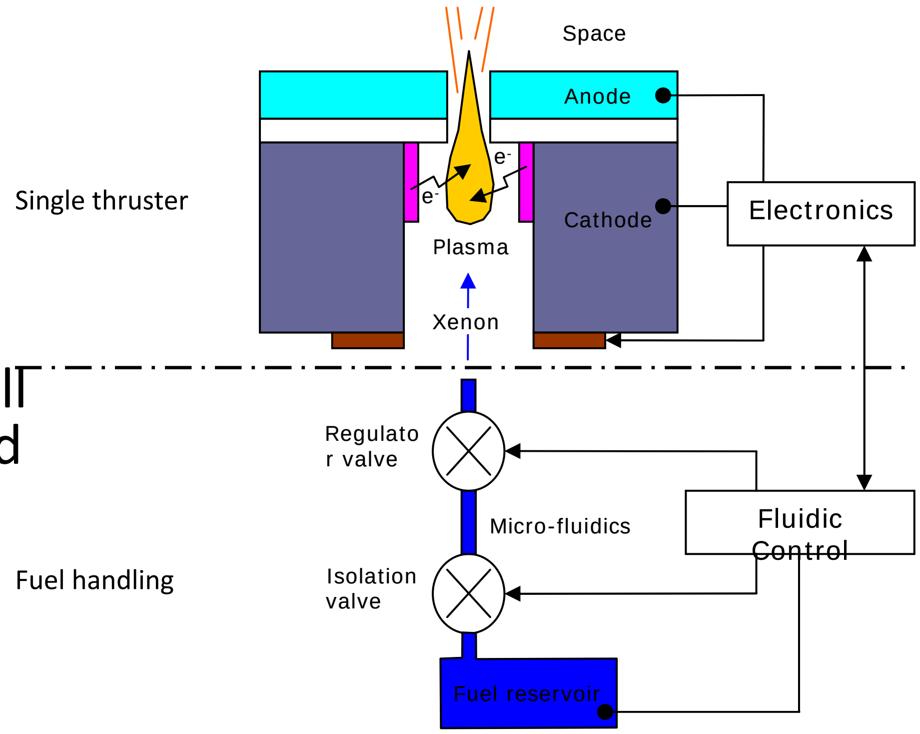



# Conclusions to Ariadna 1

- Inkjets are not capable of injecting into a pressurised combustion chamber, and have insufficient surface tension to resist pressure fluctuations.
- Diesel injector can be used in big thruster producing small droplet size, throttling capabilities and combustion instabilities control.
- Membrane atomizer will not provide any droplet size reduction if compared with a conventional injector but will be able to reduce the break-up length by a factor of 4.
- Multiplex electrospray injectors can be used providing extremely small droplet size and giving the possibility of throttling the thruster of controlling the combustion instabilities. The effect of charged particle on combustion and the injector performance with an applied $\Delta p$ must be assessed.
- ITI submitted and ESA very interested but needs a proper systems study to identify which of proposed options is feasible ( real interest in a throttable rocket engine for Europe – NONE exists; very important for future lander missions)

# Ariadna 2 – Hollow cathode microthrusters on a chip inspired by plasma TV displays

- Small study ( 25keuros); 4 months
- Collaboration with electronics and computer science department
- Feasibility study including overall system ie propellant storage and flow control as well as the thrusters themselves
- Application would be to very small spacecraft( eg cubesats,nanosats and mcirosats) for orbit and attitude control



# Ariadna 2 – Current Status

- Final report being prepared for ESA
- Several designs developed but some key gaps in our knowledge of how to scale from macroscopic hollow cathodes to micro devices have been identified :
  - There is no model for the plasma flow at these scales( micron to tens of micron size dimensions ( orifice) ( existing models do not give realistically physical results)
- Systems with integrated and separate propellant storage and flow control have been investigated

# Ariadna 2 – Some design concepts

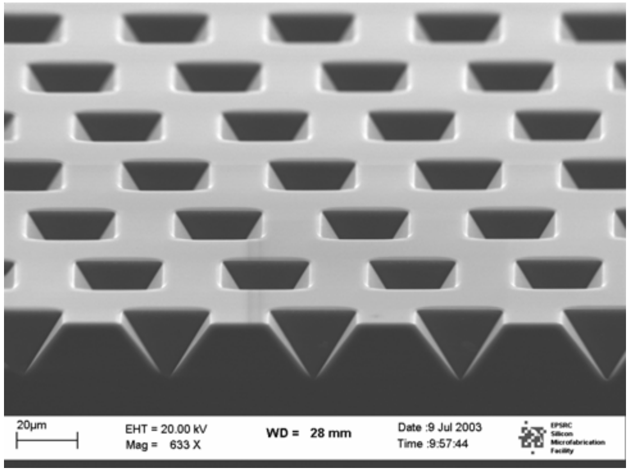
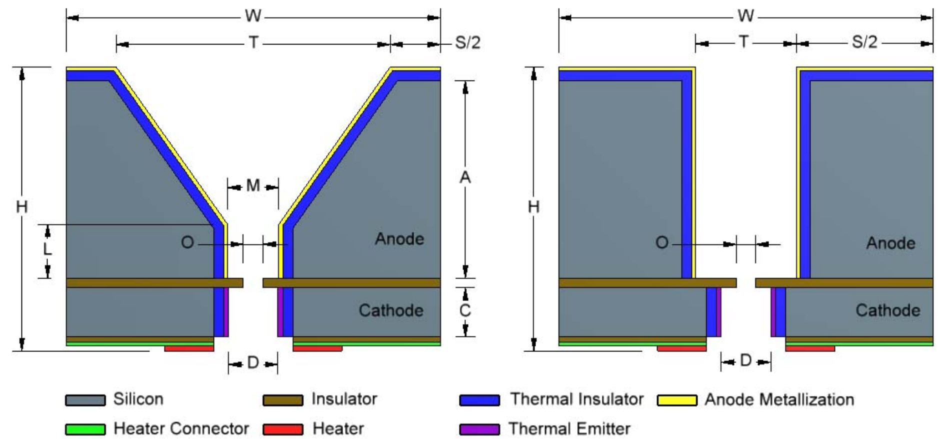
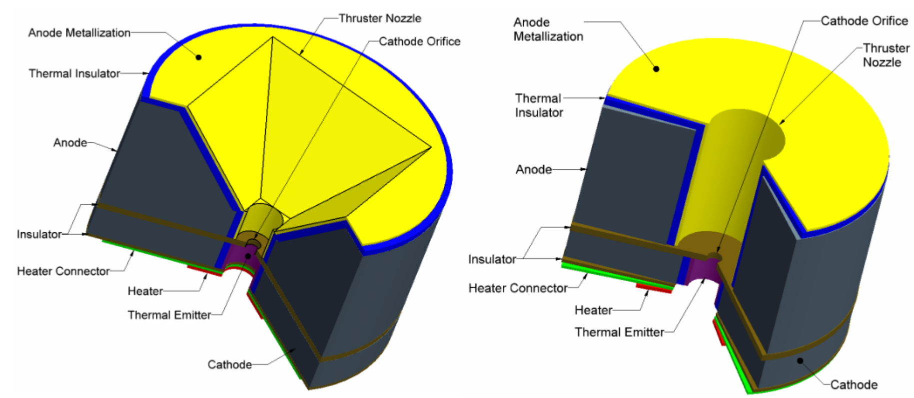
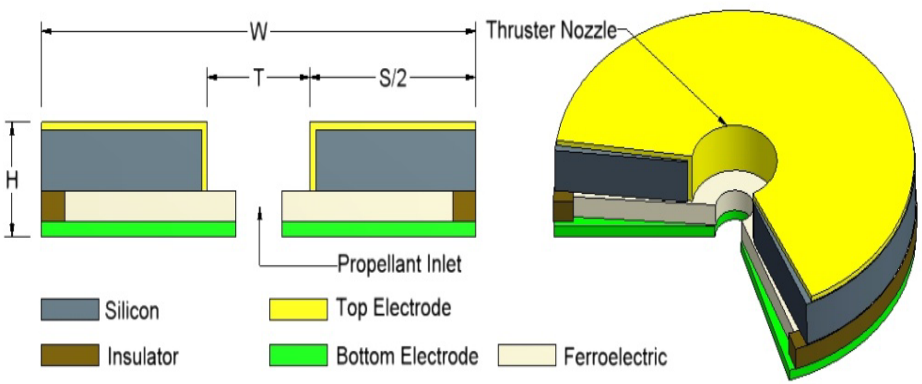



**Figure 7: Array of Type-2 inverted pyramids etched into a silicon wafer**




| D = 5 µm | | D = 10 µm | | D = 15 µm | | D = 20 µm | |
|---|---|---|---|---|---|---|---|
| L µm | W µm | L µm | W µm | L µm | W µm | L µm | W µm |
| 0 | 434.8 | 0 | 434.8 | 0 | 434.8 | 0 | 434.8 |
| 5 | 427.7 | 10 | 420.7 | 15 | 413.6 | 20 | 406.5 |
| 50 | 364.0 | 100 | 293.2 | 150 | 222.4 | 200 | 151.6 |
| 100 | 293.2 | 200 | 151.6 | 300 | N/A | 400 | N/A |

**Table 5: Minimum device widths (W) for thruster nozzles with chimneys fabricated by anisotropic etching as a function of hollow cathode internal diameter (D) and chimney length (L).**

# Conclusions

- Several promising and potentially disruptive technologies for MEMS-based space propulsion are being investigated.
- Our work is leading edge and internationally recognised but it is a very competitive field :
  - We need an injection of funding in order to keep the UK ahead in this field
  - STFC/PIPPS funding for a MEMS Pulsed Plasma Thruster(PPT) is being prepared
  - Recent ESA ITI awarded for miniature version of HFBPPT with Clyde Space and Mars Space Ltd