Plasmas: from solar to cellular

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The Space Plasma, Power and Propulsion (SP3) laboratory's research focuses on space plasmas (solar corona and exoplanet research) and space missions (mission to Mercury) in collaboration with many overseas partners [1,2,3]. Our interest is the development of advanced concepts and technologies which ranges from space thrusters (low earth orbit, geostationary and deep space) to focused ion beams (materials characterisation, forensic studies) [4]. Over the past decade the development of a range of electrodeless plasma thrusters based on geometric and magnetic plasma expansion (i.e. Helicon thruster [5], Pocket Rocket thruster [6], Naphtalene thruster [7]) has provided a wonderful platform for a better understanding of basic plasma physics. These electrodeless thruster have not yet been flown on satellites.

The International Space Station is in a 420 km altitude Low Earth Orbit and is falling to the Earth at a rate of some tens of kilometres per year. It needs to be boosted every month to maintain its orbit against the friction of the tenuous atmosphere. Satellites having an altitude below about 500 km suffer the same problem and will decay and burn up in a few years. To provide the boost, chemical thrusters are used but for smaller satellites cold gas and electric propulsion is used. Using cold gas is like expelling gas from a balloon. But the thrust is low since the exit velocity of the gas is low, around sound speed of 300 m/s. Since thrust is a force it is linearly dependent on how much and how quickly you can throw away the mass. If you throw it away twice as fast you need half the mass for the same thrust. So if you can heat the gas up you can avoid carrying a large load of propellent around with you. Using a plasma the heavy ions can be accelerated up to more than 100 times that of cold gas thereby decreasing the mass of propellant to only 1% that of the cold gas thruster. This is an immense advantage for long term space missions, raising the orbit to Geostationary Earth Orbit, to the Moon and to Mars. Logistically, plasma thrusters are used to keep telecommunication satellites on station and to remove them to a higher Graveyard Orbit at End Of Life. The large constellations of 1000s of satellites such as Starlink are initially launched into LEO then small plasma thrusters are energised to lift them from around 300 km to over 500 km where atmospheric drag is much lower and the lifetime of the satellites increased to many years. For the Earth's orbit, solar energy is eternal but propellants are not. The two most common EP systems are: gridded ion thrusters where electrodes accelerate ions from a plasma to energies of around 2kV and Hall Effect Thrusters that trap plasma electrons with crossed electric and magnetic fields and are very efficient in ionising the propellant gas. Here we used similar radiofrequency plasma technologies for our various thruster concepts and for our focused ion beam studies. The latter system uses an ion extraction system (similar to gridded ion thrusters) and an ion guided optics system for precise cellular investigation.

Oregon Physics, a high tech company in Portland Oregon has industrialised a plasma source ion beam system originally invented and developed by SP3. It is the ion source in Focused Ion Beam machines sold by a number of companies and is the brightest negative ion beam system available worldwide. Commonly used for surface analysis in laboratories around the world, it is now at the heart of a Time of Flight Secondary Ion Mass Spectrometer that can map in two dimensions the position of tagged cells signaling the onset of cancer.

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