Duke University

Plasma Display Panel

A vanished technique

Yida Chen
Dr. Hubert Bray
Math 190s: Mathematics of the Universe
31 July 2017

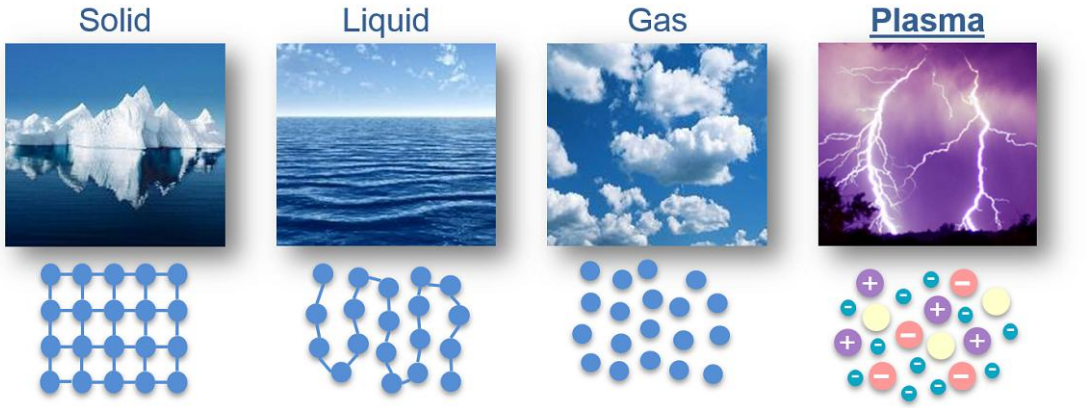
Introduction

With the establishment of the atomic theory, we begin to change the way that we use to exploit the matters. Before we understand the existence of the photon, we might never imagine how the normal matters emitted the light. Now, with the exploitation of the special illuminating phenomena of the atoms, a new type display, plasma display, which has the overwhelming advantages compared with LCD display and CRT displays, has been invented. It seems that the future of the display market will be dominated by the plasma display. However, in the second decade of the twenty-first century, the manufacturers of plasma display successively claimed that they would discontinue the production of plasma displays. For many consumers, the vanishing of the plasma displays is unreasonable. Below, I will explain the operation principle of the plasma display and reveal the reason for its vanishing.

What is the plasma?

As we have known, the solid, liquid, and gas are the three fundamental states of the matter. However, there are four fundamental states of the matter on the earth, and the plasma is the fourth." Unlike these three states of matter, plasma does not naturally exist on the Earth under normal surface conditions, and can only be artificially generated from neutral gases. "[1]Thus, the plasma that we use in the plasma display panel (PDP) is the ionized gases. These gases are composed of the negatively charged electrons and positively charged ions.

[1] Direct quote from https://en.wikipedia.org/wiki/Plasma_(physics).



[2]

Observing the description of the plasma, we can find that the composition of the plasma is same to the composition of gases in the Crookes tube. In fact, William Crookes is the first man to discover the plasma, and he also identified the Crookes tube`s ionized gases as the fourth fundamental state of the matter.[3] However, the subatomic world had not been discovered, so his theoretical views of the plasma were still incorrect. The real property of the plasma is different from the gas, though the plasma is artificially generated from the gas. Since the plasma is consist of highly charged particle, its electrical conductivity is very high, and it can sensitively respond to the electromagnetic field.

What is the Plasma Display Panel (PDP)?

"The plasma display panel is a type of flat panel display.[4]" Unlike LCD which is also a type of flat display, the Plasma display does not depend on the backlight to illuminate. The plasma display panel is composed of many tiny cells which hold a mixture noble gas and mercury vapor. When the turn on the panel, the high voltage

---

[2] The image was adapted from http://www.grinp.com/plasma/physics.html.
[3] Direct quote from the Radio-activity induced by the oscillatory discharge, or, The subsequent radio-active emanation from substances exposed to the Tesla oscillatory discharge.
[4] Direct quote from https://en.wikipedia.org/wiki/Plasma_display.

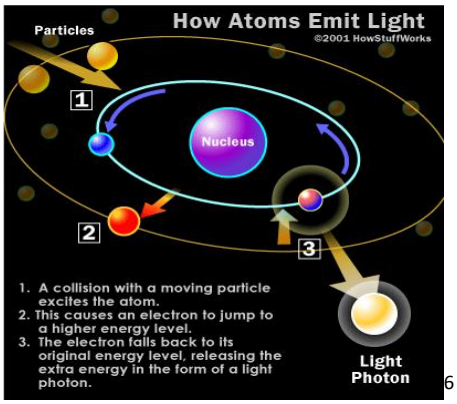
will be applied cross the cell, and gas will be ionized by the strong electric field, then the plasma is formed in the cells. With a chain reaction among the particles in the cells, the mercury atoms can emit the high-energy ultraviolet photons. The ultraviolet is invisible to the humans` eyes. To transfer the ultraviolet into a colorful visible light, the ultraviolet photons strike the phosphors that are painted inside the cells. The energy of the photons can be conveyed to the molecules of phosphors, and a colored invisible light will be emitted.

The design of the PDP

The noble gas is made up of uncharged atoms which have equal numbers of positively charged protons and negatively charged electrons. However, this balance can be easily broken by introducing additional electrons into the gas. According to the law of the Townsend discharge, the free electrons collude with gas molecules, when the electrons are accelerated by the strong electric field. These accelerated electrons will free additional electrons from the atoms` nucleus. Since the atom loses an electron, the atom has a net positive charge and becomes an ion. Subsequently, the gas is ionized and be turned into the plasma state.

"In a plasma with an electrical current running through it, negatively charged particles are rushing toward the positively charged area of the plasma, and positively charged particles are rushing toward the negatively charged area."[5]

[5] Direct quote from http://electronics.howstuffworks.com/plasma-display1.htm.



[6]

During this procedure, the particles will bombard with gas atoms. These collisions will excite the atoms. Since the atoms gain plenty energy from the collisions, the excited atom is unstable. To transfer these unstable excited atoms into a more stable form atom, the atoms need to release the energy. The carriers of this energy are the photon. Below, we have a function which can measure the energy of the photon.

$$E=hv$$

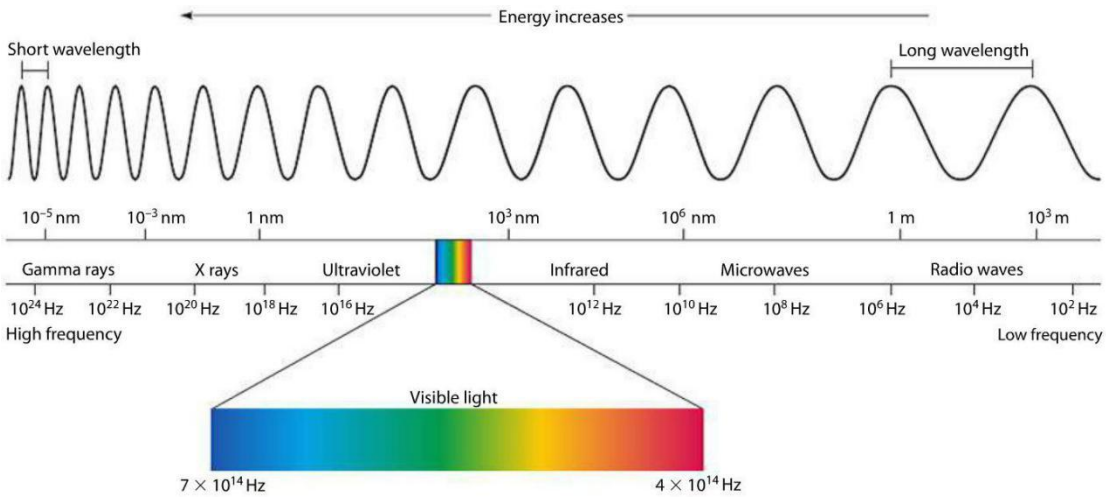
E is the energy of the photon.

h is the plank constant.

v is the frequency of the photon of the light.

From the function, we can observe that the energy of the photon is directly proportional to the frequency of the photon of the light, since the h is the constant. I have mentioned the energy of the excited atoms is very high, so the photons that the atoms release have high frequency and low wave length, which make the light invisible to the human`s eyes.

[6] The image was adapted from http://electronics.howstuffworks.com/plasma-display1.htm.



[7]

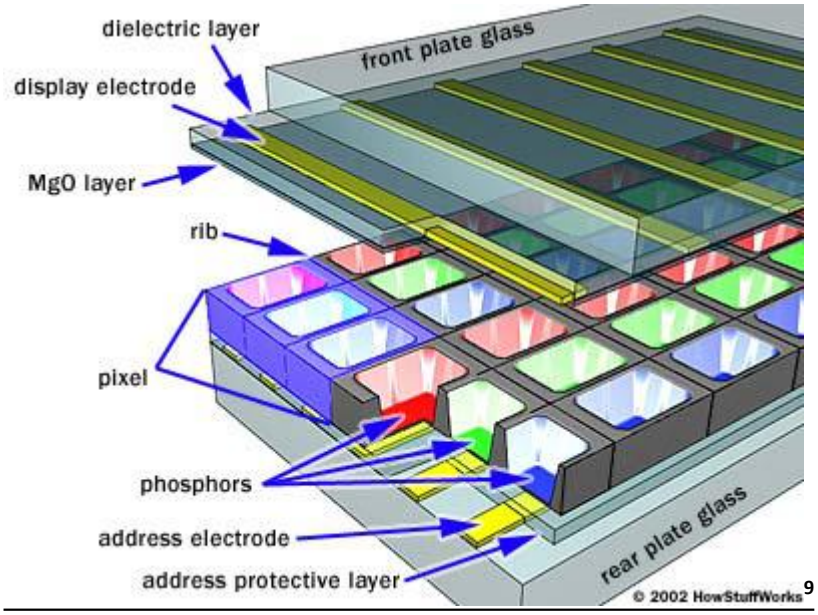
The wavelength of the visible light is between 390nm and 780 nm. According to the Yongqiang Lan, in the plasma display, the wavelength of the ultraviolet which is emitted from the excited noble gas atom is 173nm. To get the colored invisible light, the ultraviolet needs to interact with the phosphors inside the cell.

“The released ultraviolet photons interact with phosphor material coated on the inside wall of the cell. Phosphors are substances that give off light when they are exposed to other light. When an ultraviolet photon hits a phosphor atom in the cell, one of the phosphor's electrons jumps to a higher energy level and the atom heats up. When the electron falls back to its normal level, it releases energy in the form of a visible light photon.”[8]

In the plasma display, every pixel is made up of three separated subpixel cells, which are red subpixel, blue subpixel, and green subpixel. The incorporating technique of the plasma is same as that of the CRT display and LCD display. By changing the pulse of the current flowing through the cells, we can the intensity of the subpixel cells`

[7] The image was adapted from https://www.miniphysics.com/electromagnetic-spectrum_25.html.
[8] Direct quote from http://electronics.howstuffworks.com/plasma-display2.htm.

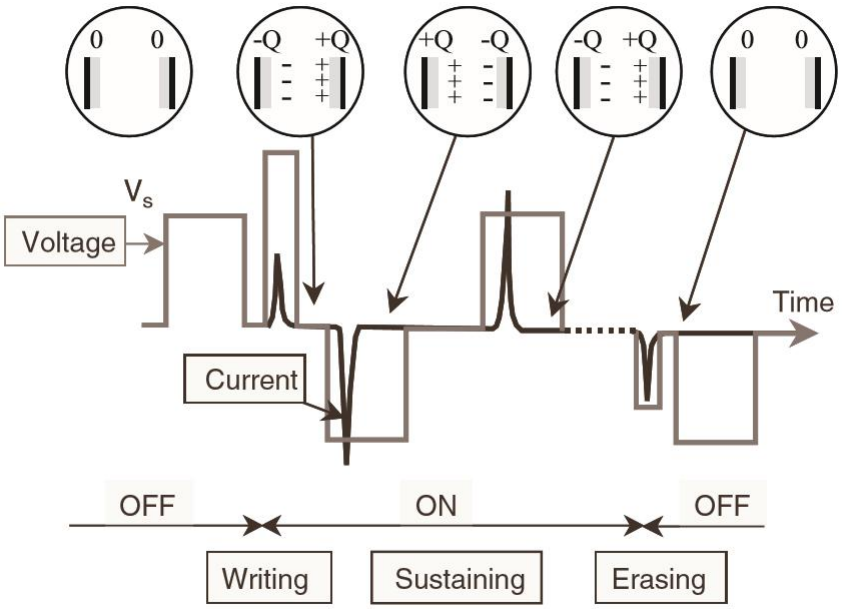
color to create hundreds of combinations of the red, blue, and green.



[9]

Control the individual cell

To create a colorful image, we need to control every individual pixel of the screen. To achieve this goal, we take advantage of the AC voltage.



[10]

The gas of the cells has a breakdown voltage. When the voltage between two plates

[9] The image was adapted from http://electronics.howstuffworks.com/plasma-display2.htm.
[10] The image was adapted from Plasma display panels: physics, recent developments and key issues.

is higher than the breakdown voltage, the gas will be ionized. “A sustaining AC voltage, V_s is constantly applied between the line and column electrodes. The amplitude of the sustaining voltage must be smaller than the breakdown voltage of the discharge cells.”[11]

Now, the status of the cell is OFF. To turn on the cell, another voltage pulse needs to be applied. This voltage pulse is the writing pulse. “The amplitude of this voltage pulse is larger than the breakdown voltage of the cells. A glow discharge forms and is quickly quenched by the charging of the dielectric layers which creates a voltage across the gas gap opposing the voltage across the electrodes. At the end of this ‘writing’ pulse, the charges on the dielectric surfaces above each electrode are−Q and+Q.” [12]The voltage of the dielectric surfaces` charge adds to the applied voltage and gas`s voltage is above the breakdown voltage. The status of the cell now is the ON.

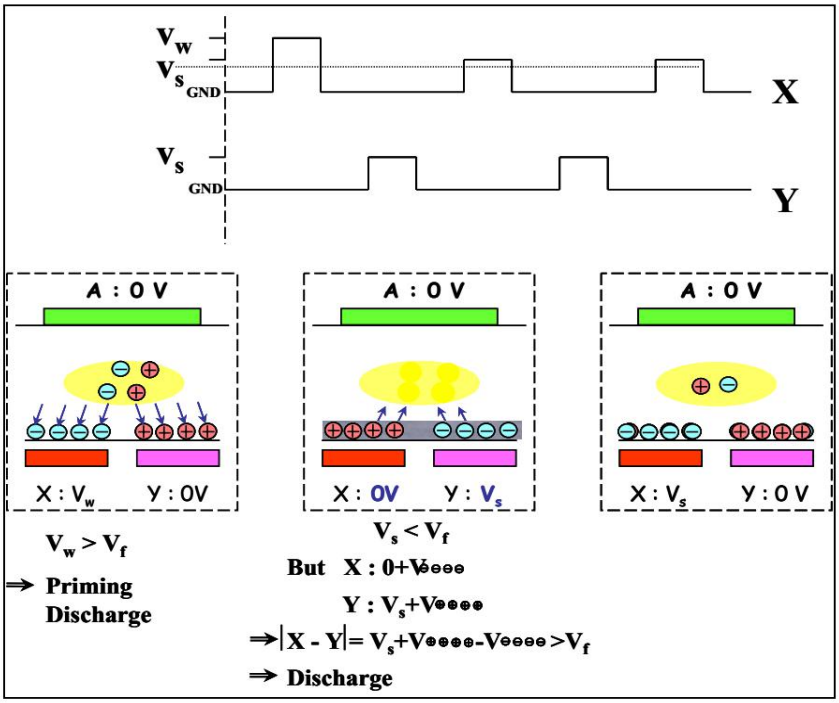
To turn off the cell, the erasing pulse is applied. The magnitude of the erasing pulse is smaller than the sustaining pulse. Before we apply the erasing pulse, the charge transferred during the sustaining pulse is 2Q. After we apply the erasing pulse the charge transferred is the Q instead of the 2Q. “After the erasing pulse, the charges on the surface at the beginning of the next half cycle are zero.”[13]

Memory: AC PDP`s special property

When we apply a voltage that is higher than the breakdown voltage between the cell, the gas will be ionized. The positive charged ions and the negative charged electrons

[11] Direct quote from Plasma display panels: physics, recent developments and key issues.
[12] Direct quote from Plasma display panels: physics, recent developments and key issues.
[13] Direct quote from Plasma display panels: physics, recent developments and key issues.

will be attracted to the two sides of the cell. The charges on the two sides of the cell will shield the applied voltage so the discharge effect will become weak before the next period of the AC voltage. In the next period, since the charges of the two sides of the cell generate a voltage, so we can apply a sustaining voltage that is lower than the breakdown voltage to sustain the illumination of the plasma in the cell.



[14]

Thus, the discharge of the plasma is related with the historical discharge of the cell. The time of the illumination of the discharging plasma is very short. Most of the illumination can only last for 2 microseconds to 3 micro seconds[15]. In the AC plasma display, if we want to change the brightness of the images, we do not change the sustaining voltage of the cell, but we can apply a voltage on the cells several times to accumulate the brightness of the illuminations.

Another usage of the "memory" property of the AC plasma display is to control the

[14] The image was adapted from Plasma technology and flat panel display.
[15] The data were adapted from Plasma technology and flat panel display

separated cells by the same voltage. “The basic idea is that once a cell has been turned ON by a writing pulse, it can be sustained at a voltage lower than breakdown (because of the memory charges deposited on the dielectric layers by the writing pulse). Therefore, some cells can be in the ON state and others in the OFF state, while the same voltage (sustaining voltage) is applied to all.”[16]

Advantages of the plasma display panel

Plasma display panel combine the advantages of the CRT displays and the advantages of the LCD displays.

It is capable for plasma display panel to produce deeper blacks for picture contrast. The LCD displays need to use the backlight as their light source, and the pixel change the brightness by decreasing the flux of the backlight. However, it is very difficult to block all the backlight the screen of the LCD display is brighter. Because plasma`s illumination depends on the glowing phosphor, the plasma can create blacker images than the LCD display can do.

Because of the polarizing plates in the LCD, the backlights will be polarized, and they will have directions, when they come out from the LCD display. Most directions of the lights are perpendicular to the screen, so we can see the slight change of the color, when we move further from the axis of the screen. The lights of the glowing phosphor in the plasma display are unpolarized, so the plasma display also has a wider viewing angle than the LCD displays.

“Less expensive for the buyer per square inch than LCD, particularly when equivalent

[16] Direct quote from Plasma display panels: physics, recent developments and key issues.

performance is considered."[17] The plasma display dominated the market of the large screen display for many years before we find an efficient way to manufacture the large screen LCD.

The energy consumption of the plasma display is a little higher than LCD, but it is much lower than that of the CRT display.

Vanishing of the Plasma display on the market

In the February of 2012, Hitachi announced the discontinued production of the plasma tv.

"In the 2013, Panasonic announced that they would stop producing plasma TVs from March 2014 onwards."[18]

"In the 2014, LG and Samsung discontinued plasma TV production."[19]

In the November of the 2014, ChangHong discontinue the production of the plasma TVs.

After the 2014, the plasma displays almost disappear from the market. The discontinuity of the production of the plasma TVs effectively kill the technology.

Reasons for the vanishing of the plasma displays

Since the low demand of the plasma displays panels, the plasma displays panel lose to the LCD in the displays market. The reasons for the low demand of the PDP can be explain by the reasons below.

The plasma display panels have strict requirement of the showrooms` conditions.

Since the output light of the plasma display is dim, the performance is worse than

---

[17] Direct quote from http://www.plasmatvbuyingguide.com/hdtv/death-of-plasma-tv.html.
[18] Direct quote from https://en.wikipedia.org/wiki/Plasma_display.
[19] Direct quote from https://en.wikipedia.org/wiki/Plasma_display.

the LCD displays` when they are disposed in the bright showrooms.

As the LCD and OLED techniques develop, it is possible for the manufacturers to make larger LCD and OLED displays with lower cost than that of plasma displays. However, it is still difficult for the manufacturers of the plasma display to make their production smaller, since the high voltage of the plasma display` circuits will be shorted when the circuits are too close with each other.

The monopoly marketing strategy of the plasma displays` manufacturers, such as Panasonic, also contributes to the demise of the plasma displays.

Conclusion

The vanishing of the plasma display panels is come from the incompatible market demand. The plasma technique still has some overwhelming advantages, and the efficacy of the plasma display can still be improved as well.

Energy	%	Loss
Electric energy dissipated in discharge	100	
	↓	60% in ion heating (from models)
Energy dissipated in electron heating	$\rho = 40$	
	↓	50% in xenon ionization, neon excitation and ionization (from models)
Energy dissipated in xenon excitation	$\eta_{Xe} = 20$	
	↓	25% transition loss (e.g. infrared emission), quenching (from models)
Energy dissipated in UV production	$\eta_{UV} = 15$	
	↓	50% VUV photons not collected by phosphors (estimation)
UV energy reaching the phosphors	7.5	
	↓	67% UV to visible photon energy conversion loss (estimation)
Visible photons production	2.5	
	↓	40% visible photons not collected on front face (estimation)
Photons reaching the user	1.5	

[20]

However, since the discover of the Organic Light-Emitting Diode and the other new illumination materials, the failure of the plasma displays seems irretrievable. Lamented by a few steadfast followers and forgotten by the others, the plasma displays died while the technology is blooming.

[20] The data were adapted from Plasma display panels: physics, recent developments and key issues.

Work Cited

"Plasma Physics." Wikipedia, Wikimedia Foundation, 24 July 2017 en.wikipedia.org/wiki/Plasma_physic

"GRINP Srl." GRINP Plasma Physics, www.grinp.com/plasma/physics.html.

Diemer, Harry Marshall., and Ralph Stuart. Cooper. *Radio-Activity Induced by the Oscillatory Discharge, or, The Subsequent Radio-Active Emanation from Substances Exposed to the Tesla Oscillatory Discharge*. 1903.

"Plasma Display." *Wikipedia*, Wikimedia Foundation, 30 July 2017, en.wikipedia.org/wiki/Plasma_display.

"How Plasma Displays Work." *HowStuffWorks*, 19 Mar. 2002, electronics.howstuffworks.com/plasma-display1.htm.

Physics, Mini. "The Electromagnetic Spectrum." *Mini Physics*, Mini Physics, 22 May 2016, www.miniphysics.com/electromagnetic-spectrum_25.html.

Boeuf, J P. "Plasma Display Panels: Physics, Recent Developments and Key Issues." Journal of Physics D: Applied Physics, vol. 36, no. 6, 2003, doi:10.1088/0022-3727/36/6/201.