The Chemistry of Television

(and Other Display Technologies)

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http://www.chemistry.wustl.edu/~walker

- OR -

How do televisions work?

http://www.willothewisp.co.uk/

Introduction

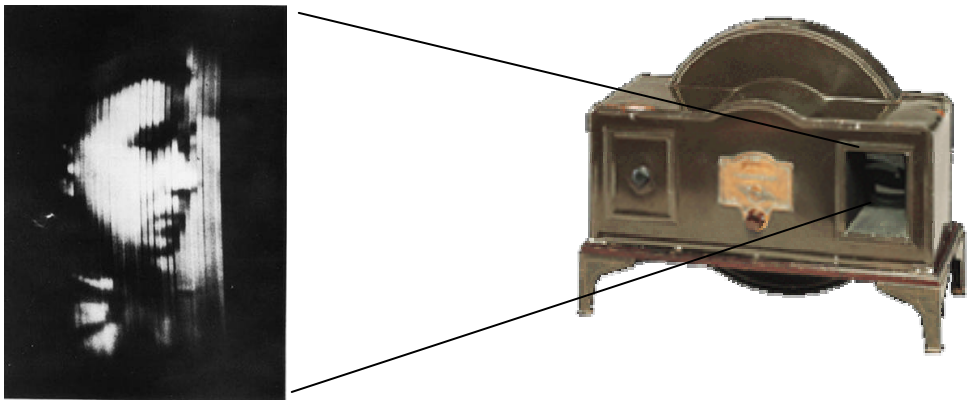
There are many different display technologies:

- CRT
- LCD
- Plasma Screen
- PLED / OLED
- ……..

All of these rely on chemistry to make them work!

Cathode Ray Tubes (CRTs)

- The “oldest” television/display technology.
- CRT first proposed in 1908 by Campbell Swinton.
- But in **January 1926** John Logie Baird demonstrated a “televisor”, a mechanical television.

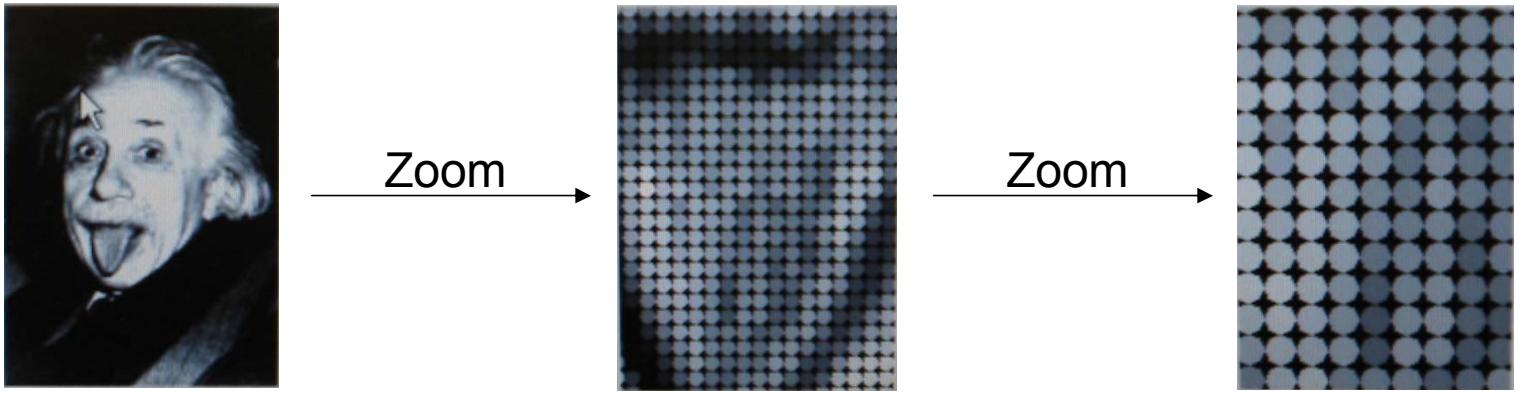


- **1928** Farnsworth demonstrates a CRT system to the press in San Francisco.
- **1936** RCA demonstrate all electronic TV with 343 lines, 30 frames per second.

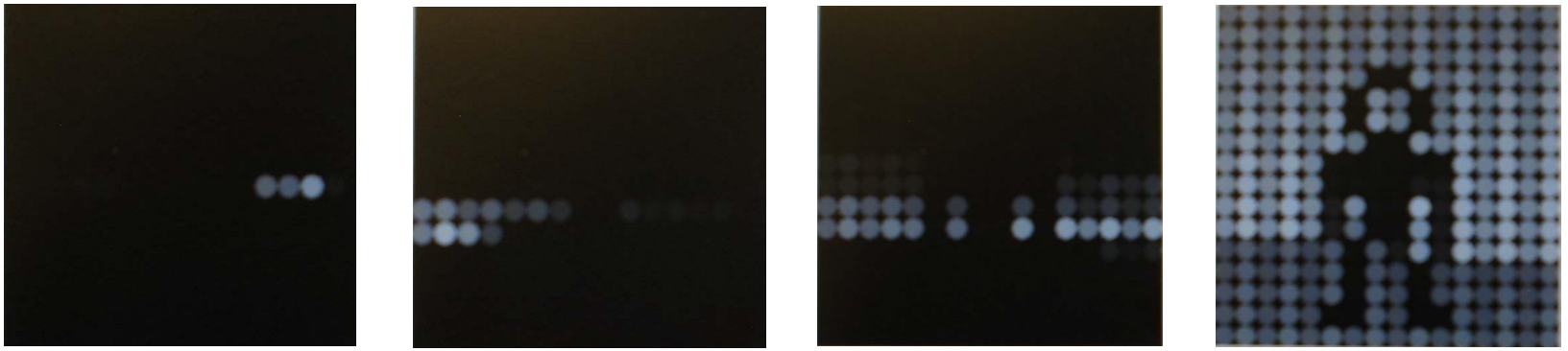
http://www.arts.uwaterloo.ca/FINE/juhde/hills961.htm; http://www.tvhistory.tv/pre-1935.htm

Cathode Ray Tubes (CRTs)
How do they work?

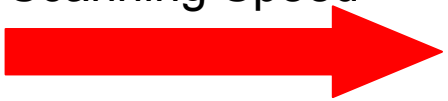
Every image on a television screen is made up of a series of spots, pixels.



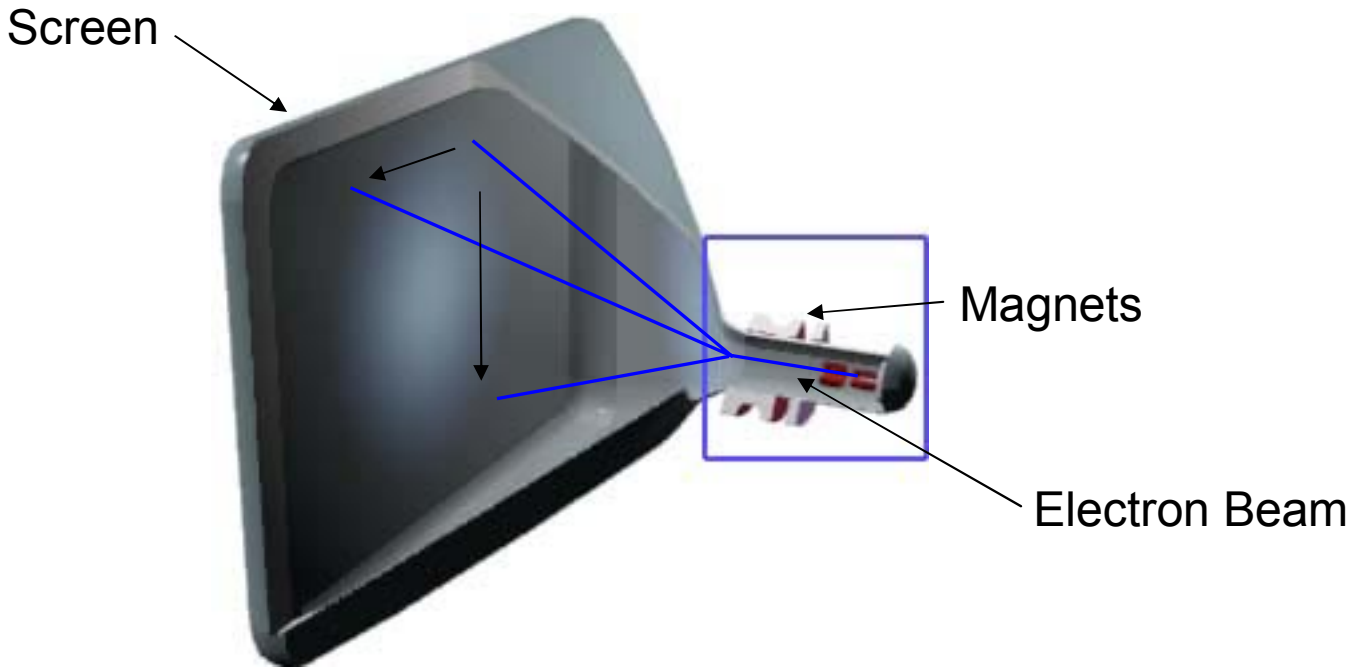
By rastering, or scanning, each pixel, a moving image can be made. As the scanning speed increases we see the image due to a property of our eyes called **persistence of vision**.



Scanning Speed



Cathode Ray Tubes (CRTs)
How do they work?

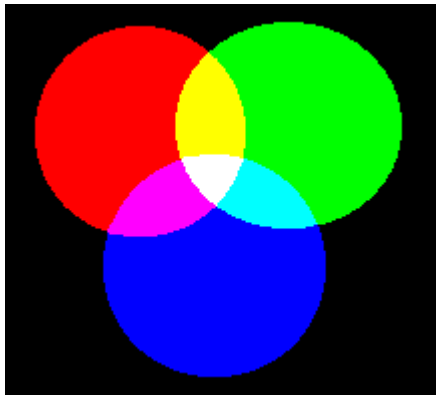


In a cathode ray tube (CRT), an electron beam is generated. The beam is then steered by magnets to hit the front screen.

When the electron hits the front screen, it strikes a **phosphor**, which then lights up. The higher the electron current, the brighter the phosphor glows.

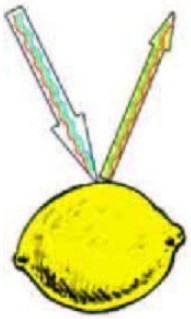
Cathode Ray Tubes (CRTs)
How do they work?

How about color?
You need only three primary light colors: **red**, **green** and **blue**.

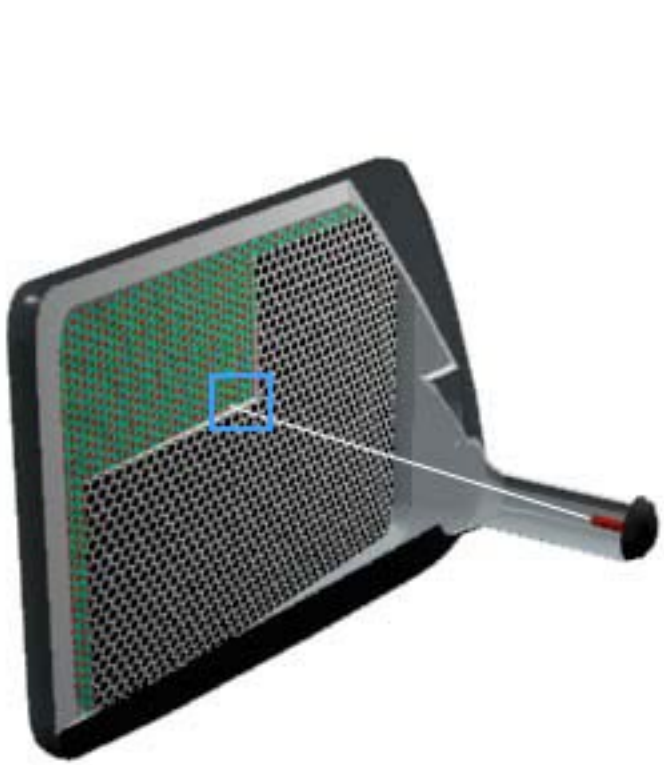


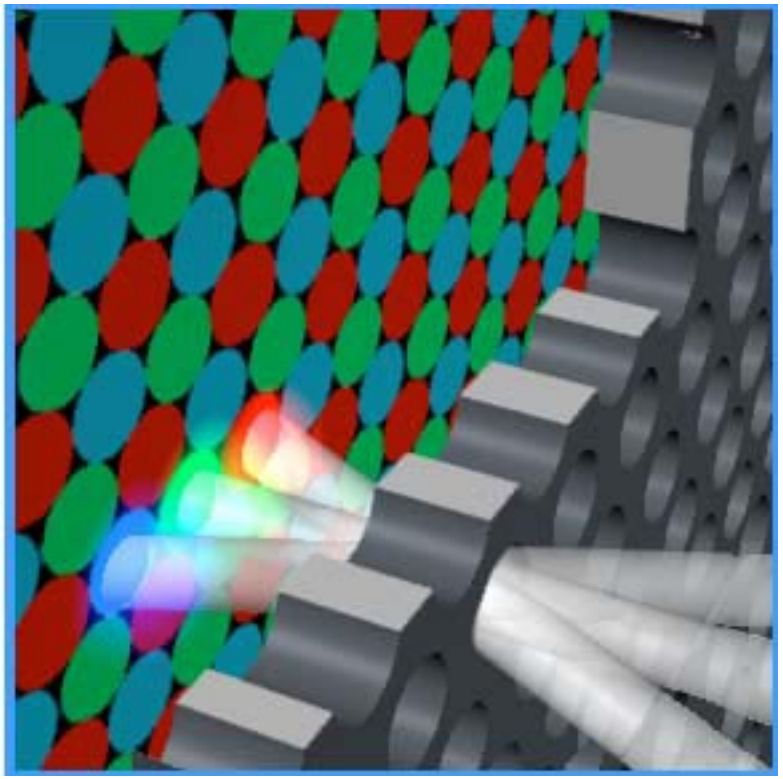
This does not work like the primary colors described in an art class. Why?

A **yellow** object **adsorbs blue light**, but **reflects green and red light**. So we see a **yellow** object.



Cathode Ray Tubes (CRTs)
How do they work?





A color television has three different phosphors for every pixel, which glow red, green and blue.

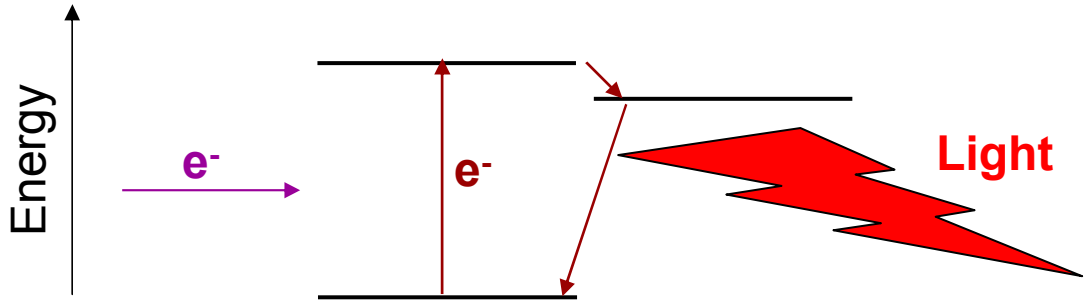
Cathode Ray Tubes (CRTs)
What is a Phosphor?

Phosphors are substances which emit light when the substance is excited.

Excitation can be electrical, due to light or due to a chemical reaction.

Light persists after excitation (if it doesn't - fluorescent.)

How?

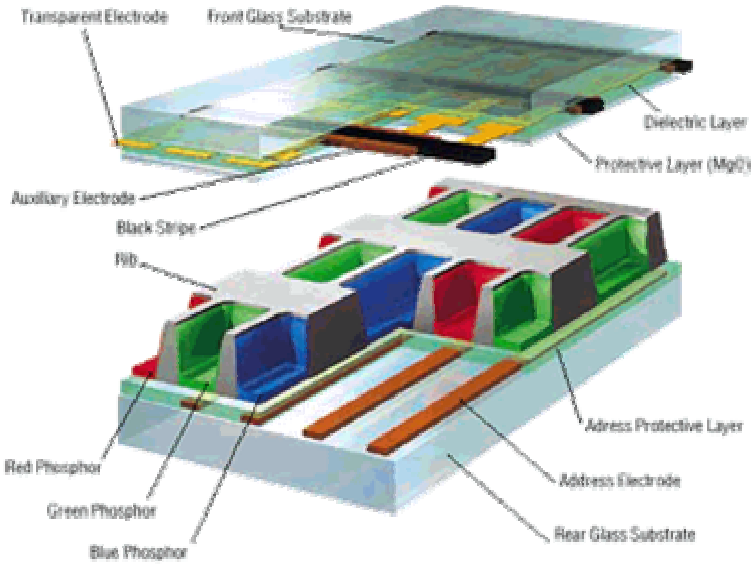


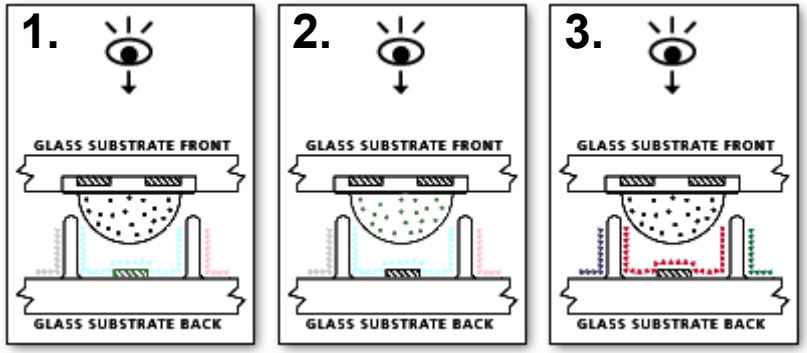
Blue	Green	Red
ZnS:Ag	ZnS:Cu,Al	Y_2O_2S:Eu
ZnS:Ag + pigment	ZnS:Cu,Au,Al	Y_2O_2S:Eu + pigment
ZnS:Ag,Cl		
ZnS:Ag,Cl + pigment		
ZnS:Ag,Al		
ZnS:Ag,Al + pigment		

Plasma Displays

One of the problems with CRTs is that they use a lot of power and so can not be made to be really large.
One solution is to use a **plasma display**.

A plasma display is split up into many pixels – just like a CRT – but in this case each cell is a low pressure gas cell filled with neon and xenon. At the back of the cell is a red, green or blue phosphor.



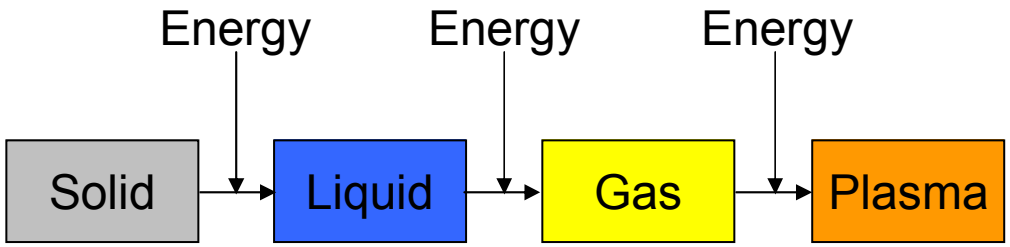


When the gas is excited, it becomes a **plasma** (step 1).
The **plasma** emits **UV light**.
The **UV light** excites the phosphors (step 2), and an image on the screen is seen (step 3).

http://www.plasmatvbuyingguide.com/plasmatv-howwork9.html; http://www.activelight.com/about_ActiveLight/about_technology.asp?X=1

Plasma Displays
What is a Plasma?

A plasma is often called the “fourth state of matter”.
It is a collection of charged particles containing approximately equal numbers of positive and negative charges. It exhibits some properties of a gas but is also a good conductor of electricity.
Plasmas contain positive ions, negative ions, electrons and neutrals (atoms or molecules).



Plasmas can be generated by ionizing a gas using external sources of radiation (light), energetic electron beams, gas discharges or heating a gas.
Using an electrical discharge is the most common approach and is used in plasma displays.

“Vacuum Technology & Coating”, September 2003

Plasma Displays
What is a Plasma?

Often said that > 99 % of all matter in the universe is in the plasma state.

Where are plasmas found ?

Plasmas in Nature….

Aurora Borealis
(in Alaska)

Lightning
(in Texas)

Flames

Plasmas in Space….

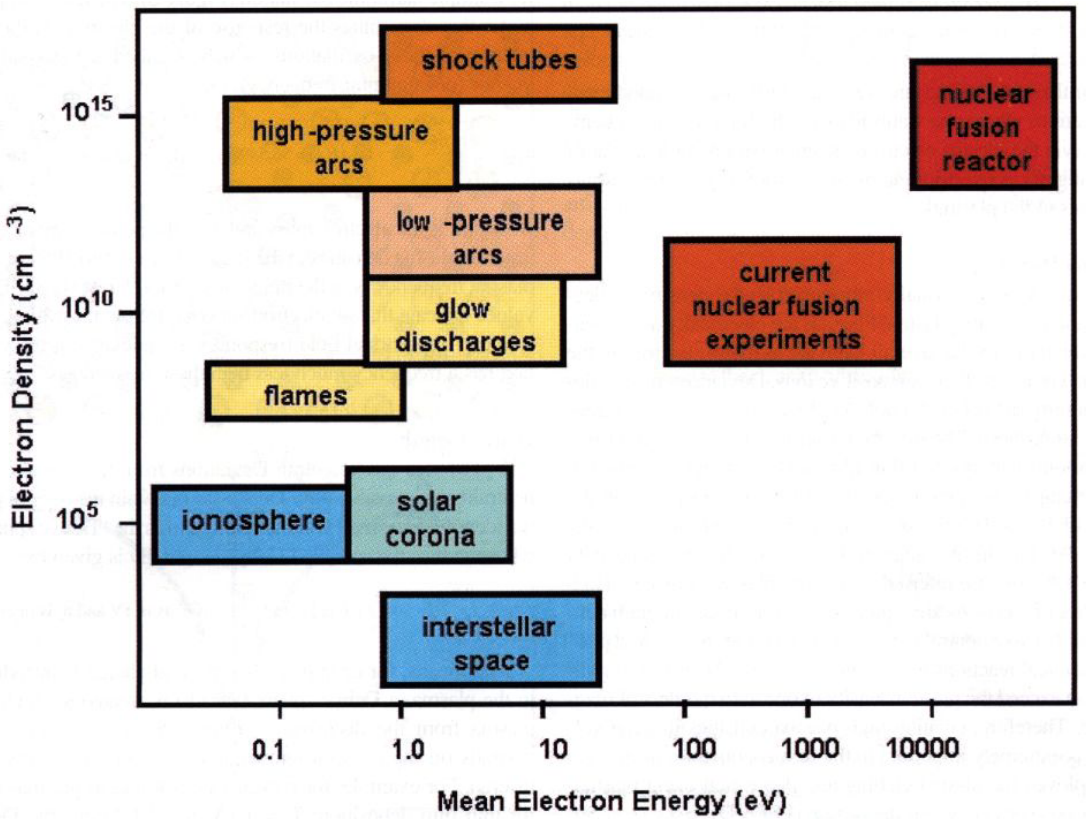
Dilute Interstellar Matter
Dense Interior of Stars (e.g. the Sun).

Man–Made Plasmas are used in microchip production.

http://www.geo.mtu.edu/weather/aurora/images/aurora/jan.curtis/index5.html; http://stormgasm.com/5-5-02TXPanhandleTornado/5-5-02TXPanhandleTornado.htm

Plasma Displays
How hot are plasmas?

1eV = 1.6 x 10^{-19} J
≈ 11604K



Plasmas are described as

- **Thermal or Hot**: The ions, electrons and neutrals are all about the same temperature. Temperatures from a few 1000 K (e.g. a plasma torch) to a few 1,000,000 K (e.g. the interior of stars).
- **Non Thermal or Cold**: The ions and neutrals are approximately room temperature. The electrons have a temperature of 100,000s K.

LCD Screens

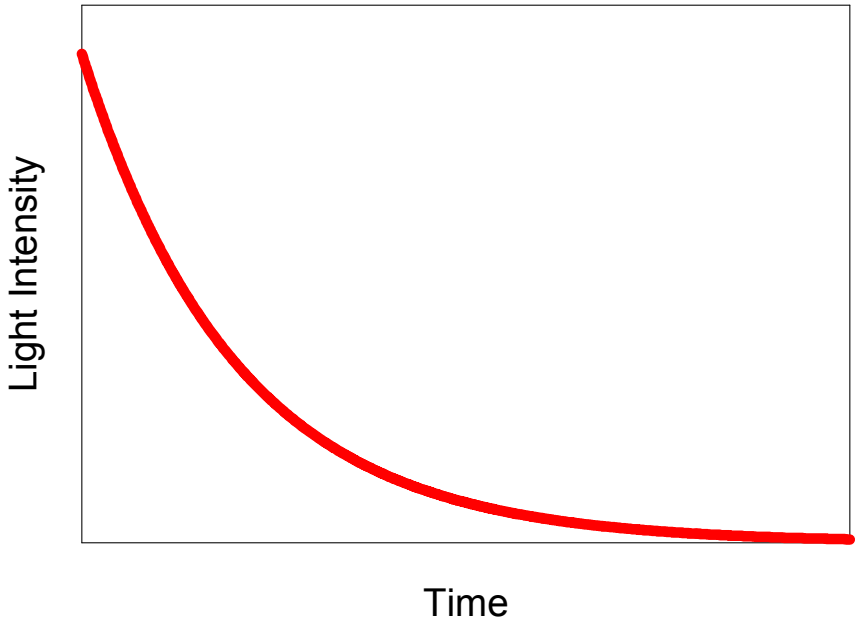
A second solution to the power consumption issue is to use a **light crystal display (LCD)**.

LCD displays use the same color perception technology as do plasma and CRT displays.
The screen is made up of red, blue and green pixels.

BUT they much easier on our eyes……

LCDs
Why is it better for your eyes?

In a **CRT or plasma display**, a phosphor is excited to make the image.
As soon as the phosphor is excited, it starts to decay and its light output decreases.

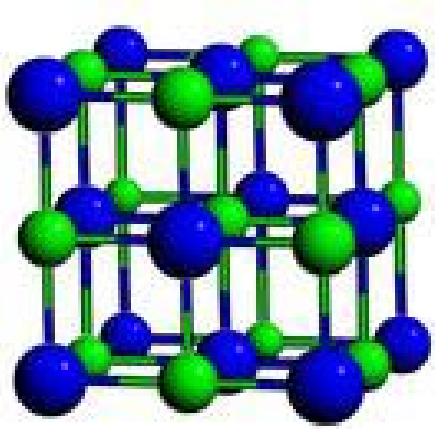


LCD displays do not use phosphors. **The screen is constantly lit.**
The image is created by controlling the LCD material at each pixel using electricity.

LCDs
What is a liquid crystal?

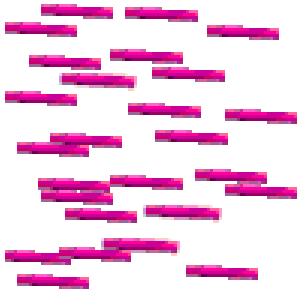
A **liquid crystal** is intermediate between a liquid and a solid.

A **crystalline solid** has long range order, e.g. NaCl.



In a **liquid**, the molecules do not have long range order. The molecules are randomly oriented.

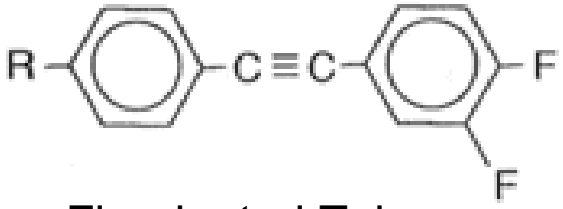
In a **liquid crystal**, the molecules have long rod shapes. The molecules' **positions** are **random** but their **orientations** can be aligned with one another in a regular pattern.



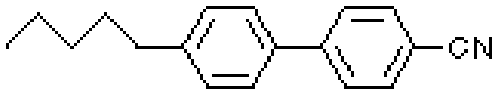
LCDs
What is a liquid crystal?

Liquid crystals were discovered in 1888 by F Reitzner (a botanist!) but were could not be used commercially for displays until the 1960s. One problem was that they were not stable at room temperature.

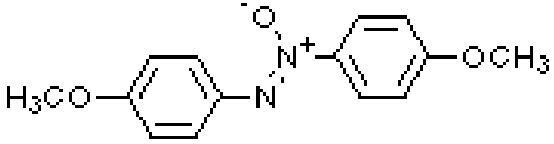
Some examples:



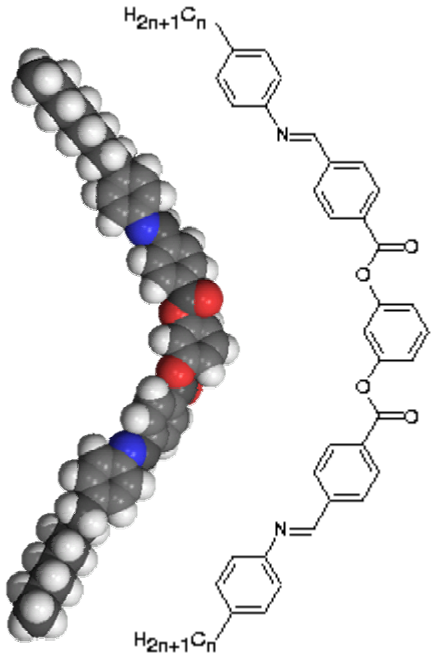
Fluorinated Tolans



5CB



PAA



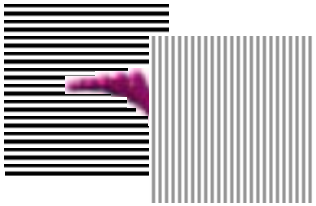
Banana Compounds

http://www.tu-berlin.de/~insi/ag_heppke/banana/materials.html; http://www.kth.se/fakulteter/tfy/kmf/lcd/lcd~1.htm

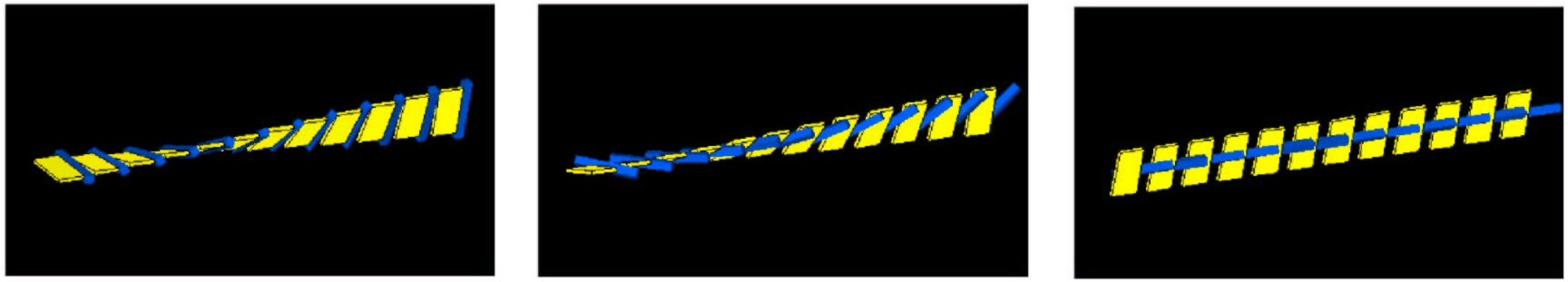
LCDs
What is a liquid crystal?

In 1963, an RCA employee discovered that the way light passes through a liquid crystal changes when it is simulated by an electrical charge.

How?



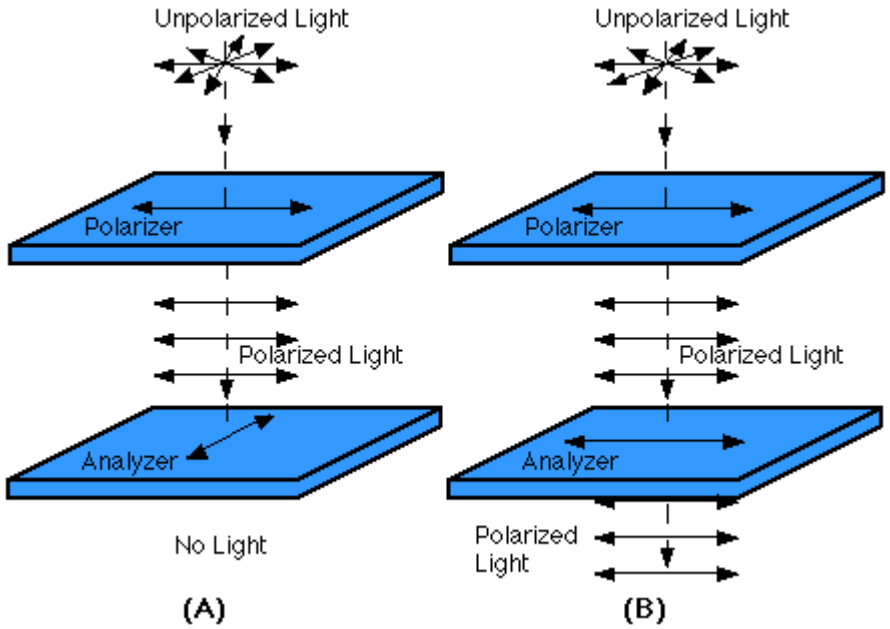
If you put a liquid crystal material between 2 pieces of glass scored with horizontal and vertical lines, the liquid crystal molecules twist to try to align with the lines in the glass.



Electric Field

LCDs

To construct an LCD pixel, we put the liquid crystal layer between two polarizers, we can control whether the pixel lights up or not.



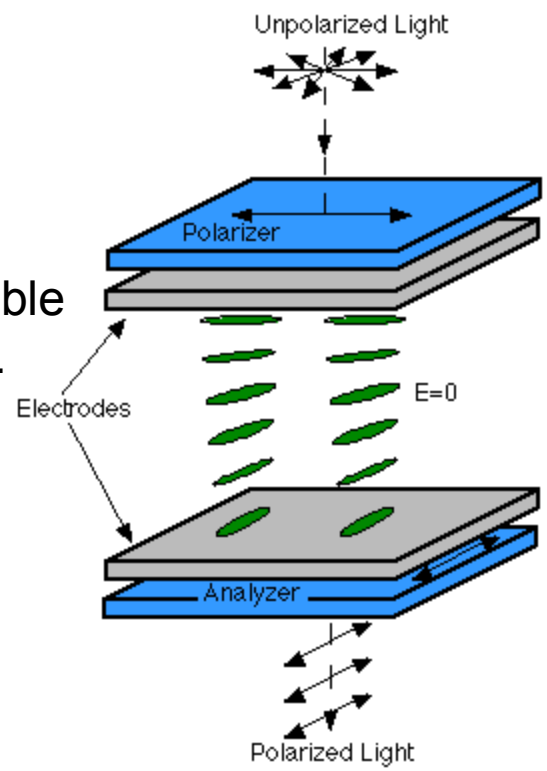
A **polarizer** allows only light with a particular electric field orientation to pass through it.

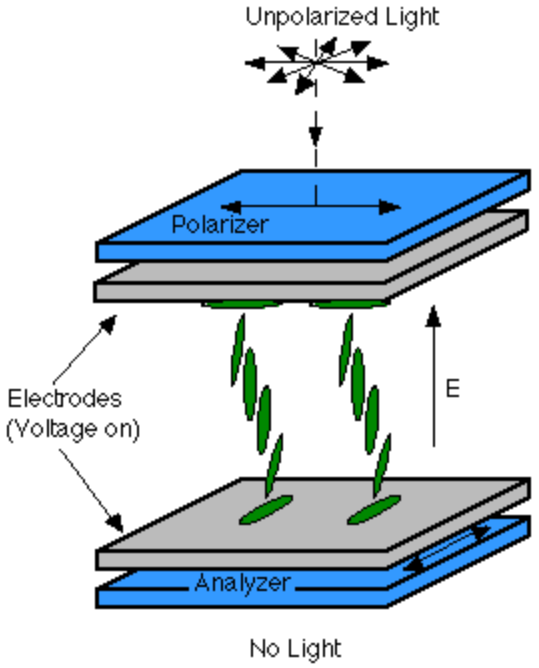
LCDs

E = 0

The liquid crystal molecules are twisted and are able to rotate the light.

Light passes through the LCD pixel.

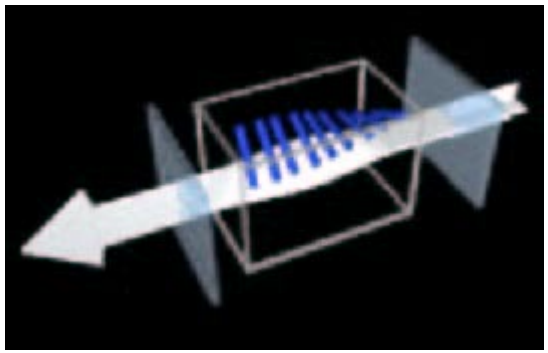


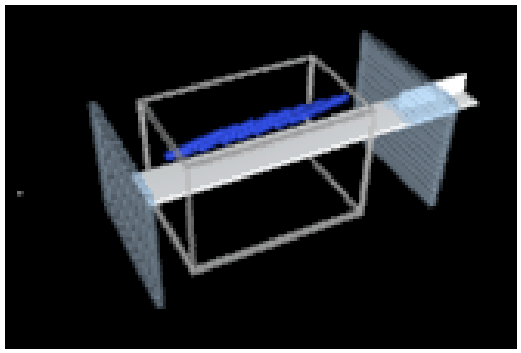


E > 0

The liquid crystal molecules are aligned, and the plane of light is not rotated.

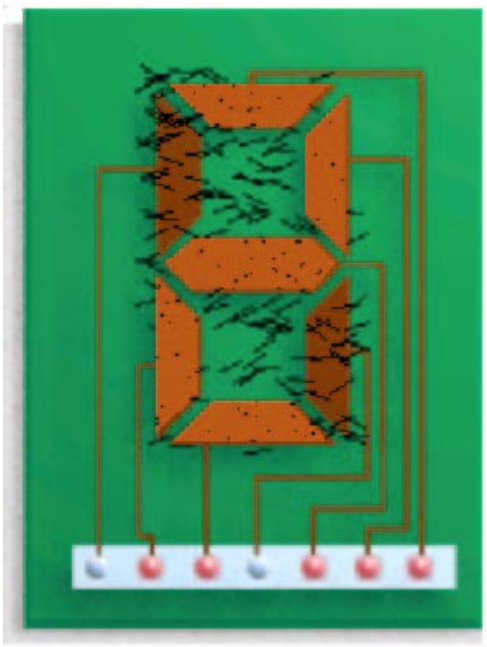
No light passes through the LCD pixel.





LCDs
Calculator Screens

Inside



You see

In a calculator to make a number you “turn on” the cells that you want to make. The LCD molecules untwist and prevent light from passing through the cell.

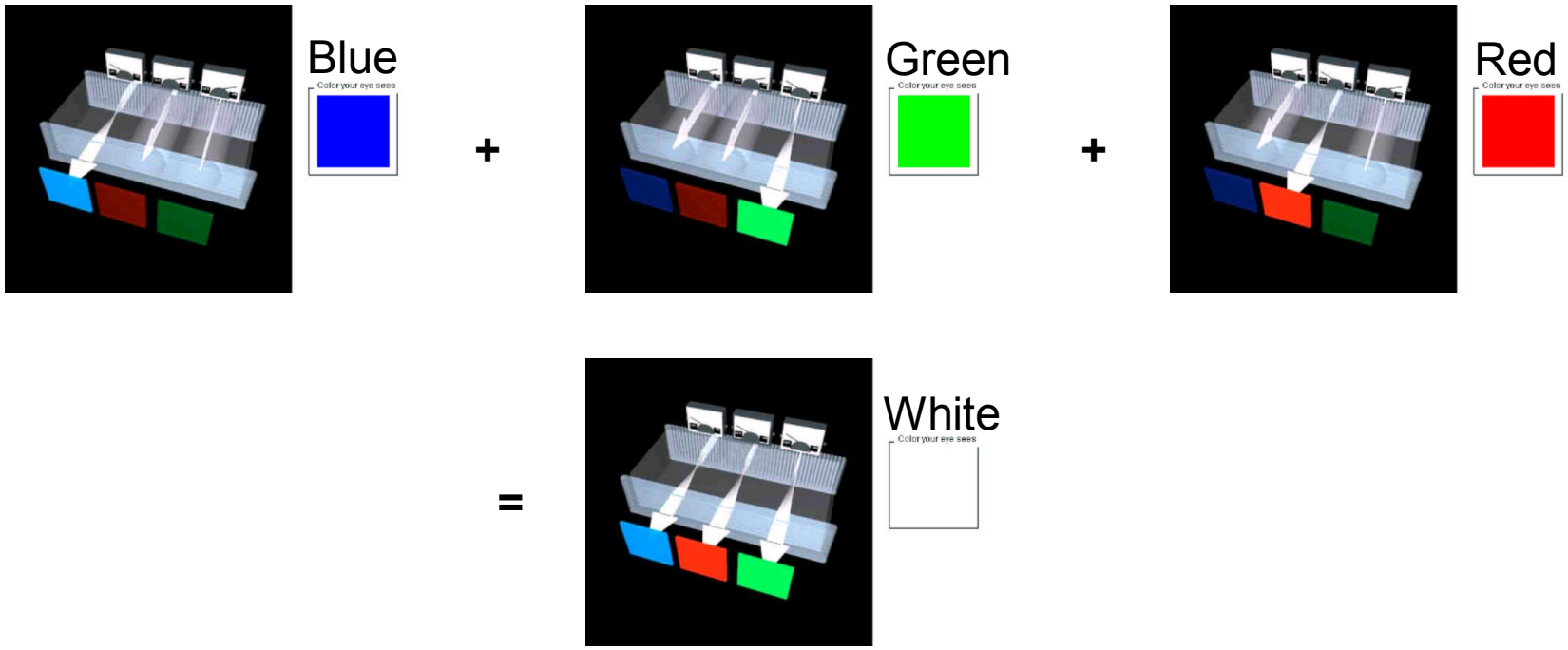
LCDs
Colors and Contrast

- **Contrast**

  This can be controlled by the electric field applied to the liquid crystal.
  The higher the electric field, the less light that goes through the pixel.

- **Color**

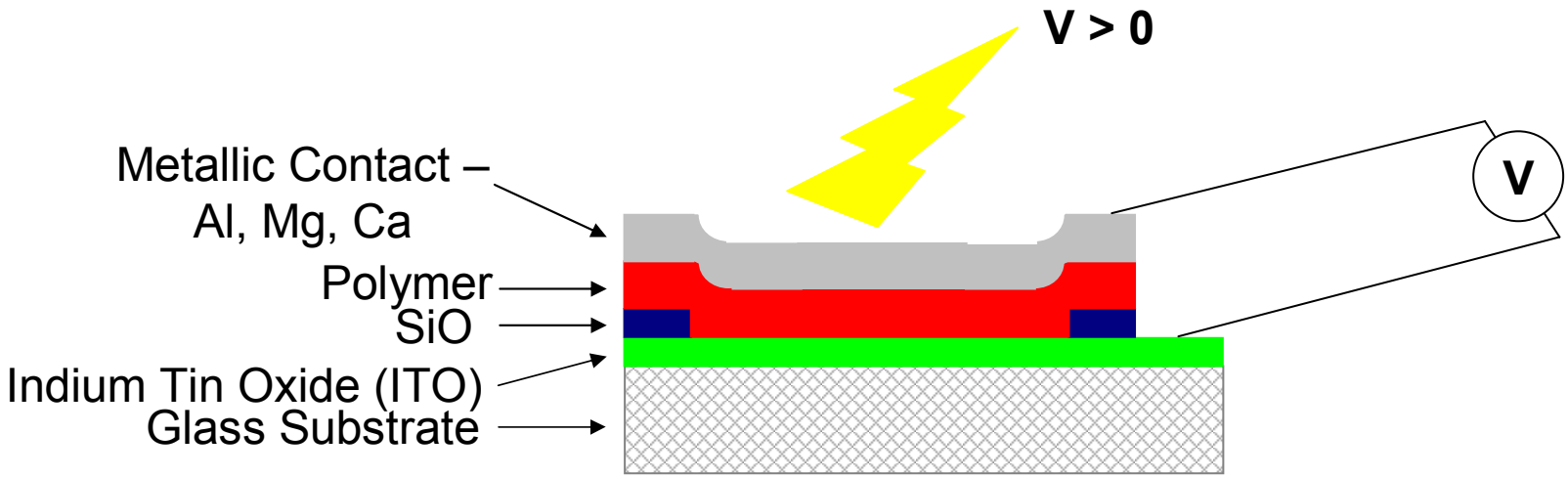
  Each LCD pixel is made up of a red, green and blue cell.
  By controlling the electric field in each cell, the colors can be turned on and off.



Organic LED Displays
The Future

What is an organic LED?

- It's an electronic device made by placing a series of organic thin films between two conductors.
- When an electric current is applied between the conductors, a bright light is emitted - electrophosphorescence.
- Discovered in ~1990 by Friend and Holmes group at University of Cambridge.

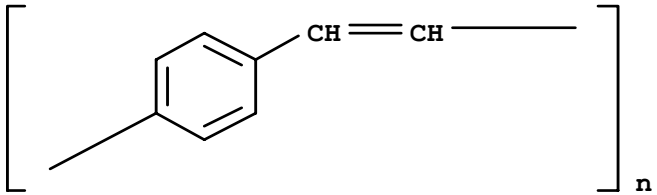


http://www.olight.com/dupont/olight/public/;J.J. Halls, C.A. Walsh, N.C. Greenham, E.A. Marseglia, R.H. Friend, S.C. Moratti, A.B. Holmes, Nature 376 (1995) 498

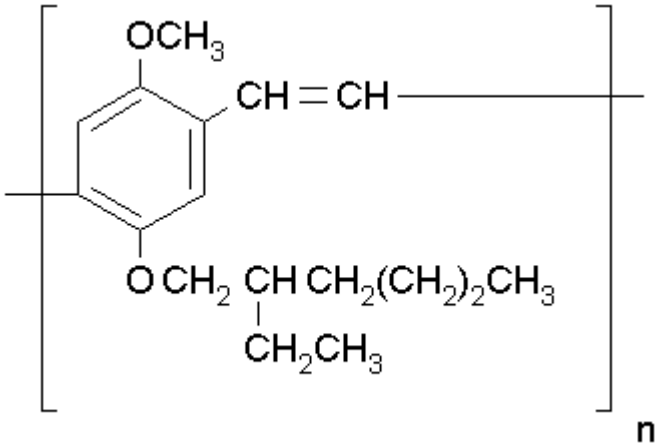
Organic LED Displays
The Future

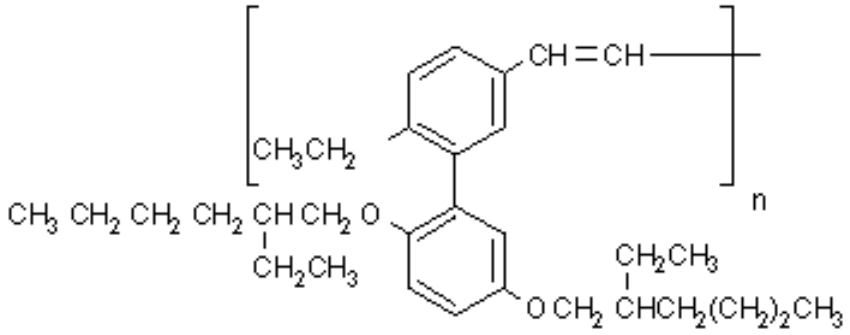
What kind of molecules are used in OLEDs?

These are typically highly conjugated polymers so it is easy for electrons to travel through the polymer.



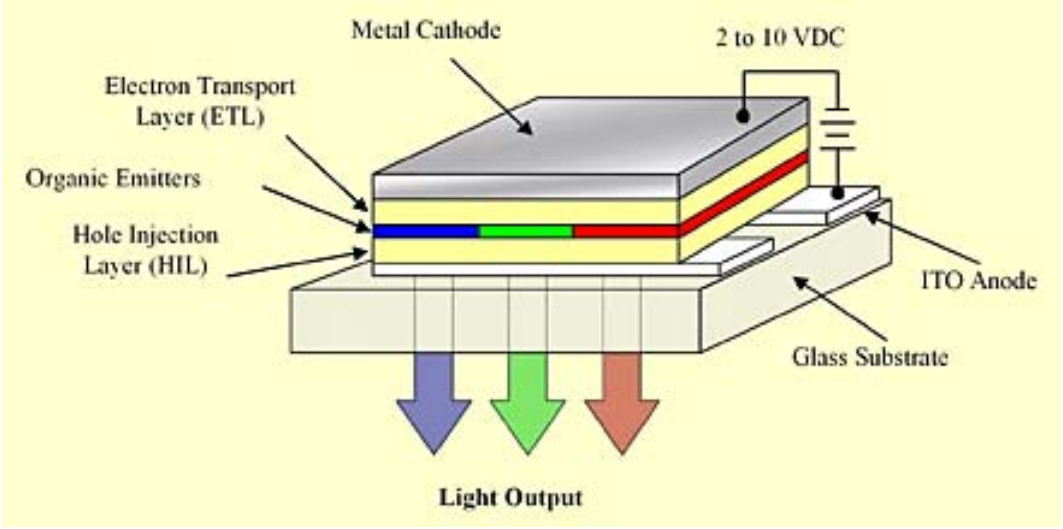
Molecules are often based on **poly(p-phenylenevinylene).**





Two derivatives of PPV

Organic LED Displays
The Future



To make the picture that you see, the pixels are split up into red, blue and green cells (as CRTs, LCDs and plasma displays.

So what are the advantages of OLED displays?

http://www.sensorsmag.com/articles/1202/oled/main.shtml

Organic LED Displays
Advantages

- **OLED displays use less power that LCDs.**
  - They do not need to have backlighting.
  - Can work with 2-10 V applied.
- **They are brighter than LCDs.**
- **They have a faster response time.**
- **They are lighter than LCDs, CRTs and plasma displays.**
- **They have a wider operating temperature range than LCDs.**
  - LCDs have a limited temperature range since their properties vary widely with temperature.
- **They have a wider viewing angle up to 160°.**

http://www.sensorsmag.com/articles/1202/oled/main.shtml

Organic LED Displays Advantages

- They can also be made to be very thin, < 500 nm.

And the coolest thing about OLEDs is……

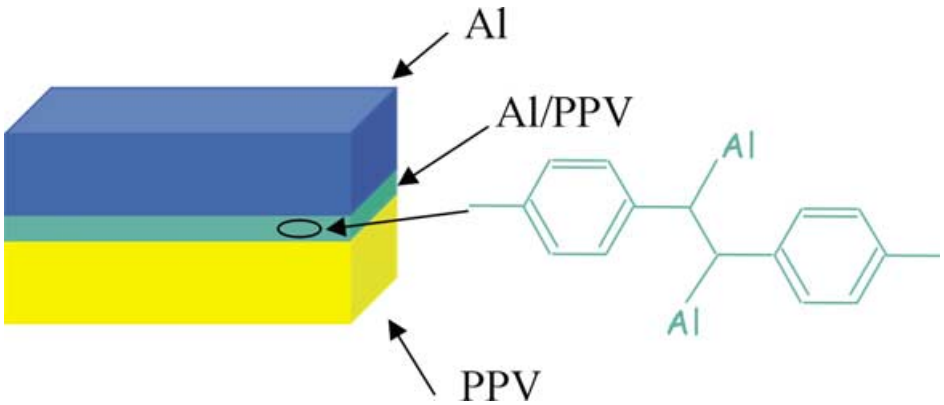
http://www.universaldisplay.com/foled.php

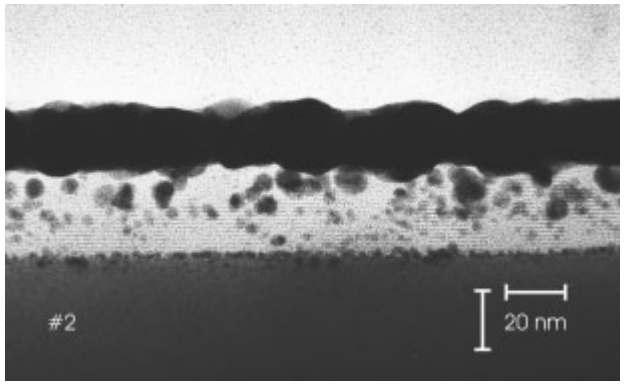
Organic LED Displays

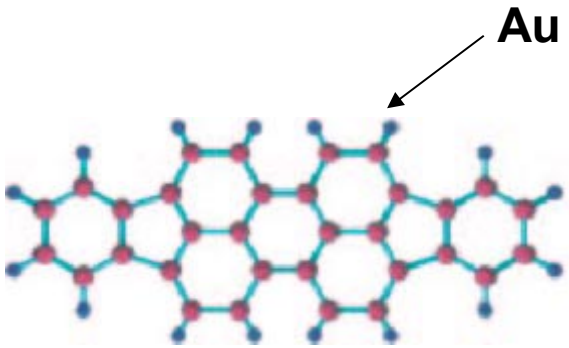
One of the biggest issues in OLED research is the interaction of the deposited metal with the polymer.

If the deposited metal is too reactive, it will destroy the polymer.

If the deposited metal is too unreactive, it will not form a good contact.



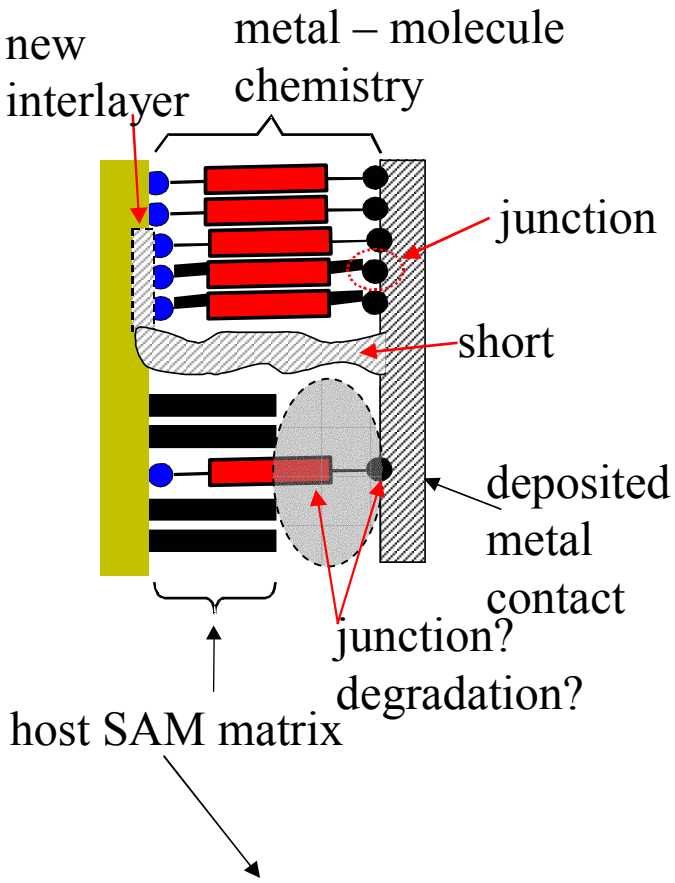




diindenoperylene

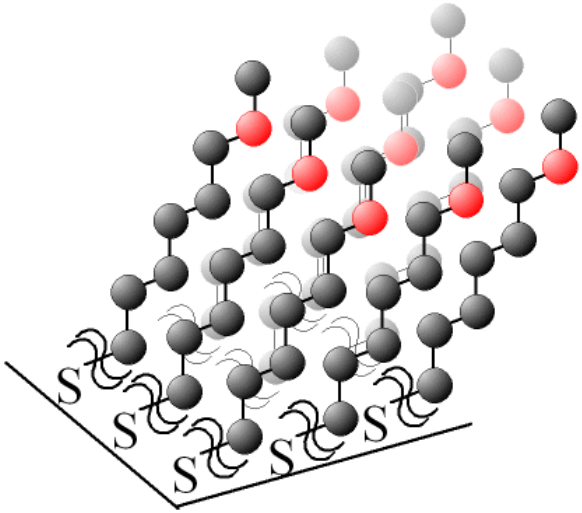
M.Fahlman, W.R. Salaneck, Surf. Sci. 500 (2002) 904;A. Dürr, F. Schreiber, M. Kelsch, H.D. Carstanjen, H. Dosch, Adv. Mater. 14 (2002) 961

Studying Metal-Molecule Interactions

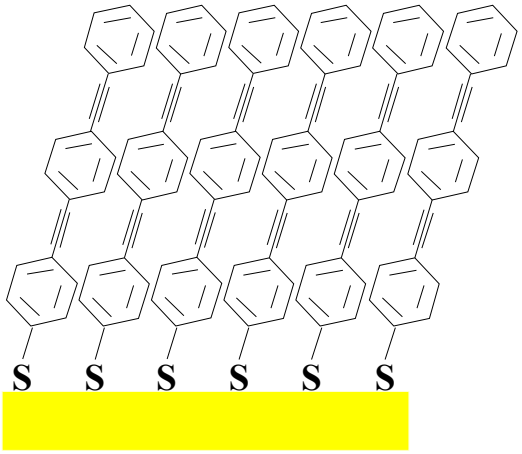


This is a model system –
a self-assembled monolayer.

Alkanethiols



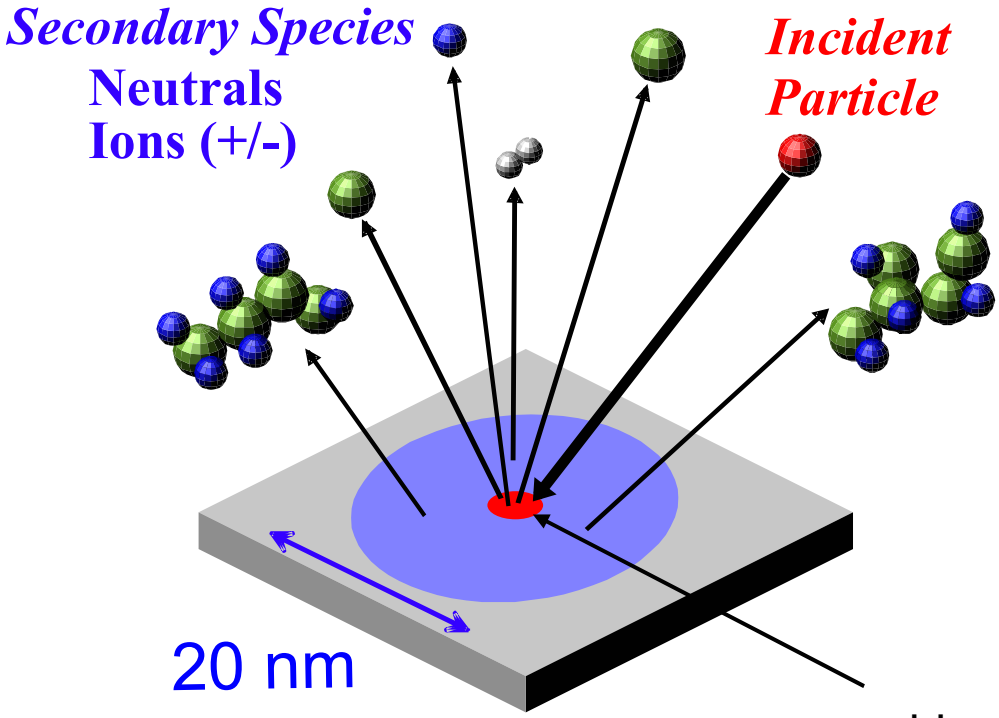
Molecular Wire
4,4'-(ethynylphenyl)-1-benzenethiol

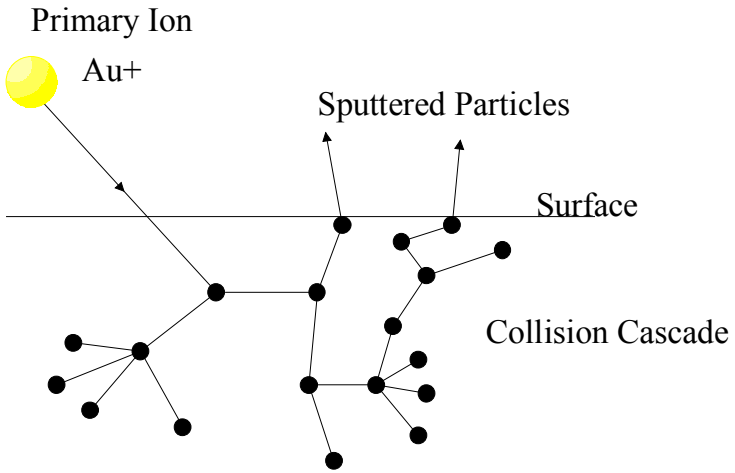


Studying Metal-Molecule Interactions

We use **time-of-flight secondary ion mass spectrometry** to look at the metal – molecule interactions.

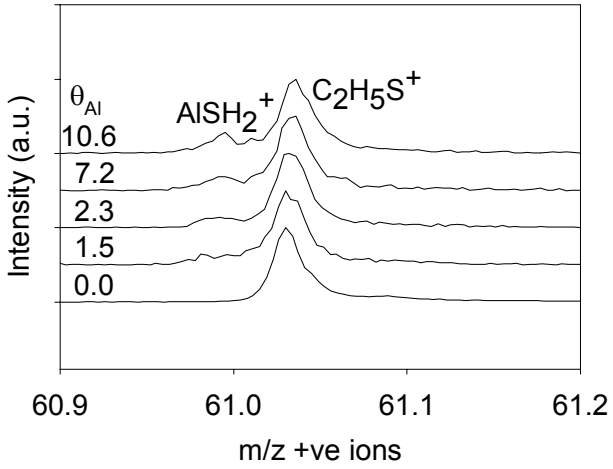
We examine the secondary ions using a **mass spectrometer**.

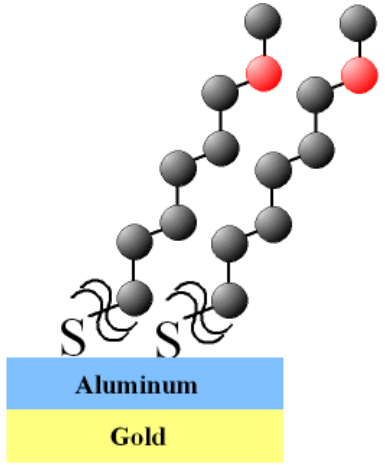


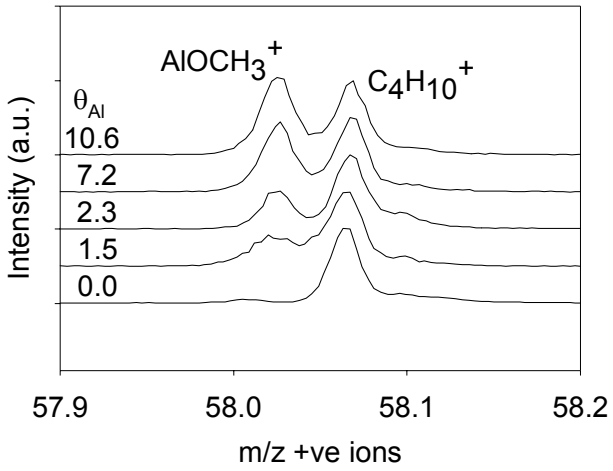


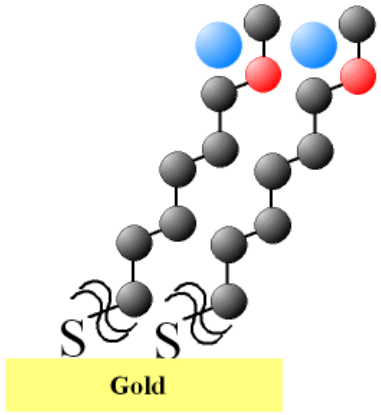
Studying Metal-Molecule Interactions
Time-of-Flight Secondary Ion Mass Spectrometry: The Instrument

Studying Metal-Molecule Interactions
Time-of-Flight Secondary Ion Mass Spectrometry: Analysis

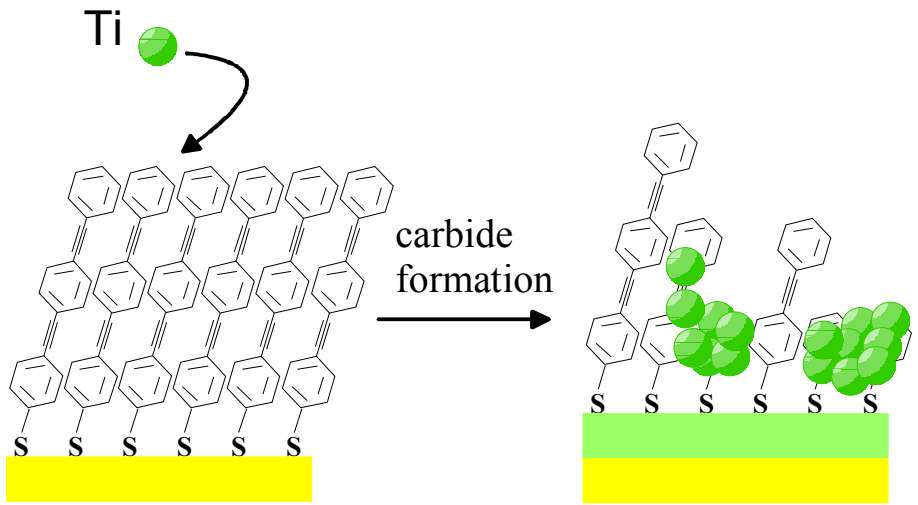




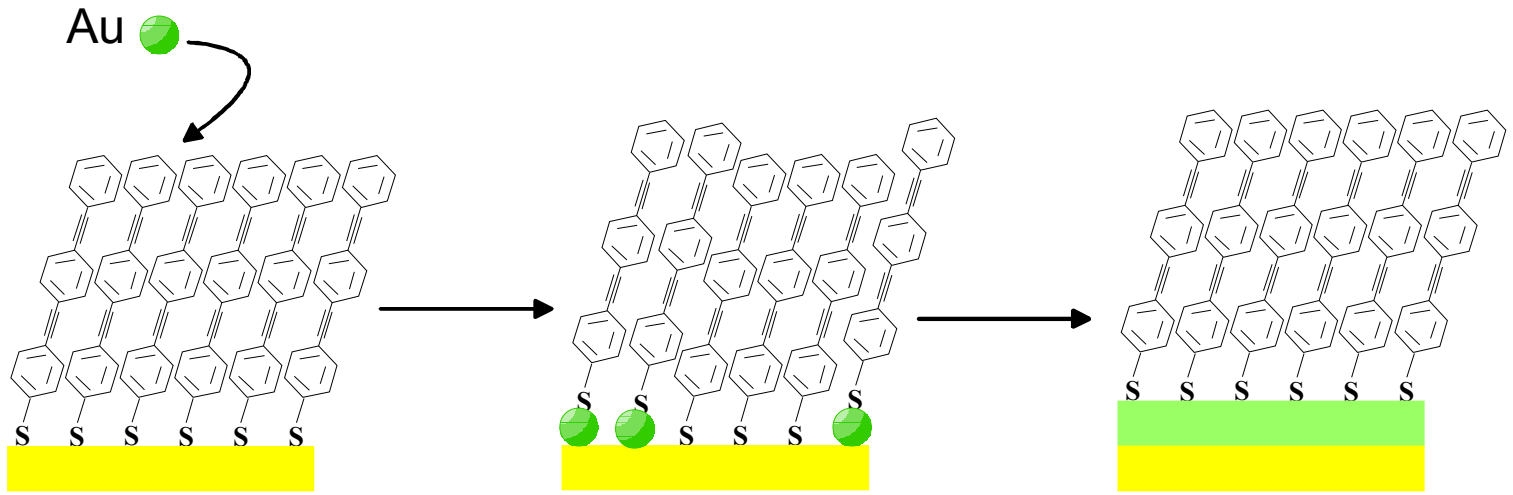




Studying Metal-Molecule Interactions

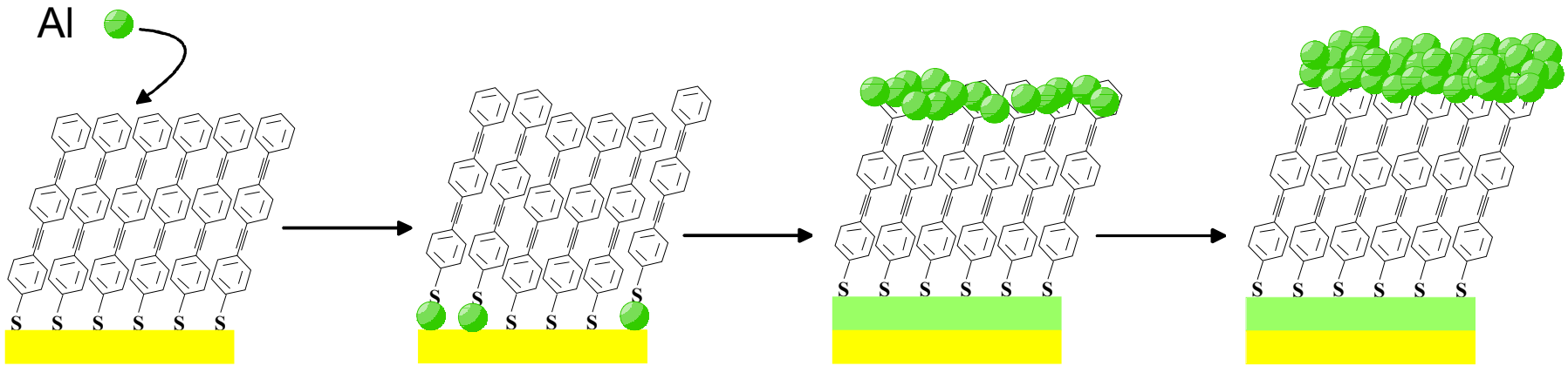


Ti destroys the monolayer
Not a good contact!

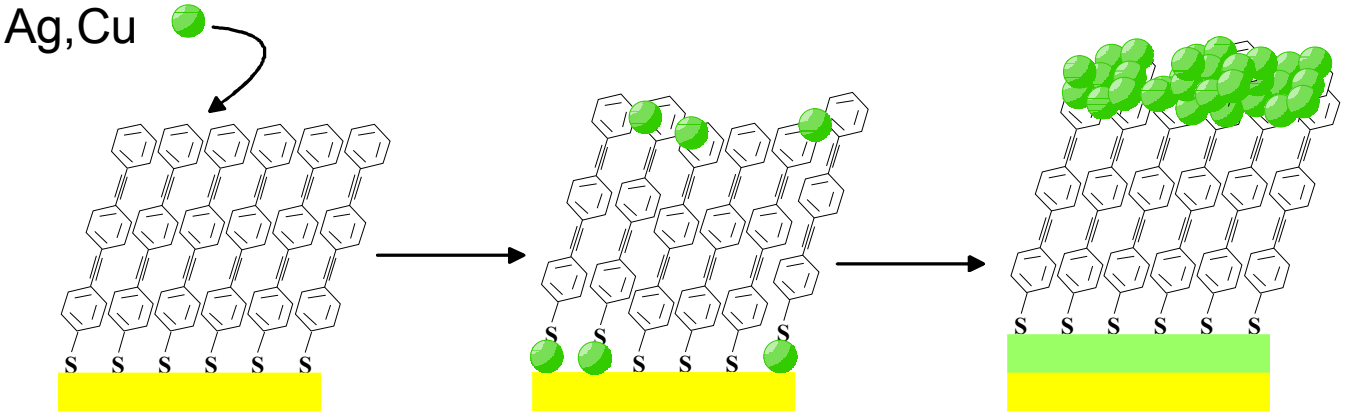


Au goes through the monolayer
Not a good contact!

Studying Metal-Molecule Interactions



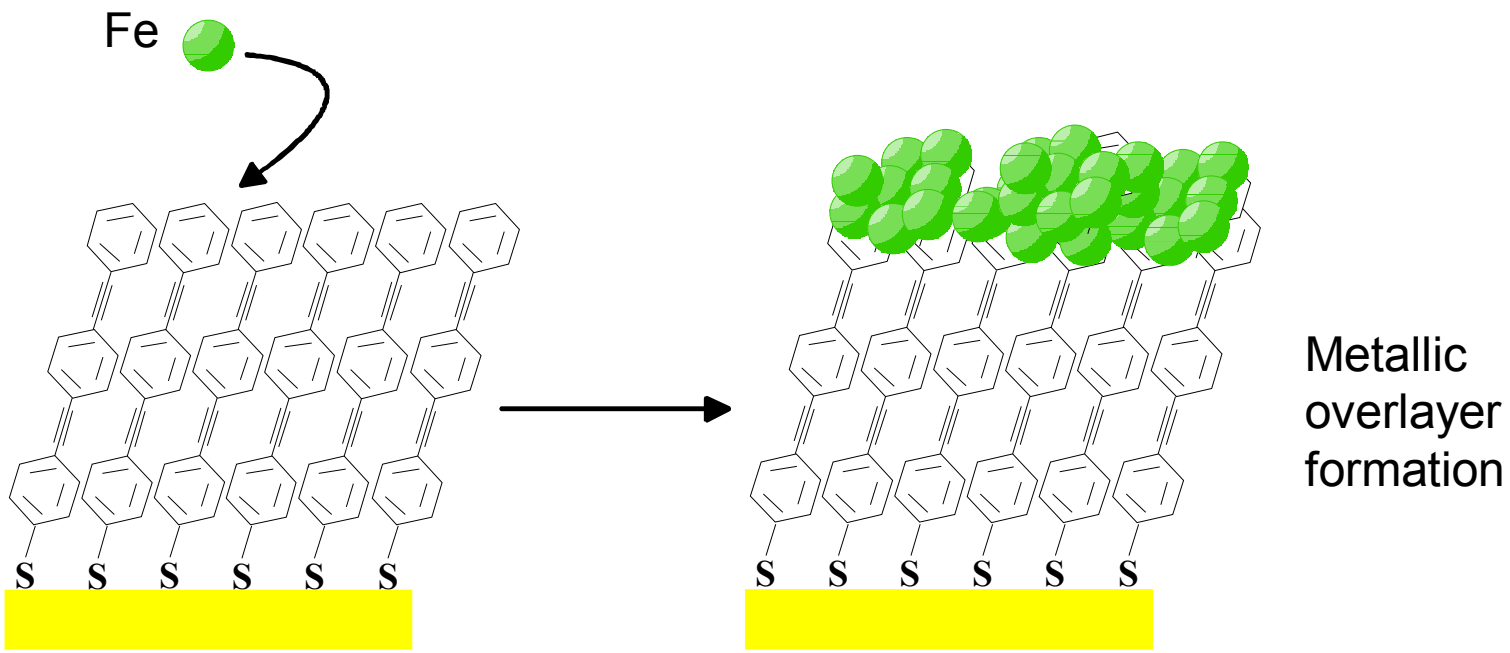
Al penetrates to the Au/S interface until 1:1 Al:Au ratio is obtained.
After this, metallic overlayer forms.



Cu and Ag penetrate to the Au/S interface at all coverages studied.

Al, Cu and Ag are not good contacts!

Studying Metal-Molecule Interactions



Fe forms a good contact!

Summary of Sources

http://www.colorado.edu/physics/2000/index.pl
Physics 2000, a University of Colorado at Boulder Website
http://www.tvhistory.tv/index.html
Television History, the First 75 Years
http://www.elis.ugent.be/ELISgroups/lcd/index.html?http://www.elis.ugent.be/ELISgroups/lcd/lc/lc5.html&2
The Liquid Crystal Group at the University of Ghent
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