Introduction to Fusion and Plasma

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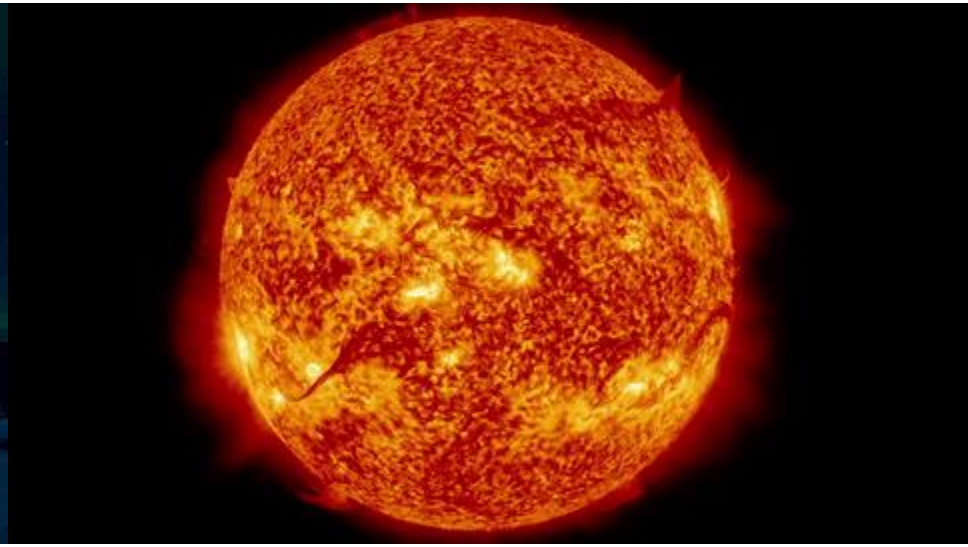
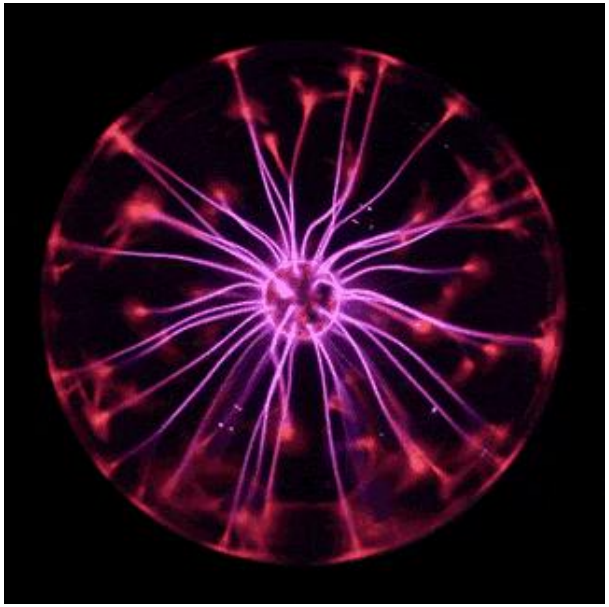
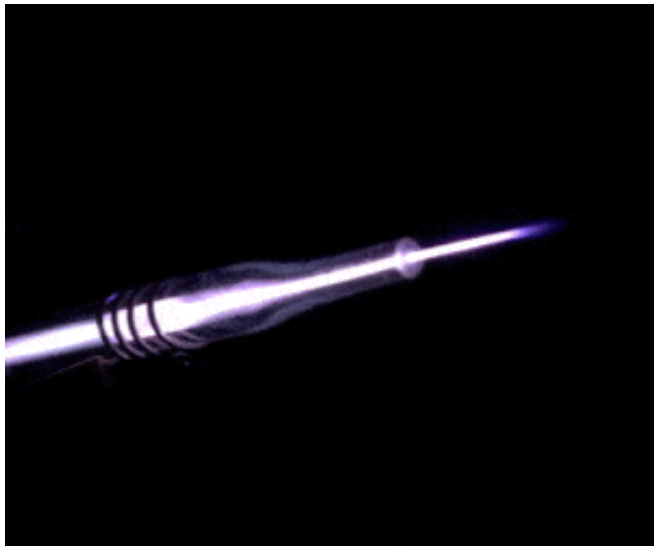
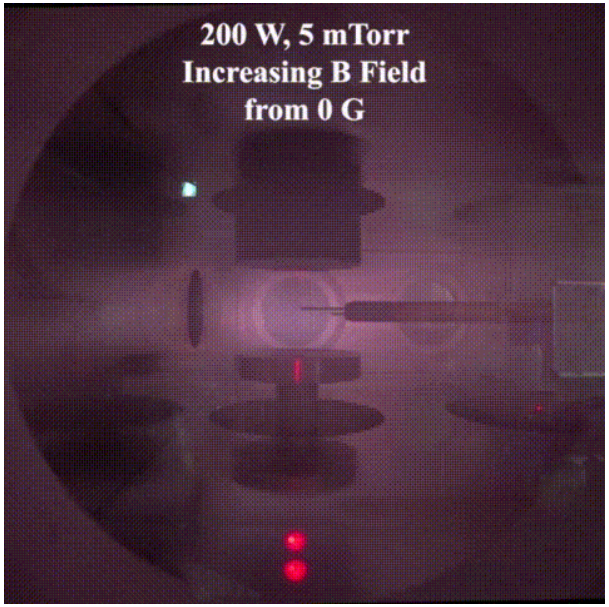
Plasmas around us



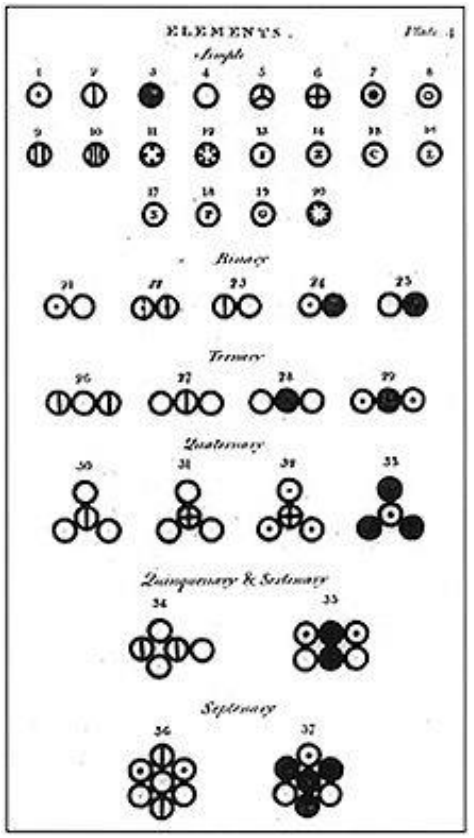






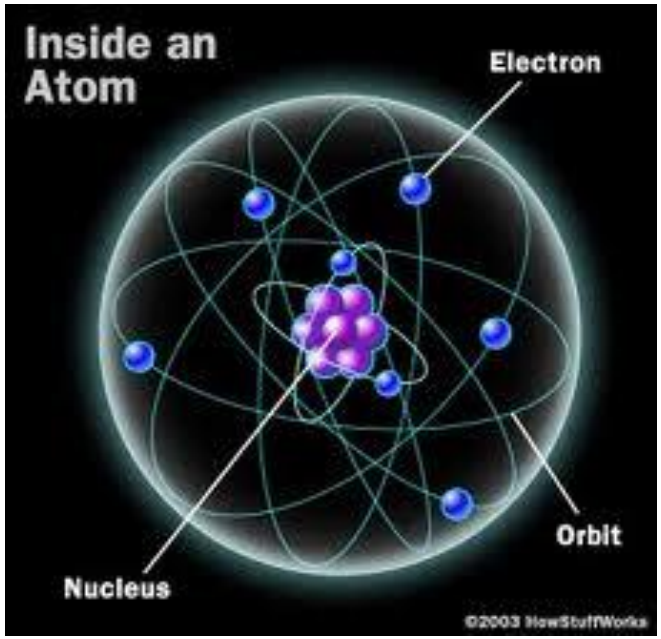
Atom: scientific approach

- Dalton's atomic theory (John Dalton, 1808)
  1. Elements are made of extremely small particles called atoms.
  2. Atoms of a given element are identical in size, mass, and other properties; atoms of different elements differ in size, mass, and other properties.
  3. Atoms cannot be subdivided, created, or destroyed.
  4. Atoms of different elements combine in simple whole-number ratios to form chemical compounds.
  5. In chemical reactions, atoms are combined, separated, or rearranged.



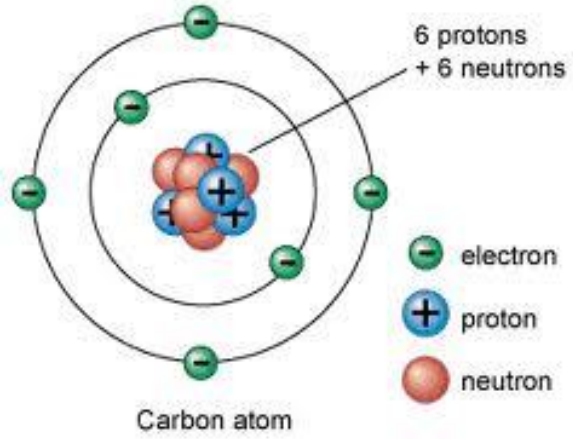
The structure of atom

- Every atom is composed of a nucleus and one or more electrons bound to the nucleus. The nucleus is made of one or more protons and typically a similar number of neutrons. Protons and neutrons are called nucleons.
- More than 99.94% of an atom's mass is in the nucleus.



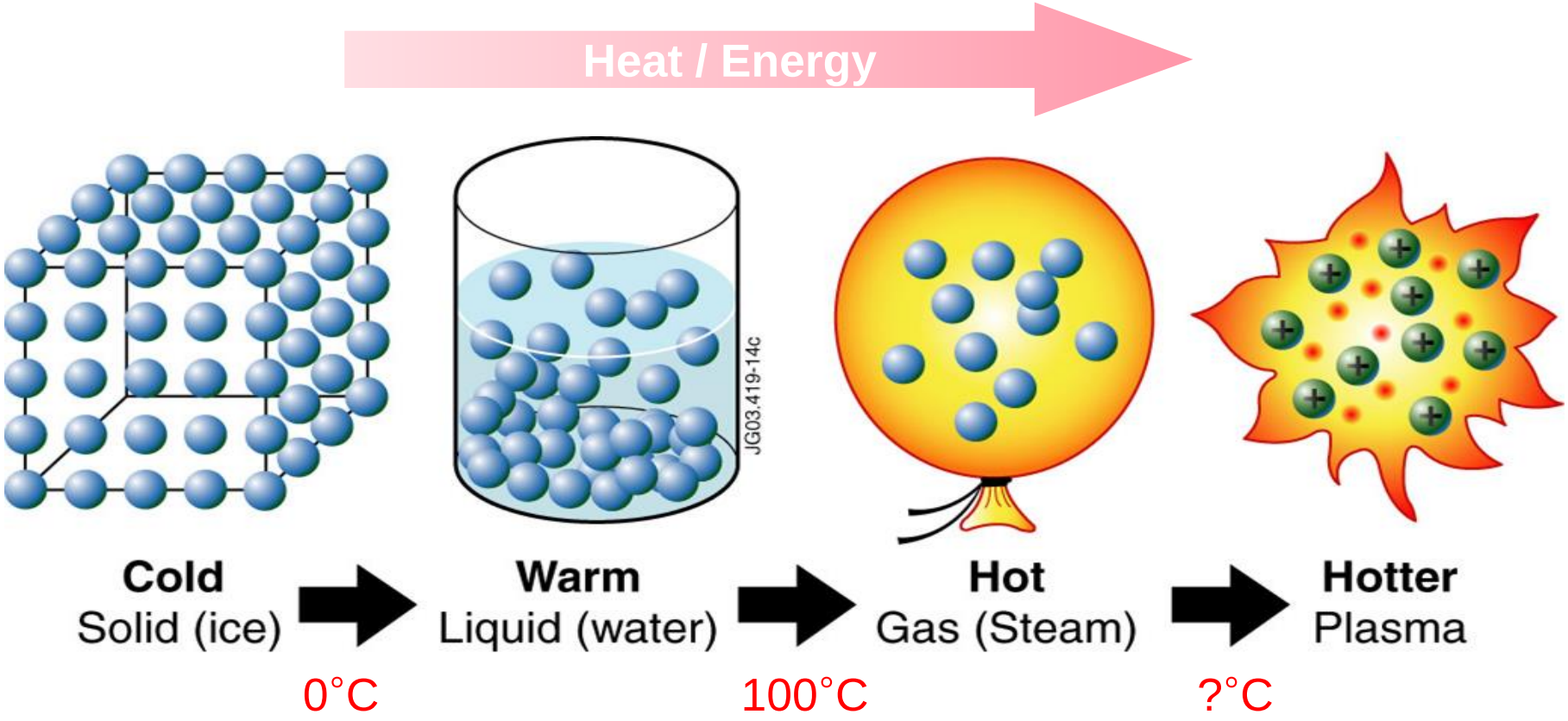
- Proton (p, H^+)
  - mass (m_p) = 1.67×10^{-27} kg
  - charge (q_p) = $+1.6 \times 10^{-19}$ C (+e)
- Electron (e)
  - mass (m_e) = 9.11×10^{-31} kg
  - charge (q_e) = -1.6×10^{-19} C (-e)

$$\frac{m_p}{m_e} \approx 1837 \qquad \left|\frac{q_p}{q_e}\right| = 1$$



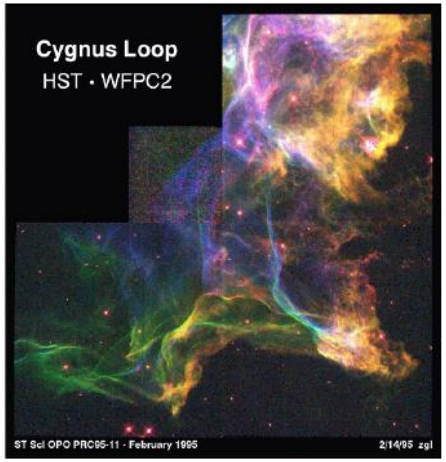
$^{12}_{6}\mathrm{C}$

Plasma: 4th state of matter



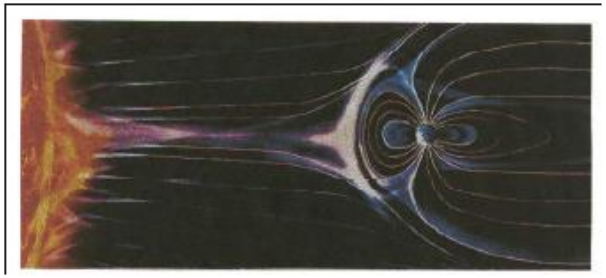
- A Plasma is quasi-neutral gas of charged and neutral particles which exhibits collective behavior. (Francis F. Chen)
- Plasma is a gas in which a certain portion of the particles are ionized. (Wikipedia)

Space plasmas

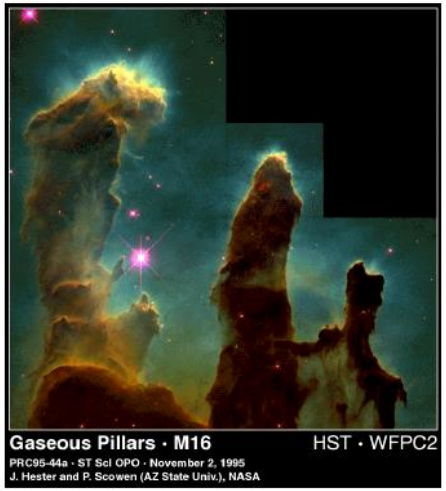


Gaseous nebulae are plasmas.

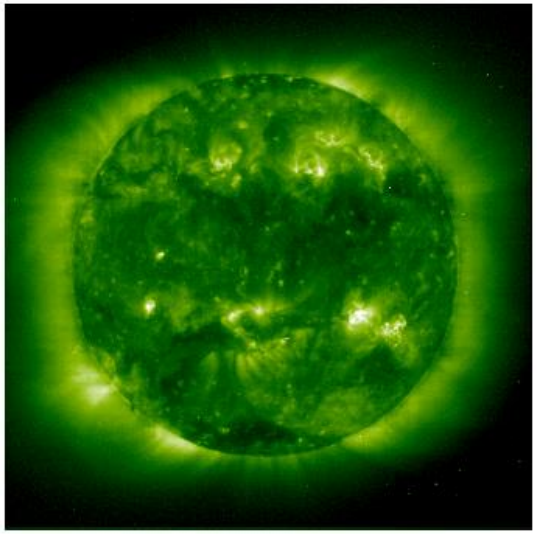
A cooler plasma: the Aurora Borealis



The earth plows through the magnet-ized interplanetary plasma created by the solar wind.



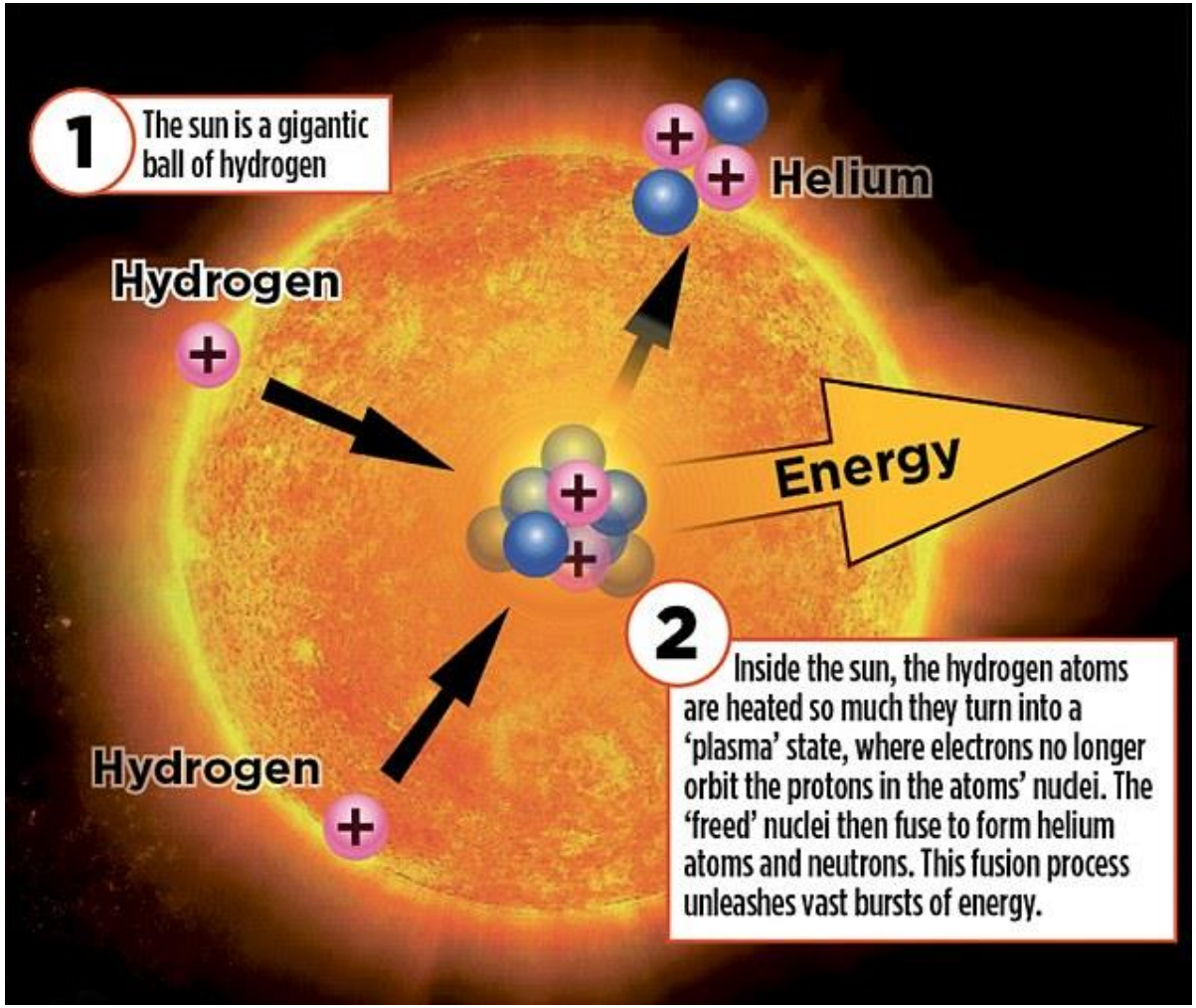
Plasmas at the birth of stars

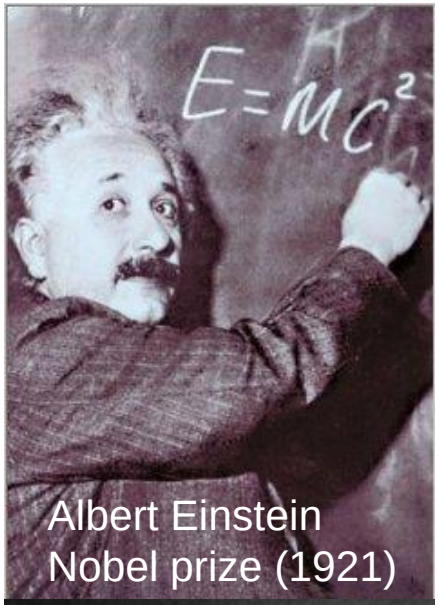


Most of the sun is in a plasma state, especially the corona.

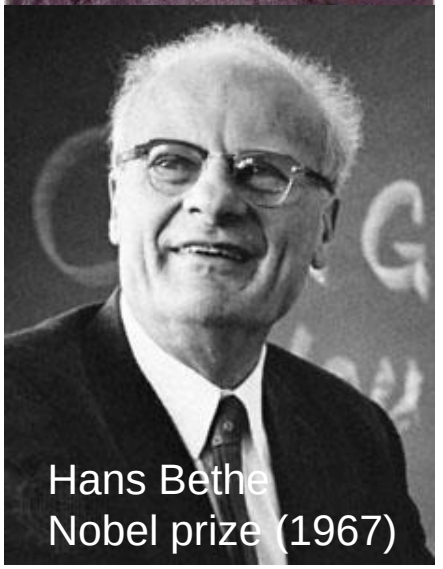
Comet tails are dusty plasmas.

The Sun's energy



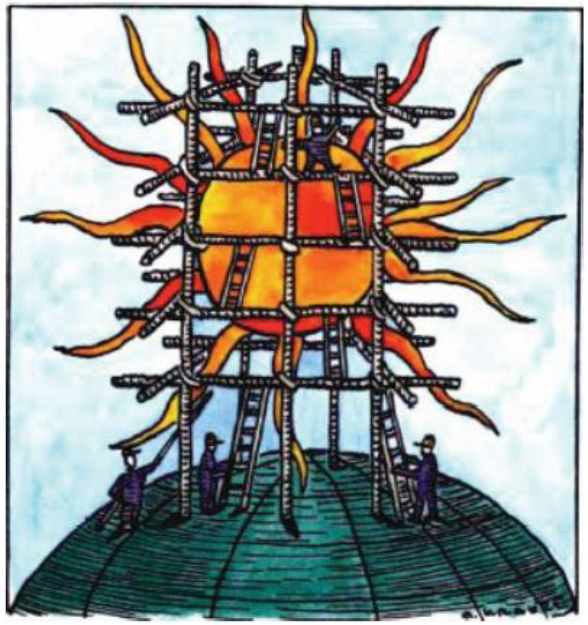


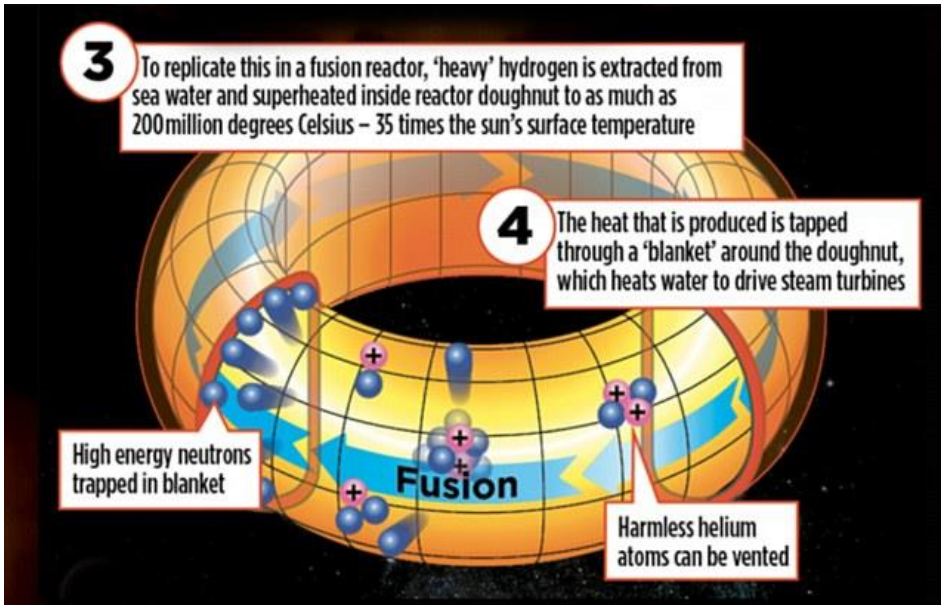
Albert Einstein
Nobel prize (1921)

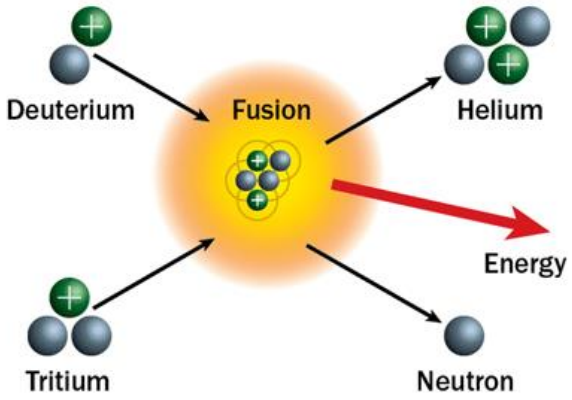

Hans Bethe
Nobel prize (1967)

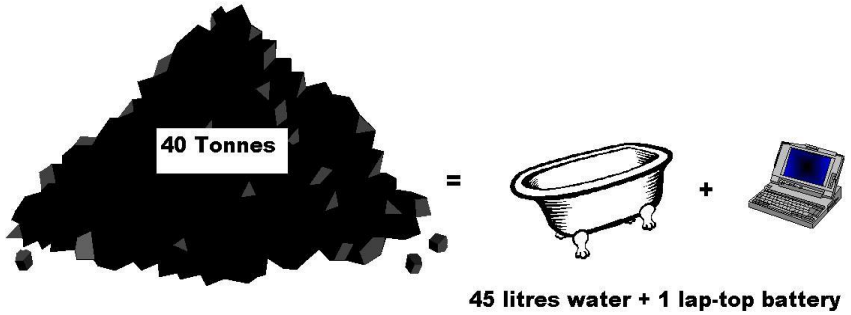
$$4\,{}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + 2\gamma + 2\beta^{+} + 2\nu + 26.72\ \mathrm{MeV}$$

Man-made fusion







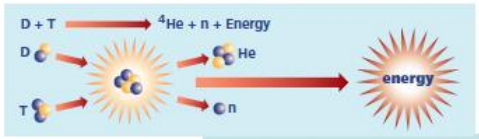


노트북 배터리 1개 + 욕조 절반 물
(≥ 달걀컵 1개 분량 중수) = 200 MW
→ 55년 사용량

ITER project

What is fusion?

Fusion is the energy source of the sun and the stars. In the fusion process on Earth, two isotopes of hydrogen, deuterium and tritium, fuse together to form a helium atom and an energetic neutron. The energy potential of the fusion reaction is superior to all other energy sources that we know on Earth.



What is the goal of ITER?

ITER is a large-scale scientific experiment that aims to demonstrate that it is possible to produce commercial energy from fusion.

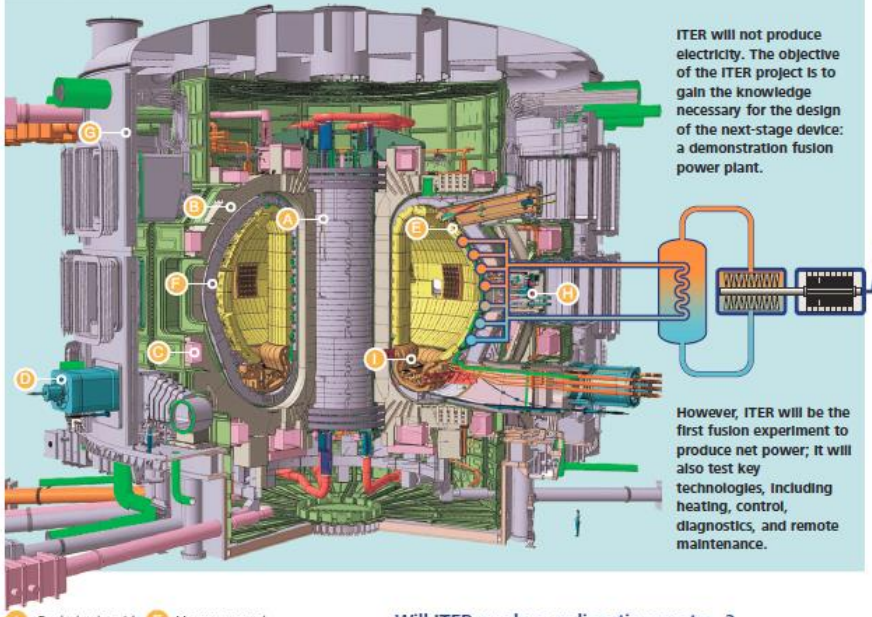
From 50 MW of input power, the ITER machine is designed to produce 500 MW of fusion power – the first of all fusion experiments to produce net energy.

During its operational lifetime, ITER will test key technologies necessary for the next step: the demonstration fusion power plant that will prove that it is possible to capture fusion energy for commercial use.

The fusion machine

ITER is based on the 'tokamak' concept of magnetic confinement, in which the plasma is contained in a

doughnut-shaped vacuum vessel. The fusion fuels are heated to temperatures in excess of 150 million °C, forming a hot plasma. Strong magnetic fields are used to keep the plasma away from the walls; these are produced by the superconducting coils that surround the vessel and by an electrical current driven through the plasma.



ITER will not produce electricity. The objective of the ITER project is to gain the knowledge necessary for the design of the next-stage device: a demonstration fusion power plant.

However, ITER will be the first fusion experiment to produce net power; it will also test key technologies, including heating, control, diagnostics, and remote maintenance.

A Central solenoid
B Toroidal field coil
C Poloidal field coil
D Diagnostics
E Blanket module
F Vacuum vessel
G Cryostat
H Heating system
I Divertor

Will ITER produce radioactive waste...?

Is ITER safe? What is the protection of ITER against external hazards? The FAQ section on our website, which is updated regularly, answers the questions that are most commonly asked by visitors to the ITER site and to our Facebook and Youtube pages. Please also visit our web pages specifically dedicated to safety issues: **www.iter.org/safety.**

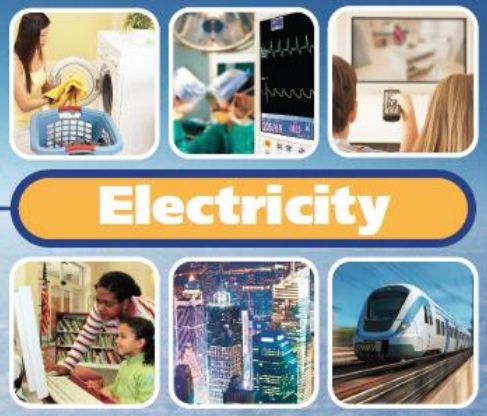
china eu india japan korea russia usa

ITER and the environment

Fusion has the potential to play an important role as part of a future energy mix for our planet. It has the capacity to produce energy on a large scale, using plentiful fuels, and releasing no carbon dioxide or other greenhouse gases. ITER is an important step on the road to fusion power plants; in Cadarache, Southern France, the project is being planned with great respect for the local environment, in keeping with the aim of producing an environmentally benign form of energy. **[For further information please visit our website www.iter.org]**

International cooperation

With ITER, 34 nations – representing half of the world's population – have joined their forces and their knowledge to take fusion energy to the industrial level.

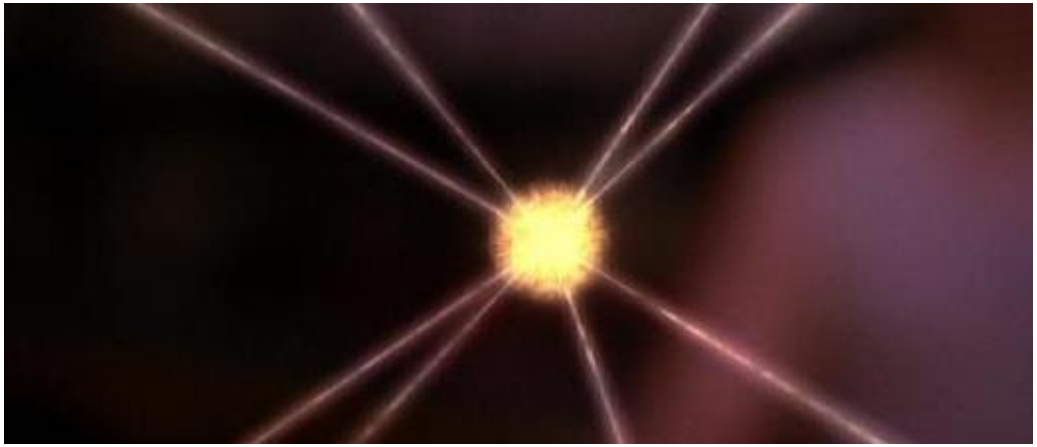


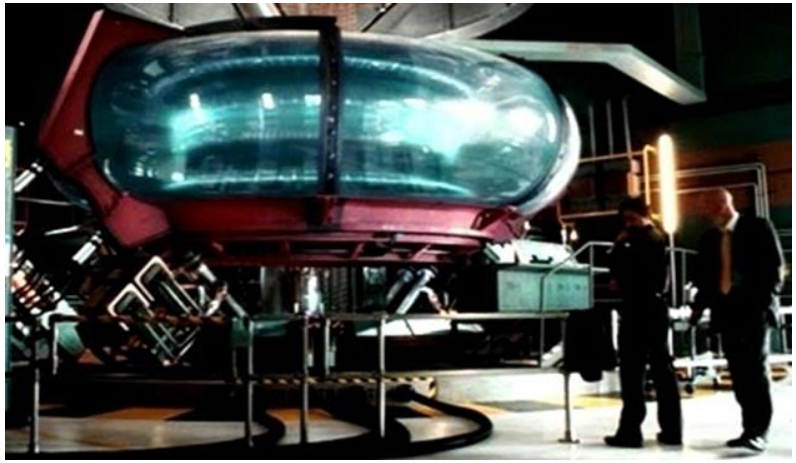
"In our opinion, the use of fusion energy is a 'must' if we want to be serious about embarking on sustainable development for future generations".

Osamu Motojima
Director-General ITER

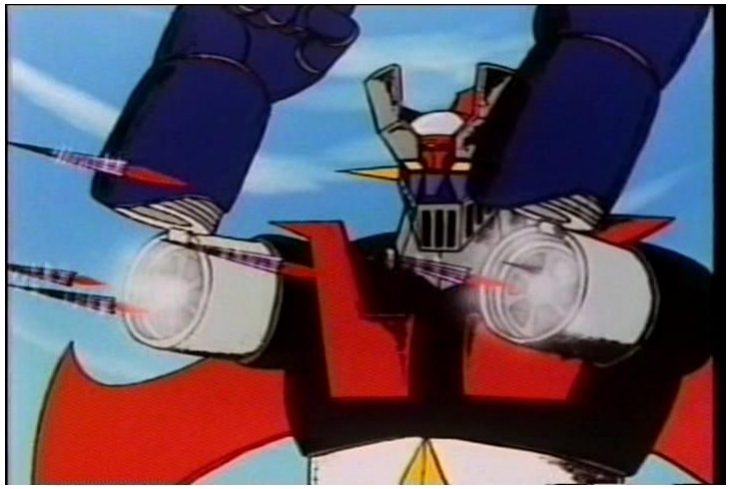
Fusion in movies

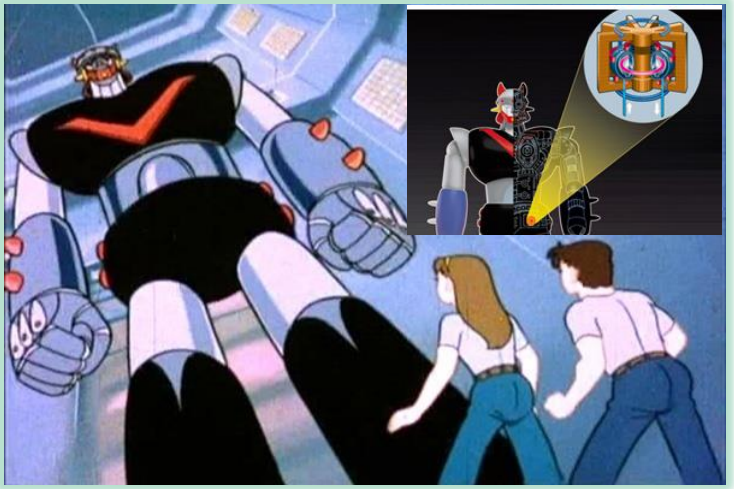
- Magnetic confinement? Inertial confinement?
- Or, cold fusion?





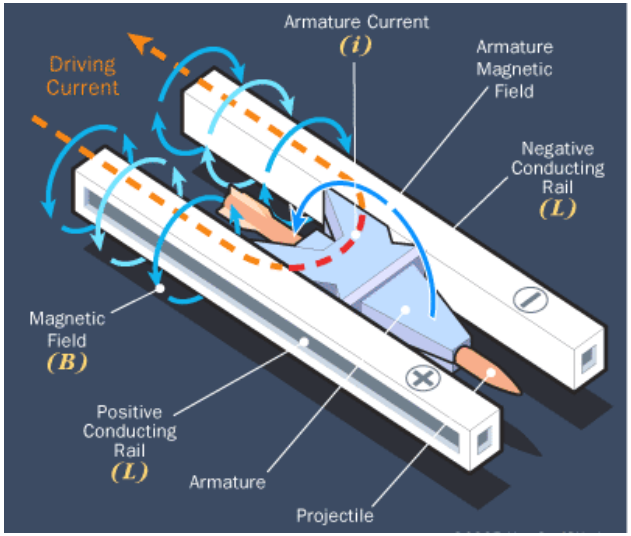
What are energy sources?





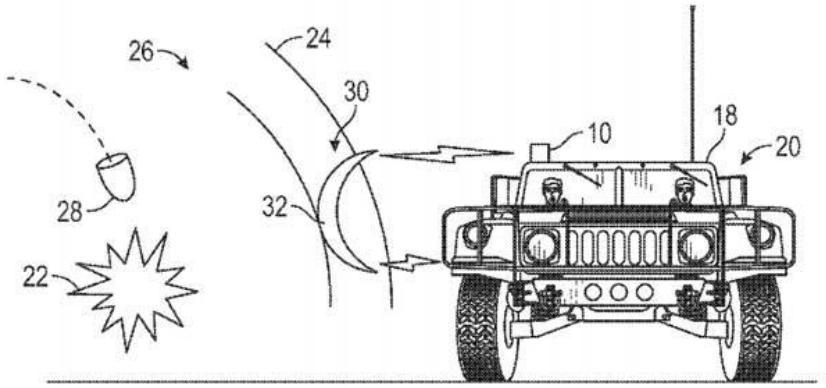
Military plasmas

- Railgun



Military plasmas

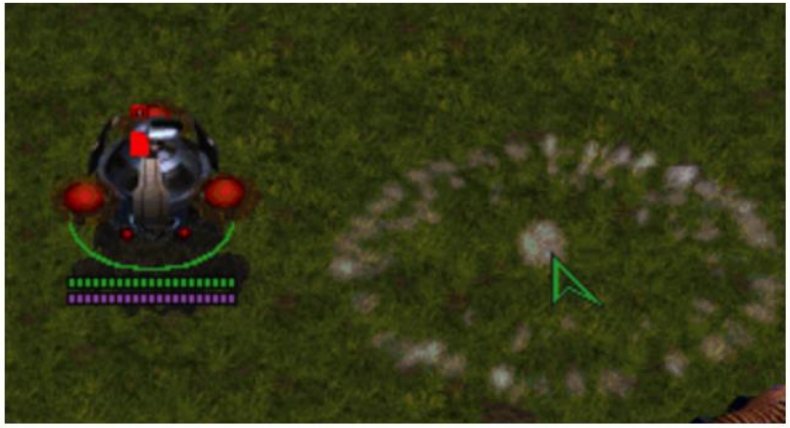
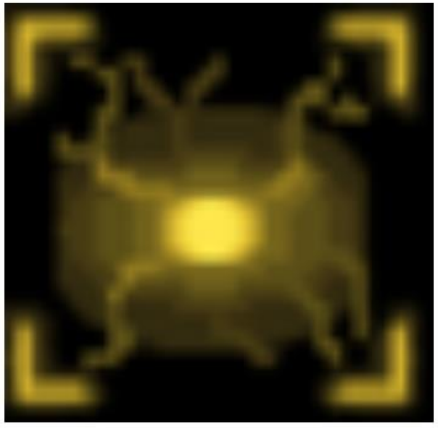
- Plasma shield

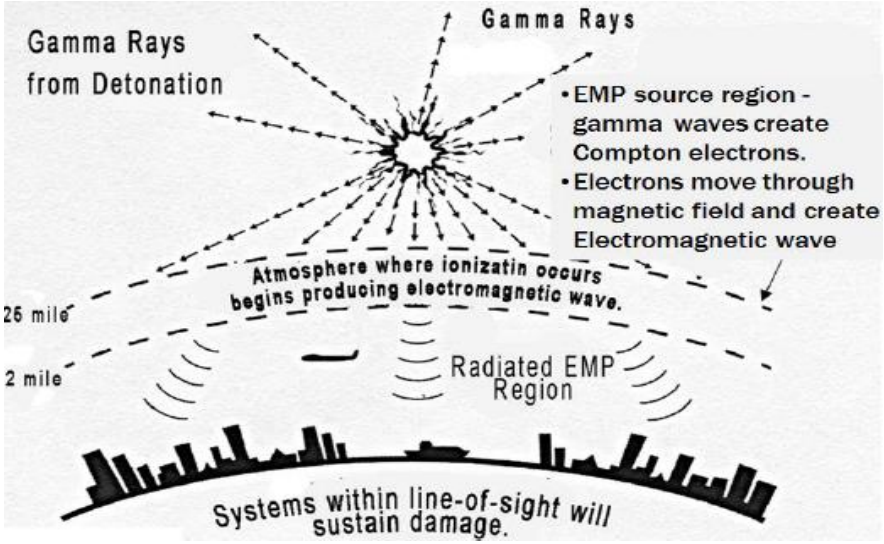


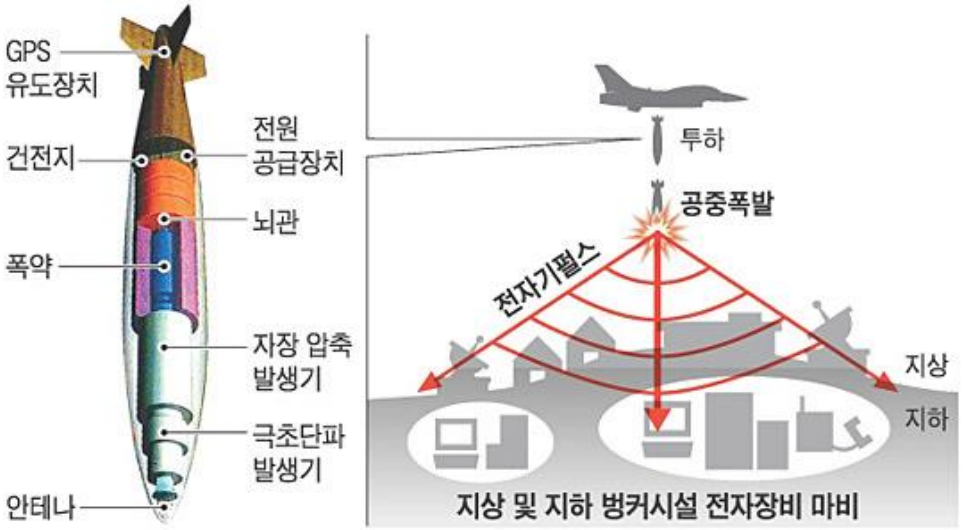
Boeing's patent: protection system from explosive shockwaves

Military plasmas

- EMP (electromagnetic pulse): nuclear-EMP or non-nuclear EMP

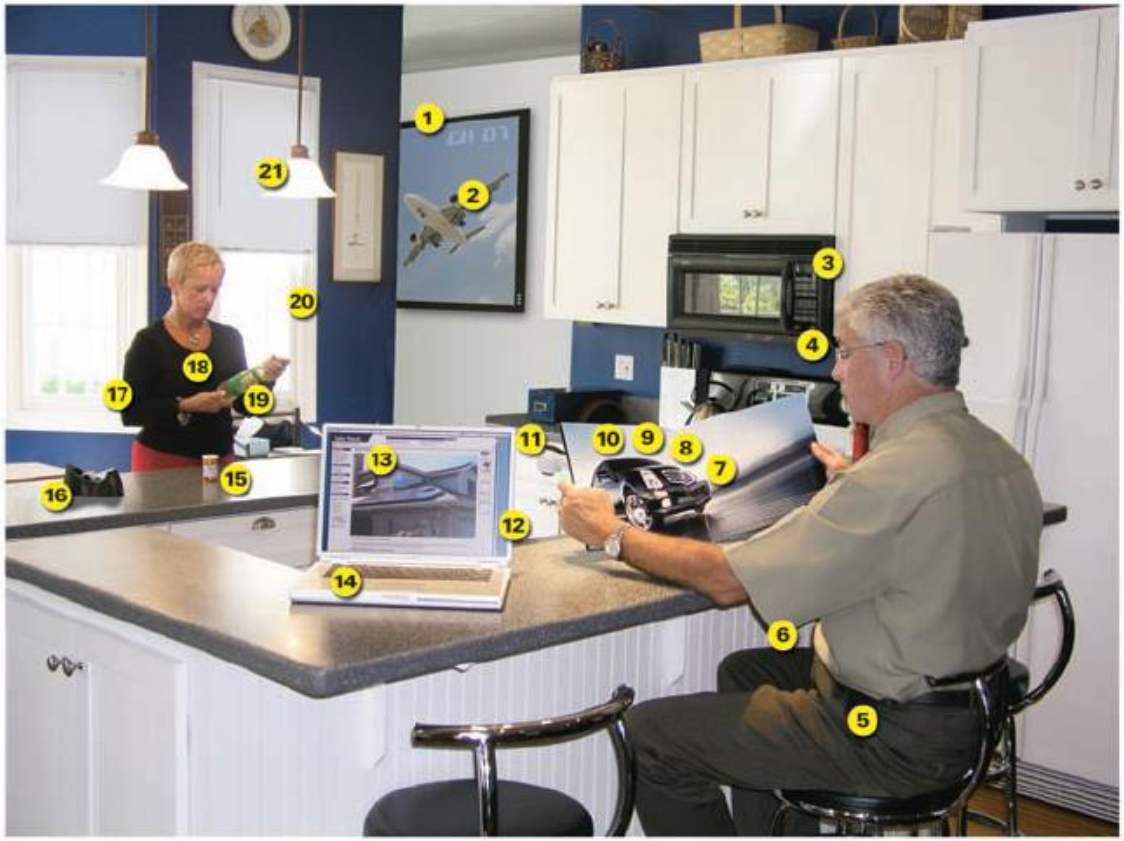




Lightning

- Lightning is a sudden electrostatic discharge that occurs typically during a thunderstorm. This discharge occurs between electrically charged regions of a cloud (called intra-cloud lightning or IC), between two clouds (CC lightning), or between a cloud and the ground (CG lightning).

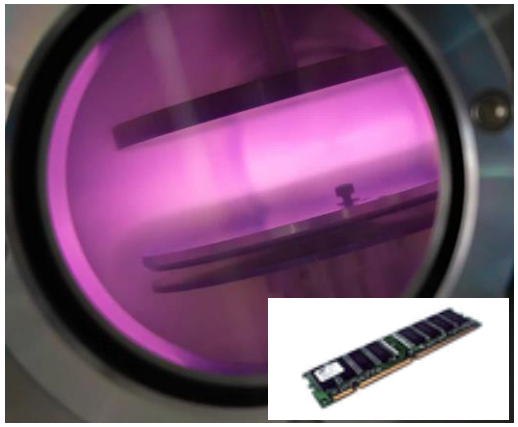
Plasmas in everyday life



01—Plasma TV
02—Plasma-coated jet turbine blades
03—Plasma-manufactured LEDs in panel
04—Diamondlike plasma CVD eyeglass coating
05—Plasma ion-implanted artificial hip
06—Plasma laser-cut cloth
07—Plasma HID headlamps
08—Plasma-produced H_2 in fuel cell
09—Plasma-aided combustion
10—Plasma muffler
11—Plasma ozone water purification
12—Plasma-deposited LCD screen
13—Plasma-deposited silicon for solar cells
14—Plasma-processed microelectronics
15—Plasma-sterilization in pharmaceutical production
16—Plasma-treated polymers
17—Plasma-treated textiles
18—Plasma-treated heart stent
19—Plasma-deposited diffusion barriers for containers
20—Plasma-sputtered window glazing
21—Compact fluorescent plasma lamp

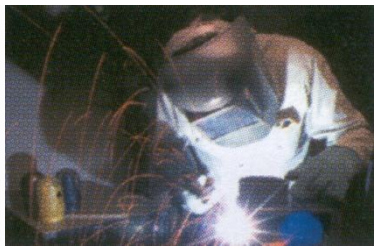
Plasmas in industry

반도체 식각



플라즈마 디스플레이

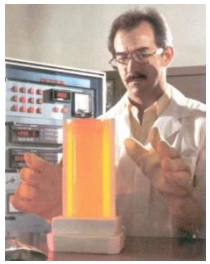
플라즈마 용접



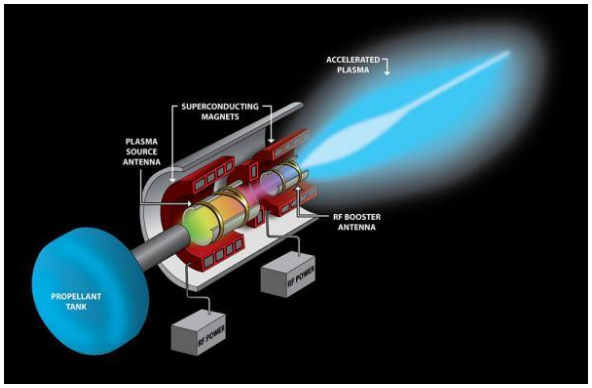
폐기물 소각

인조 다이아몬드

세라믹 가공

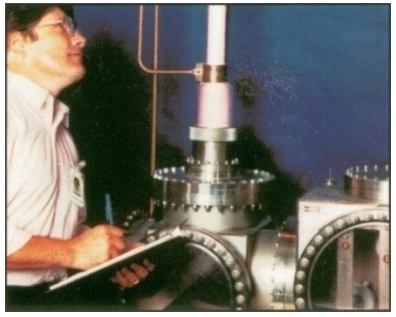


플라즈마 추진



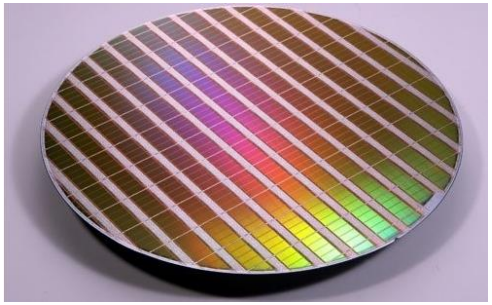
플라즈마 발파

플라즈마 코팅

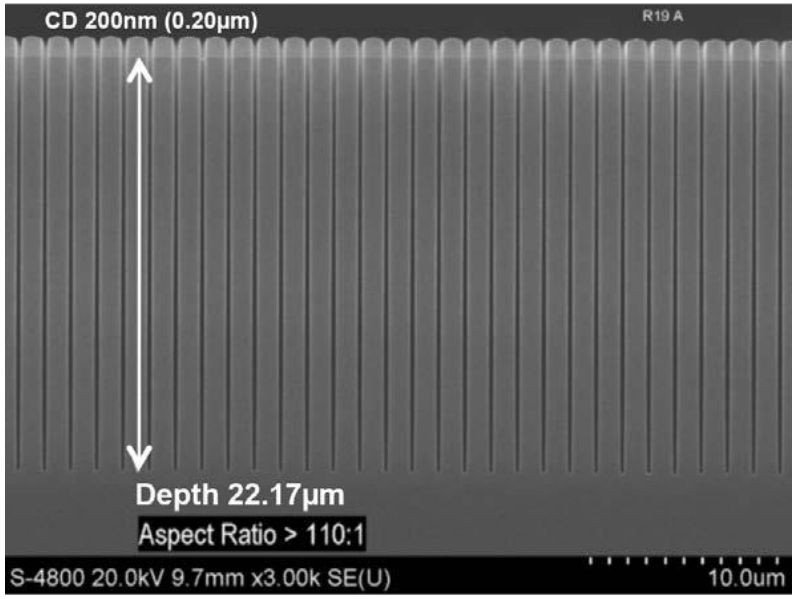


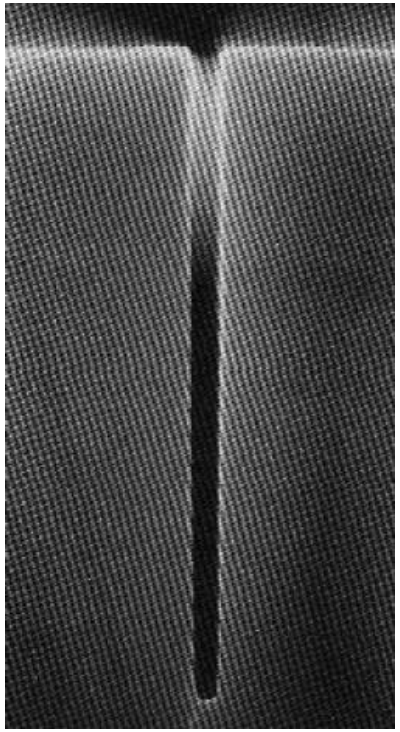
플라즈마 전구

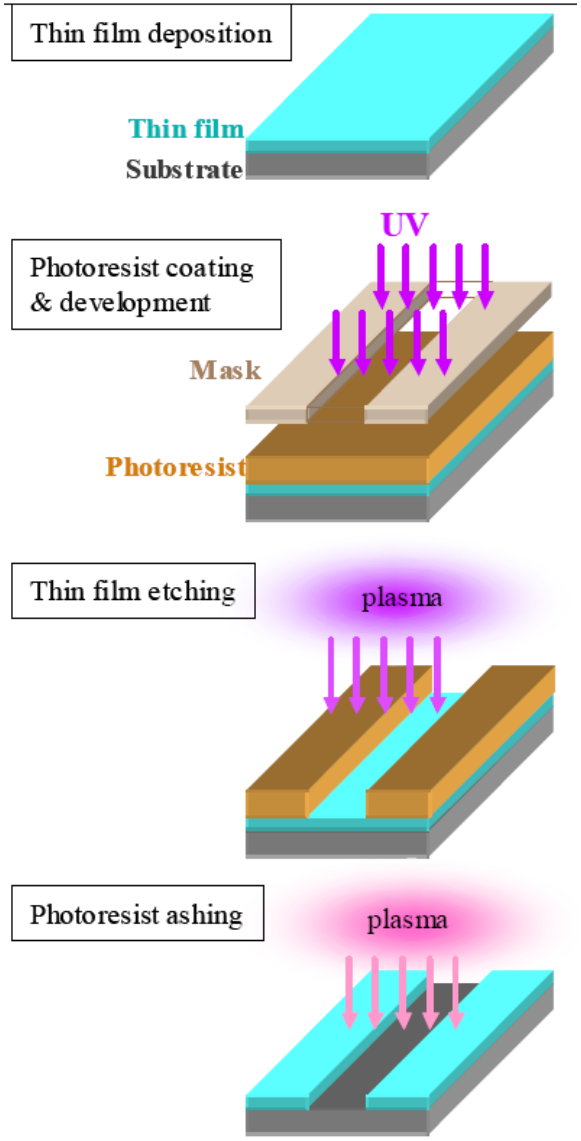
Plasmas in semiconductor fabrications



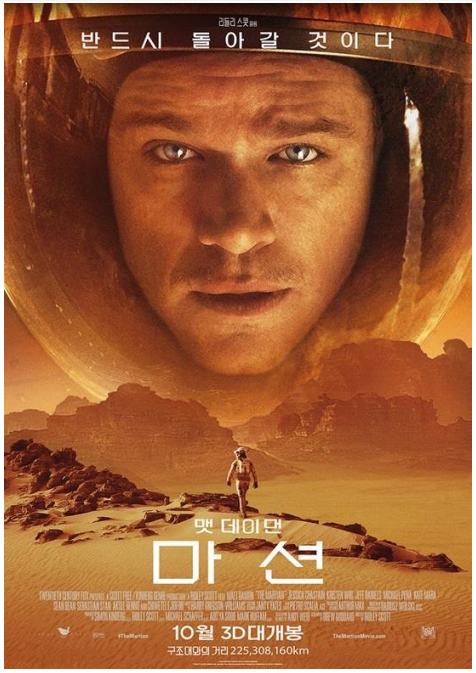
All-in-One Etch
(Oxide / DRIE / PR Clean)

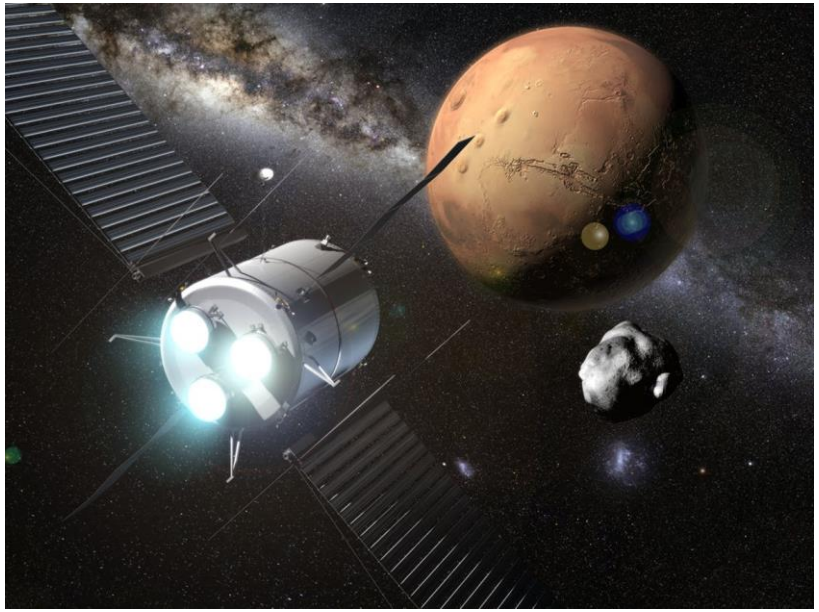


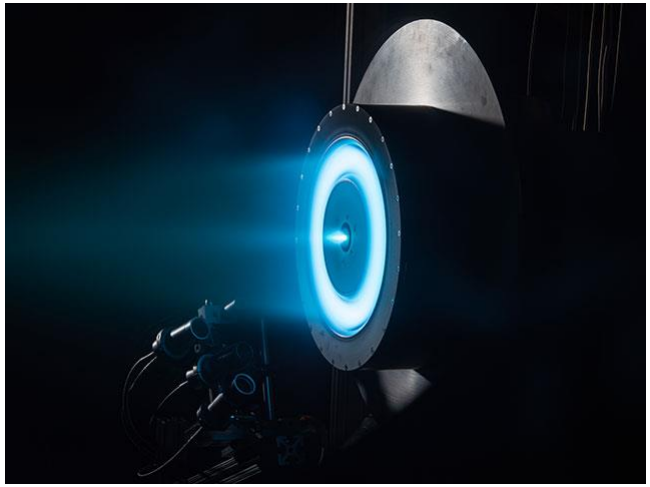


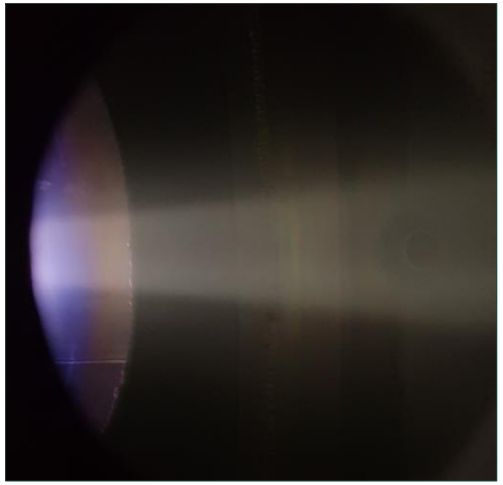


Plasmas in space applications

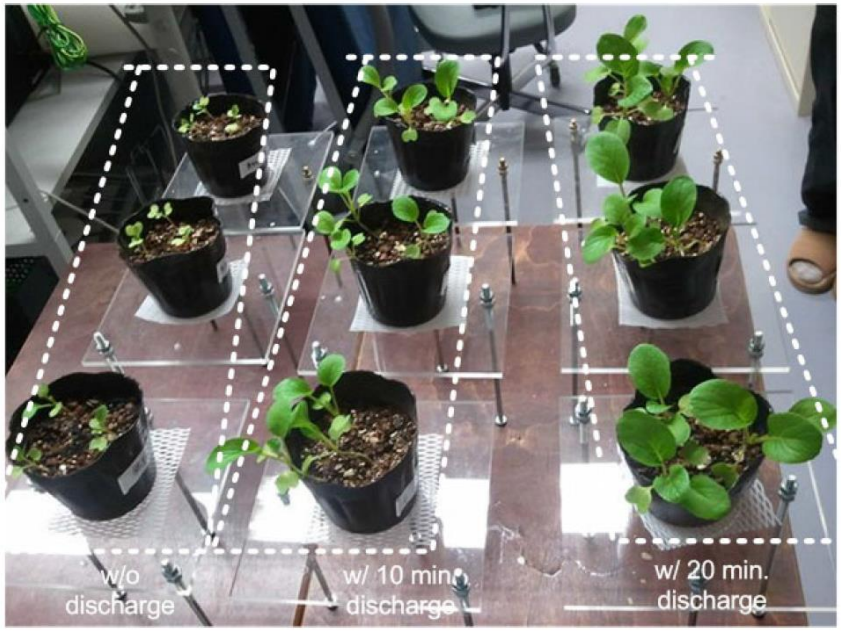


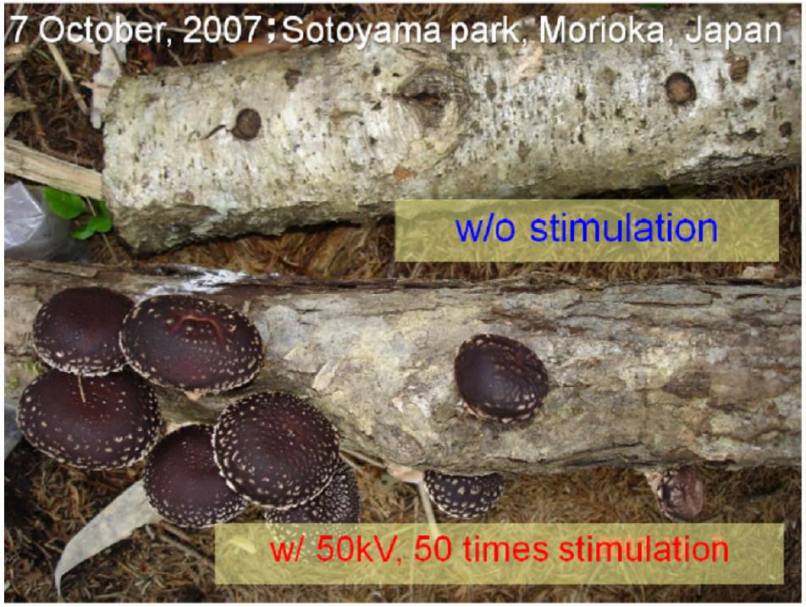


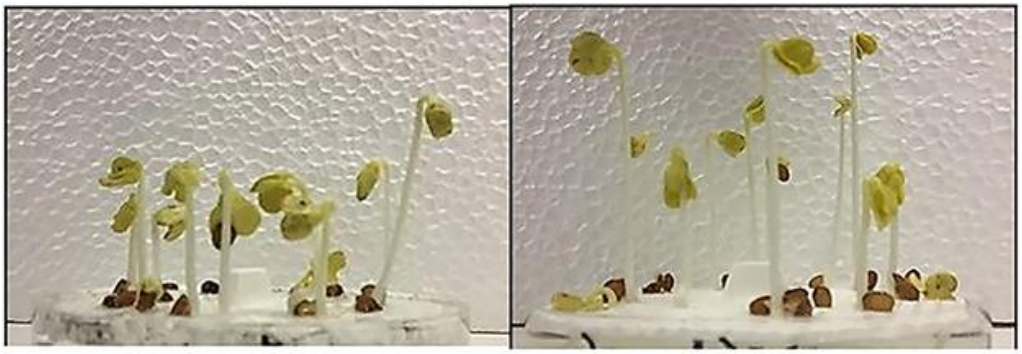




Plasmas in agriculture







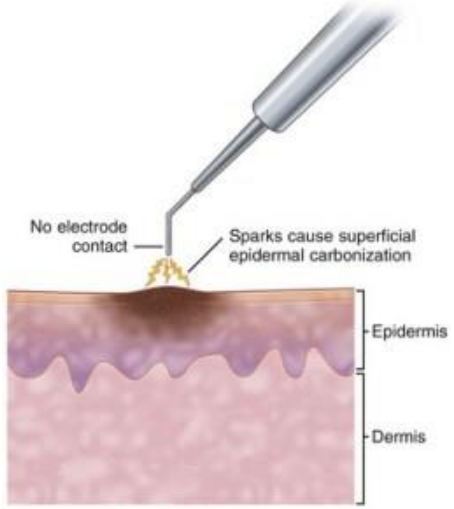
(a) Cultivated in non-treated water

(b) Cultivated in plasma-treated water

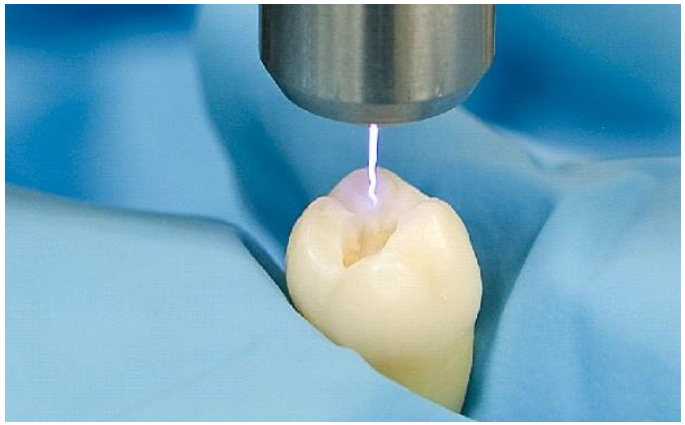
Plasmas in biomedical applications

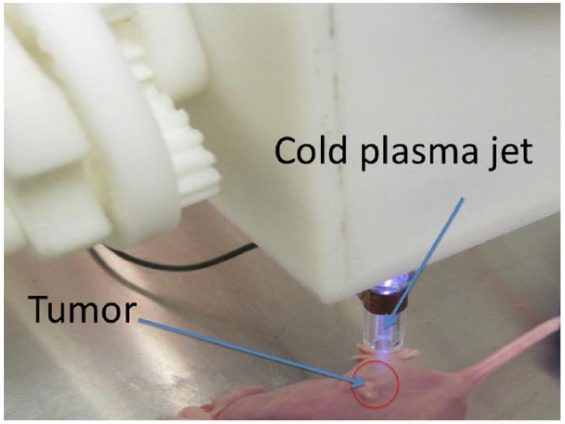
Plasma surgery

Plasma therapy

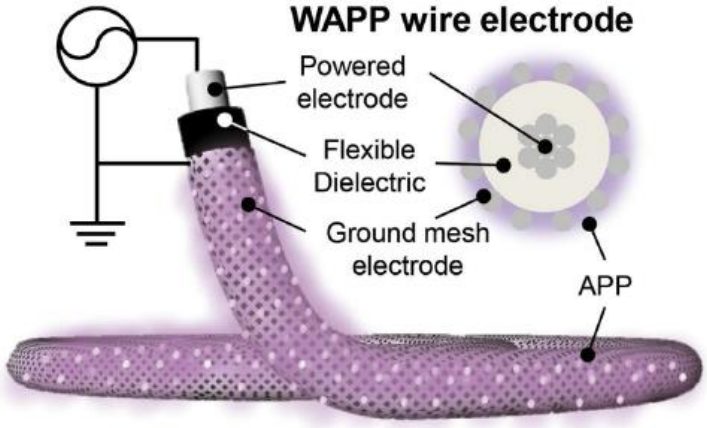


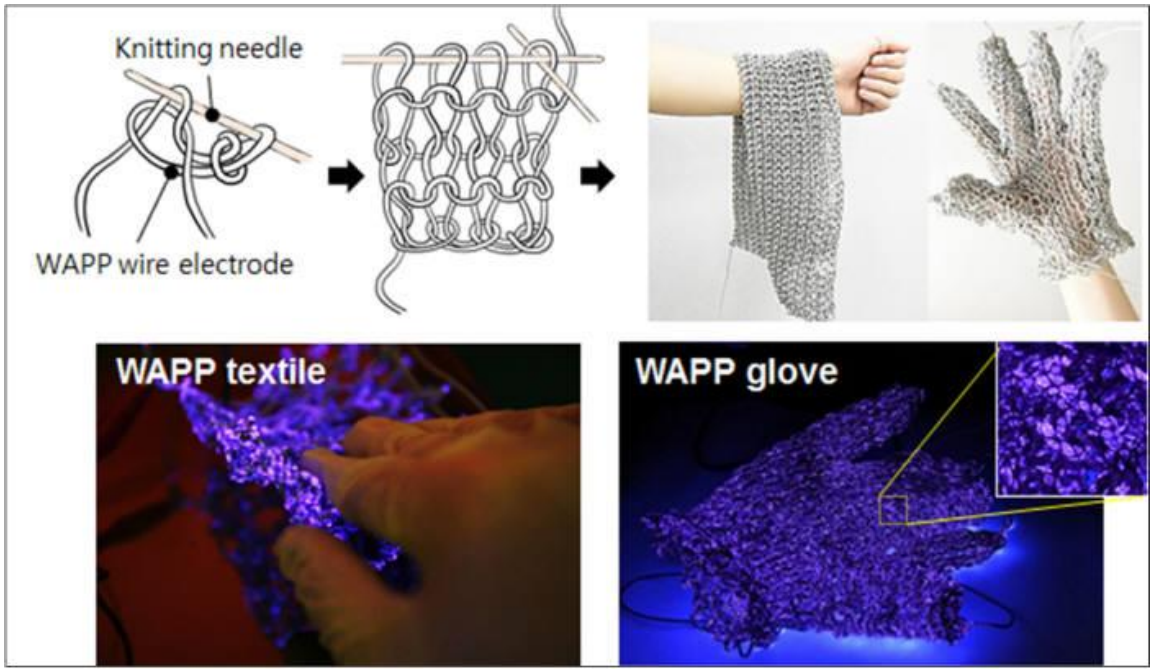
Plasma dentistry





Wearable plasma fabric





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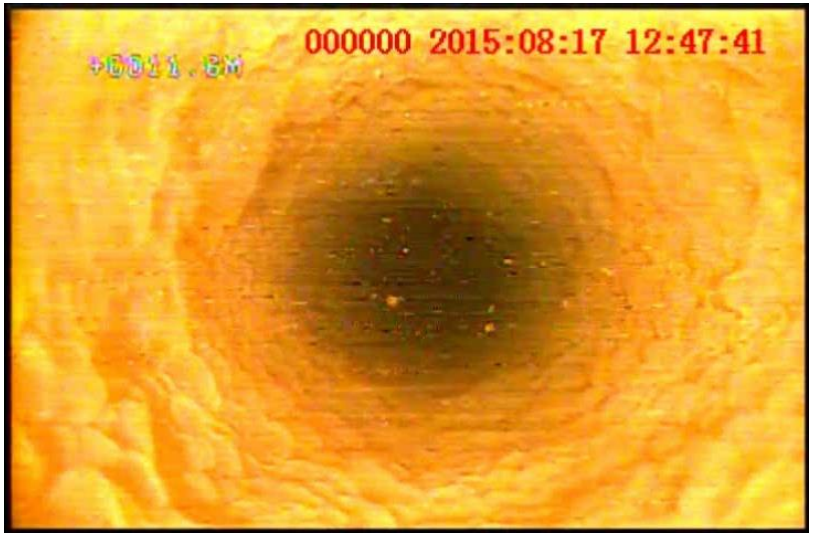
Many other applications

펄스방전 처리 전



펄스방전 처리 후