Plasma – The Fourth State Of Matter

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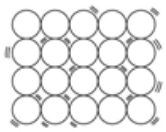
Abstract: Get an easy-to-understand, fun-to-learn insight into the fourth state of matter – Plasma, and learn how it is created and how it is different from the other three states. We further look into the principle behind the working of neon lights and Plasma TVs.

Index Terms: electrodes, gases, lights, neon, plasma, photons, television

1 INTRODUCTION

If I ask you to tell me the different states of matter, you would probably say solids, liquids and gases. Let us now take a glance at these three states and their properties.

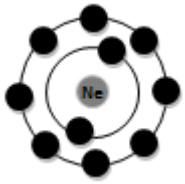
SOLIDS	LIQUIDS	GASES
		
✓ Particles are tightly packed and have strong inter- molecular forces of attraction between them. ✓ Very low compressibility. ✓ Has definite shape and volume. ✓ Very good conductors of heat.	✓ Particles are not that tightly packed. So, they have weaker forces of attraction between them. ✓ Compressible. ✓ Has definite volume, but takes the shape of the container that holds it. ✓ Fairly good conductors of heat.	✓ Particles are loosely packed. Hence, they have very weak, or no force of attraction between them. ✓ Highly compressible. ✓ Occupies whatever space is available to them. Hence, no definite shape or volume. ✓ Poor conductor of heat and electricity.

Till now, we have only dealt with substances that fall into one of these categories. But do all known substances to man fall into these three categories?
Let's find out…

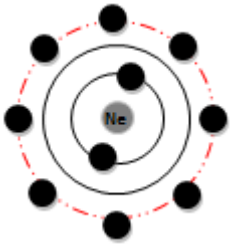
2 AN ILLUSTRATION

We have all seen and admired the beauty of neon lights in cars and signboards. But have you ever wondered how it works?

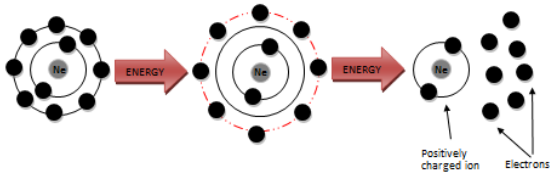
Let us study how the neon lights work…Neon lights consist of a tube in which neon gas or a similar gas is filled. The ends of this tube are connected to the cathode and anode on either ends. A neon atom consists of 10 electrons – 2 in the inner shell, 8 on the outer shell. It looks somewhat like this:



Now, when electricity flows through the tube, it "excites" the electrons on the outermost shell. That is, the electrons jump from a lower energy level to a higher one due to the energy supplied.



Soon, the electrons move back to their lower energy level to stabilize the atom once again. Always remember: Whenever an electron moves from a lower energy level to a higher one, energy is absorbed. That is why the electrons in the valence (or outermost) shell moved one energy level up by absorbing the energy from electrons flowing from the cathode to the anode. The reverse process is also true, that is: Whenever an electron moves from a higher energy state to a lower one, energy is released. In this case, the energy is emitted in the form of photons (light particles), which results in the light we see at the OPEN sign in front of the café. Now, this process keeps repeating itself until the electrons absorb enough energy to break apart from the neon atom and move freely. Meanwhile, the neon atom becomes a positively charged ion.



- ✓ The particles of this substance are loosely packed, just like a gas.
- ✓ It has no definite shape, but has definite volume, just like a liquid.
- ✓ It is an excellent conductor of heat and electricity, just like metals (mostly solids).

So, which state of matter does it belong to?
Here, my friends, is where I introduce to you the fourth state of matter – "PLASMA".

3 THE FOURTH STATE

So, what is plasma? “Plasma” is a Greek word which means “that which is diffused” that is, unclear or semi – transparent. It is also defined by scientists as “ionized matter”. It is, in simple terms, a mixture of negatively charged electrons and positively charged ions. It is formed when high voltage or temperature knocks off the outermost electrons from an atom, which in turn knock off electrons in the neighbouring atoms.Some uses of plasma

- ✓ Micro – plasma welding is a method which is used to join paper thin sheets of metals, which is extensively used in the manufacture of stainless steel water storage tanks and other kitchen implements.
- ✓ Plasma spray is the only process that enables us to coat any material on to any other one:
  - ❖ Metal on to metal: titanium on to steel, to prevent corrosion.
  - ❖ Metal on to non-metal: copper on to porcelain, used in capacitors.
  - ❖ Non-metal on to metal: alumina on to stainless steel, to reduce wear and tear on stainless steel.
  - ❖ Non-metal on to non-metal: Teflon on to ceramics, to prevent corrosion by acids.
- ✓ Cold plasmas are used in sterilizers and hand-washers.
- ✓ They are also used to make plastics attract or repel liquids, which is used in printers.
- ✓ As we discussed earlier, neon in its plasma form is used for lighting.
- ✓ And of course, one important use, which I shall discuss in the next section…

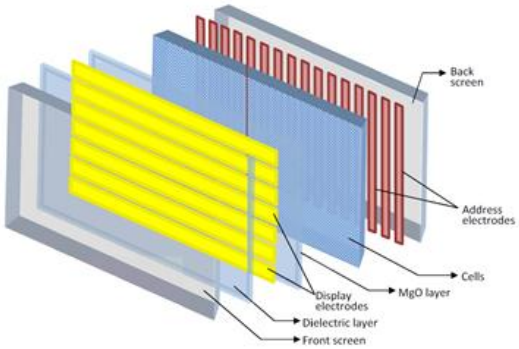
4 PLASMA TV

4.1 Introduction

We all are familiar with the Plasma TV. But have you ever wondered why they were named “Plasma” TV? Yes, you might have guessed by now that it has got something to do with the plasma I talked about in the last few pages. Well, you’re right! The display on the plasma screens is created by converting gases like neon, xenon etc. into the plasma state. Let’s go a little deeper into the working of a plasma TV…

4.2 Working Principle

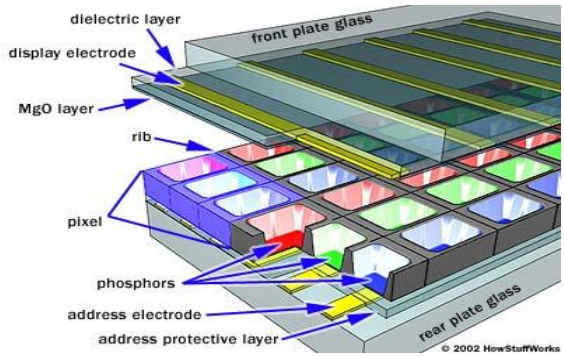
The screen of the plasma TV isn’t just one, but two screens put together. Between these two screens lie thousands of tiny cells filled with a mixture of xenon and neon gases. Also stuffed between the two screens are two rows of electrodes arranged in a grid pattern that extends across the entire screen, on opposite sides of the cells: the display electrodes are the horizontal ones on the front of the screen, while the address electrodes are the vertical ones in the back of the screen. They are arranged in such a way that at every cell, a display electrode will overlap an address electrode. The display electrodes are surrounded by a dielectric protective layer on the front, and another protective layer, this one made of magnesium oxide, behind it. Thus the cross-section of a plasma TV would look something like this:



Now when the switch is turned on, electricity passes through the electrodes (obviously). The voltage of the display electrodes is more than that of the address electrodes. At each cell, due to the voltage difference between the two sets of electrodes, current flows from the display electrode to the address electrodes. This process keeps repeating and in turn ionizes the gases in the cells, which in turn emit photons. Everything is going smoothly with no problems. Now let’s see the display on the TV:

It's still looks blank to me. Why do you think so? Well, the answer is that it isn't actually blank. Photons are being emitted by the gas. The only problem is that the gases are emitting ultraviolet photons, which are invisible to the naked eye. This problem was solved by coating the cells with a substance called phosphor. Phosphors are substances that give off light when they are exposed to another light. When a released ultraviolet photon hits a phosphor atom in the cell, one electron in the phosphor atom jumps to a higher energy level and the phosphor atom heats up. Soon when the electron gets bored and falls back to its own (lower) energy level, it releases energy, this time in the form of a visible light photon.Let us look at our TV now, after coating all the cells with a red light phosphor:

Yes, it has lit up! But we need to display videos with a mixture of colours, not just two or three colours. Here is where we introduce the very common term that you all must have heard somewhere before: pixels. In order to produce a large variety of colours, only three different phosphors are required: red, green and blue. So, the cells were alternately coated with these colours. Each set of three cells (red, blue and green) came to be known as a pixel, and each individual cell was termed as a "sub-pixel". To make things a bit clearer, here's another image of the inside of a plasma screen, this one from the internet and not like the rest of the ones I had created myself:



The control system is then attached to the back of the TV along with all the other necessary components which I won't be explaining about because that would be going off-topic. By varying the amount of current flowing through the different cells, the control system can increase or decrease the intensity of the colour in each sub-pixel to create hundreds of combinations of red, blue and green. In this way, the control system can produce colours across the entire visible spectrum. Now our TV is almost ready to go. Just one thing left…

4.3 Tuning In

Many of the first plasma displays on the market weren't actually televisions, technically speaking, because they didn't have TV tuners. The television tuner is the device which takes a TV signal (either from satellite or cable wire) and interprets it to create a video image. Now let's tune in our TV and check out how the screen looks now:

Perfect!

5 FIFTH STATE OF MATTER?

Okay, now we have four states of matter: Solid, Liquid, Gas and Plasma. All is well. But do all matter still fall into one of these categories? Let us consider an important property of matter for this – "Movement of particles".

S. No.	State of Matter	Movement of Particles
1	Solid	No movement as such, just vibrations about its own position.
2	Liquid	Random movement in all directions.
3	Gas	Random movement in all directions.
4	Plasma	Random movement in all directions.

Now that we have seen the movement of particles in solids, liquids, gases and plasma, we can take the case of particles of light from a source, say a table lamp. In this case, the particles of light move harmoniously in one direction only. Heat is formed when the particles collide with each other. This does not take place at all in the case of the light particles. In fact, all the other four states of matter we have discussed about are thermal, even solids, due to the slight vibration. This creates the need for us to introduce one more new state of matter, and this happened to be called Beam. Since this article is supposed about plasma, I shall not go much into detail about beams.

Note:

Many other states of matter have been classified by scientists, but there are actually only four fundamental states of matter – solid, liquid, gas and plasma; the rest of them – such as the Bose-Einstein condensate and even, in fact the beam I just explained about – either exist only at extreme temperatures, or are only theoretical and have not yet been found to exist.

REFERENCES

[1] http://www.youtube.com/watch?v=YIS24yOZZSk

[2] http://electronics.howstuffworks.com/plasma-display2.htm

[3] http://www.mindreality.com/seven-states-of-matter-everything-is-mind

[4] http://en.wikipedia.org/wiki/Plasma_(physics)

[5] http://www.google.com/imghp

[6] http://electronics.howstuffworks.com/plasma-display2.htm