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States of Matter – Part II. The Three Additional States: Plasma, Bose-Einstein Condensate and Fermionic Condensate

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Abstract

This is a continuation of Part I, and contains descriptions of the three additional states of matter: Plasma, Bose-Einstein Condensates (BEC) (discovered by Ketterle, Cornell and Wiemani in 1995) *and Fermionic Condensates (discovered by Jin in 2003). Plasma consisting of ions and electrons exists at high temperatures beyond the gas state; and the two condensates, Bose-Einstein and Fermionic, exist at temperatures close to absolute zero. The former is composed of boson particles that obey the Bose-Einstein particle statistics; and the latter is made up of Fermion particles that obey the Fermi-Dirac particle statistics.*

Most of today's cutting-edge technologies -- smaller, faster computer chips, micro-electro-mechanical systems (MEMS) and quantum computers -- are positioned in the twilight zone between the quantum and macroscopic worlds. BECs are big enough visible quantum creatures, so BECs are in a position to advance these technologies and discover others in future.

Keywords: *Ions, electrons, particle statistics, plasma, boson particles**,** Fermi-Dirac particle, micro-electro-mechanical systems*

Additional States

The Plasma State

Plasma, shown in Fig. 8, is the fourth state of matter. This state was discovered in 1879 by Sir William Crookes in England, but its application was delayed until 1929 when Irving Langmuir, an American chemist and physicist, used it to obtain fluorescent light. However Hannes Alfvén (1908-1995), a Swedish physicist, is considered the father of modern day *plasma science*. He received the Nobel Prize in 1970 for his contributions to basic plasma physics and for his studies of space plasmas (Vu *et al.,* 2004).

Plasma occurs abundantly in the universe. More than 99% of all visible matter in the universe is in the plasma state. Plasma appears on earth only in places like lightning bolts, flames, auroras, and fluorescent lights. Natural plasma exists only at very high temperatures, or low temperature vacuums. Artificial plasma can be created by using electrical charges on gases (Kasinart 2004).

As shown in Fig. 10, matter changes state as it is exposed to different physical conditions. Ice is a solid with H_2O molecules arranged in definite regular patterns. When ice melts its pattern changes into the liquid state pattern and water is formed. As the water is warmed the molecules separate further to form steam. On heating steam further, it may be ionized. If heated sufficiently, repeated ionization occurs and creates clouds of free electrons and positive ions. But some are left intact without being ionized. This mixture of ions, electrons, and neutral atoms is plasma. However, a collective response to electric and magnetic fields may be observed only when sufficient numbers of charged particles are present. In other words *plasma density* must be sufficient.

On the microscopic scale, plasma contains electrons and ions and, therefore, conducts electricity. But on the macroscopic scale, it is neutral as the number of electrons and positive ions in the whole system are equal. The charged plasma particles are propelled by external electric and magnetic fields. This motion of the particles generates