

# Electronique organique

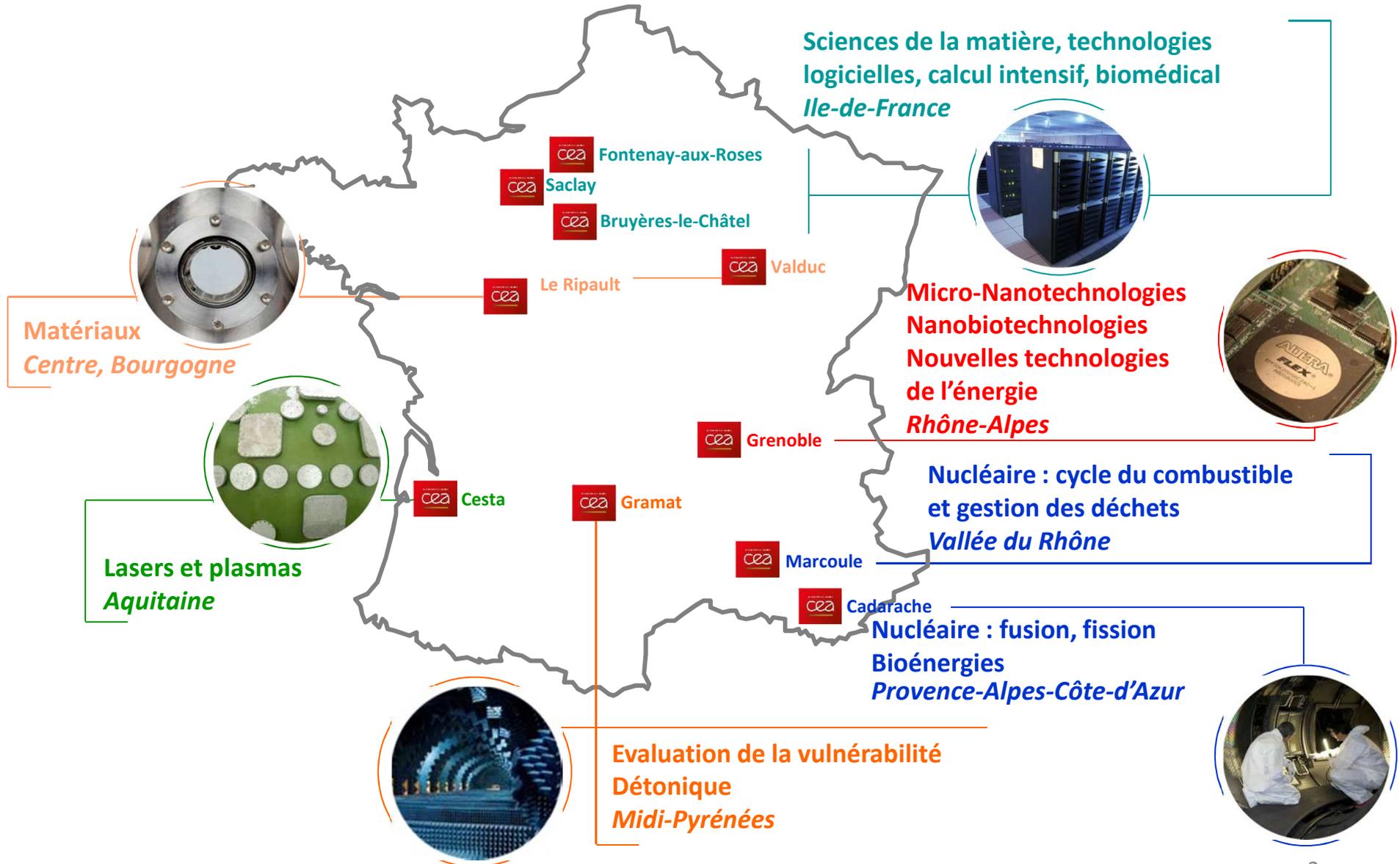
Jean-Marie VERILHAC

[verilhacjm@cea.fr](mailto:verilhacjm@cea.fr)

CEA Grenoble

17 Juin 2014

# Commissariat à l'énergie atomique et aux énergies alternatives





# Les axes stratégiques

**Défense et  
sécurité globale**



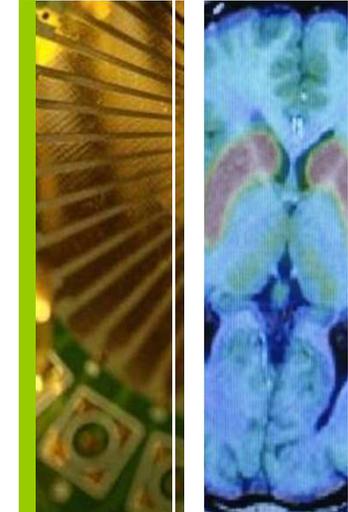
**Très grandes  
infrastructures  
de recherche**



**Energies  
bas carbone**



**Technologies  
pour l'information  
et la santé**



**Recherche fondamentale**

**Enseignement supérieur  
et formation**



**Valorisation et diffusion  
technologique**

# La défense et la sécurité globale.



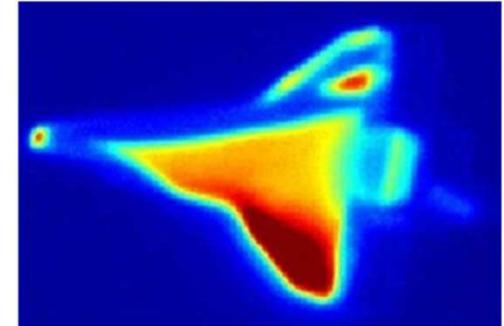
1960 gerboise bleue  
1<sup>er</sup> essais nucléaire français



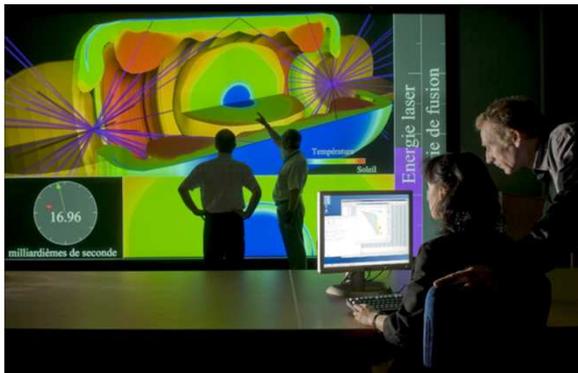
Le Charles de Gaulle



Le Triomphant



Furtivité



1996 Programme Simulation  
+ expérimentation LMJ



Sofradir (Militaire)

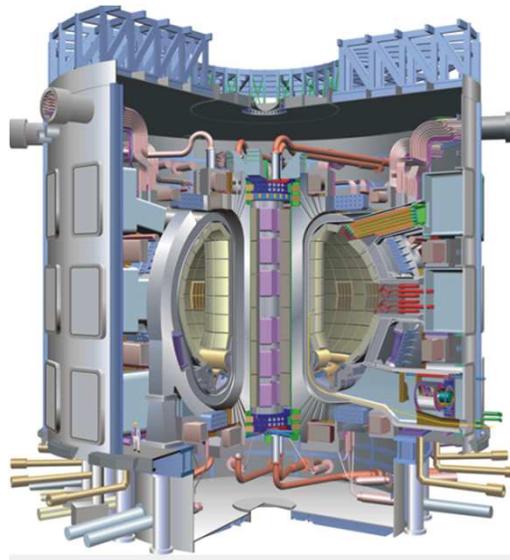


Ulis (Civil)

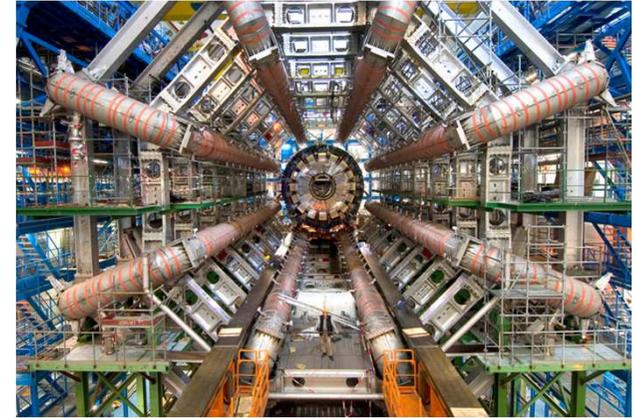
# Les très grandes infrastructures de recherche,



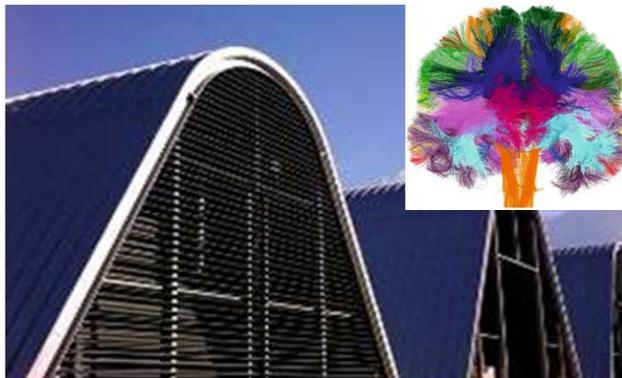
Laser mégajoule



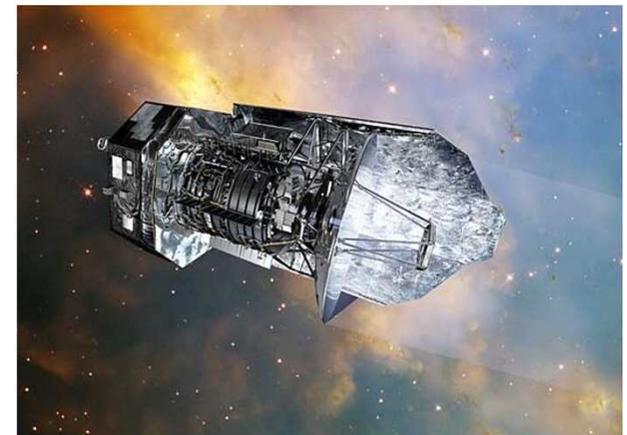
Iter (fusion nucléaire)



CERN

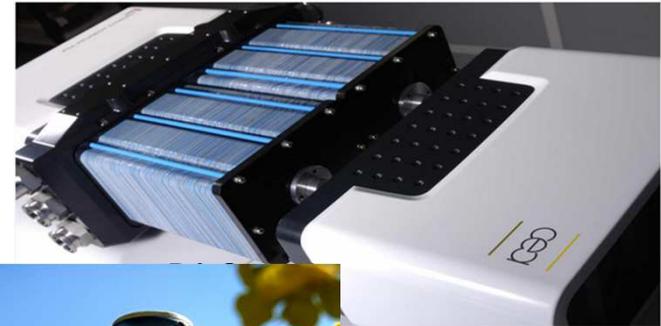


NeuroSpin

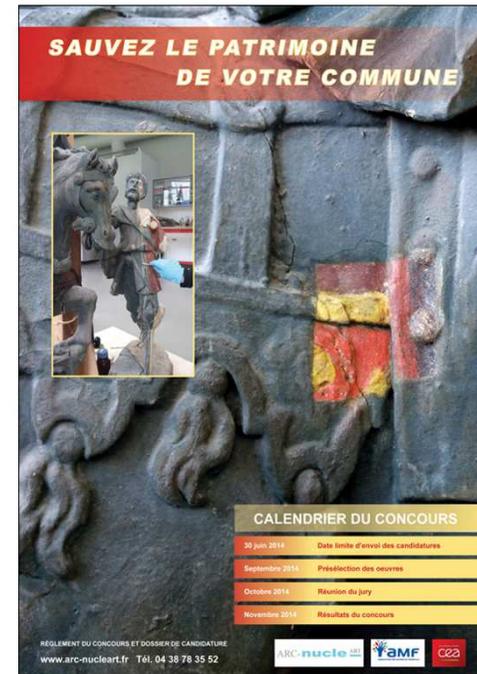


Herschel (infrarouge)

# Les énergies bas carbone (nucléaire et renouvelables),



# Quand le nucléaire mène à l'art: ARC-Nucleart



# Les technologies pour l'information et les technologies pour la santé

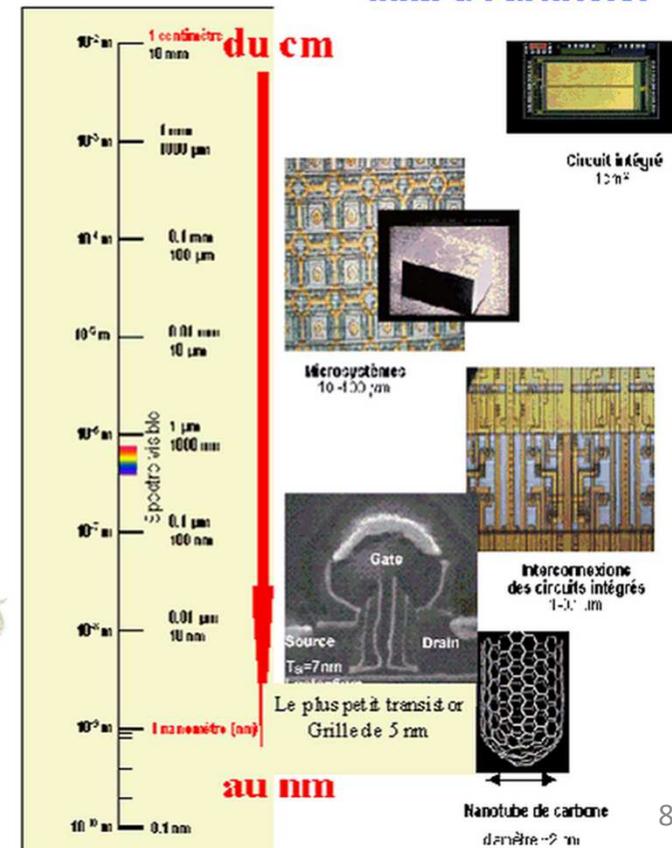
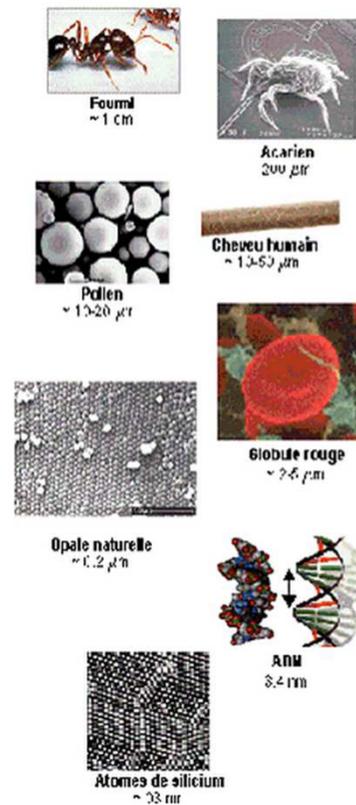


MINATEC (Grenoble)

## L'échelle des dimensions

Du naturel.....

..... à l'artificiel



# Microélectronique et Nanotechnologies

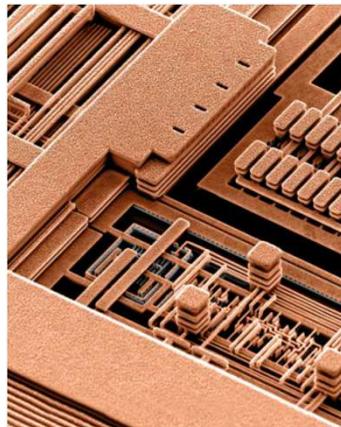
Objets quotidiens...



... et ce qui se cache dessous

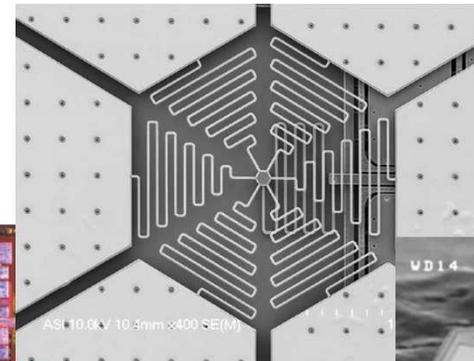


transistor

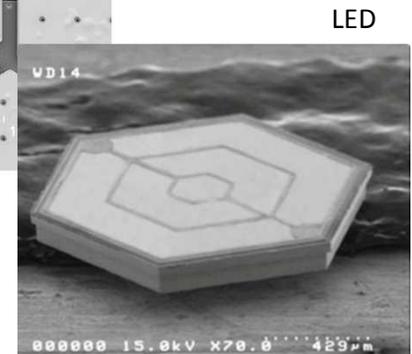


Interconnections

Circuits intégrés



MEMS (capteurs de mouvements)



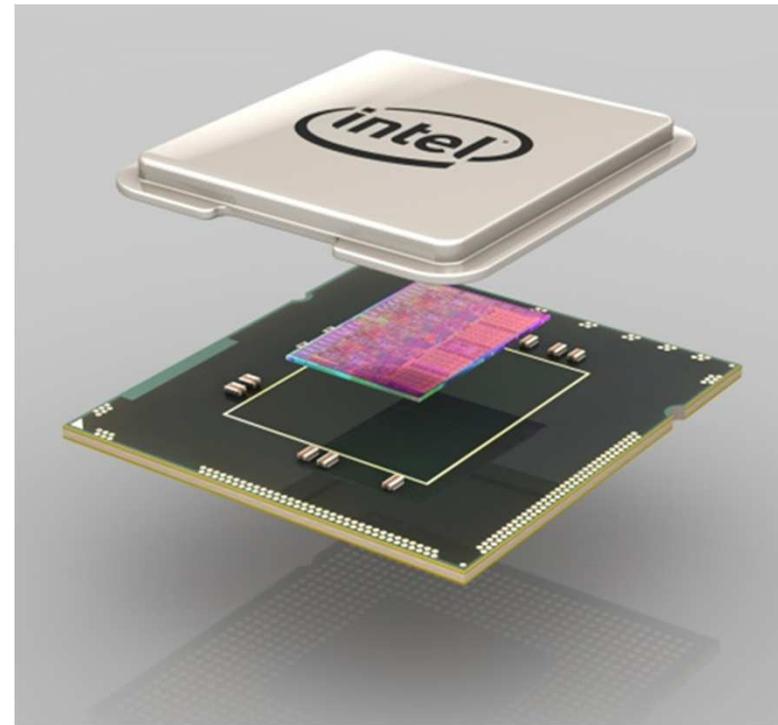
LED

1947



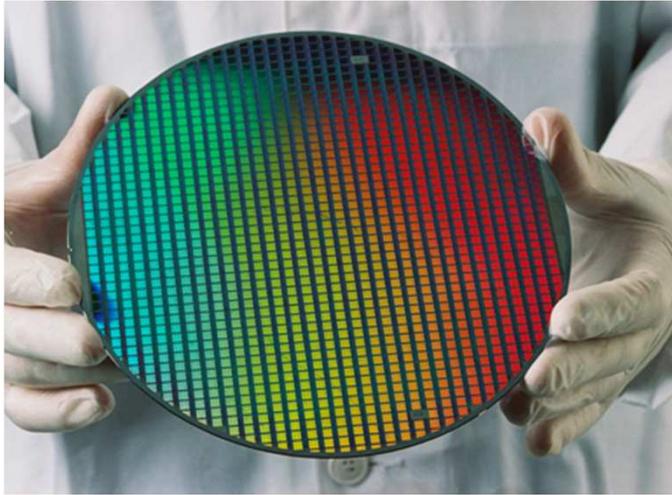
1 transistor/cm<sup>2</sup>

2014



1 milliard transistors/cm<sup>2</sup>

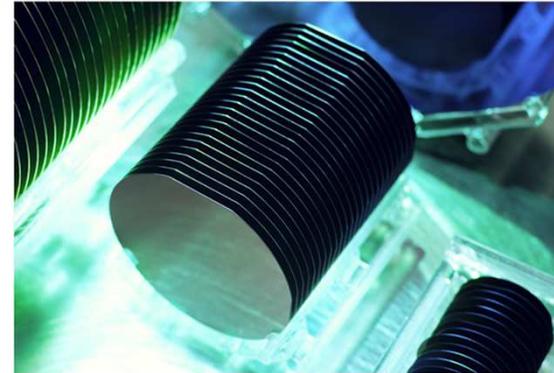
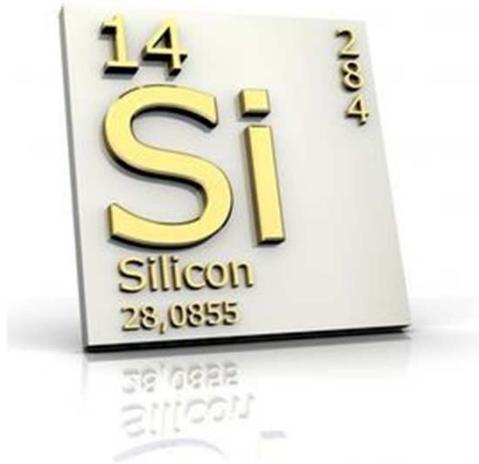
# Salles blanches



particules /m<sup>3</sup>

Classe	0,1 µm	0,2 µm	0,3 µm	0,5 µm	1 µm	5 µm
ISO 1	10	2	0	0	0	0
ISO 2	100	24	10	4	0	0
ISO 3	1 000	237	102	35	8	0
ISO 4	10 000	2 370	1 020	352	83	0
ISO 5	100 000	23 700	10 200	3 520	832	29
ISO 6	1 000 000	237 000	102 000	35 200	8 320	293
ISO 7	∞	∞		352 000	83 200	2 930
ISO 8	∞	∞	∞	3 520 000	832 000	29 300
ISO 9	∞	∞	∞	35 200 000	8 320 000	293 000

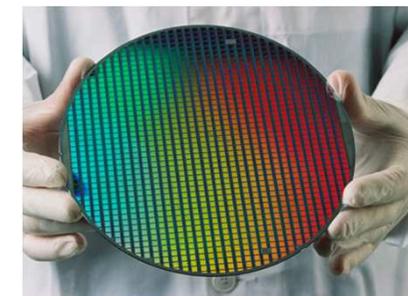
# Microélectronique traditionnelle (technologie du Silicium)



Wafer de silicium

Chiffre d'affaire 2013

- ❑ IBM ~ 100 milliard de \$
- ❑ Intel ~ 53 milliard de \$
- ❑ ST Microelectronic ~ 6 milliard de \$

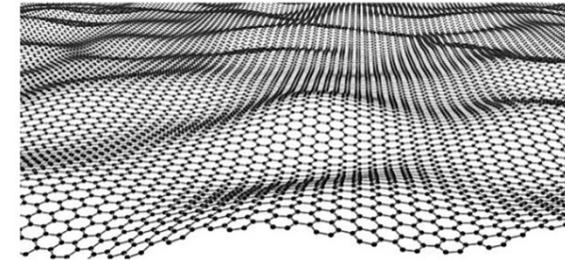
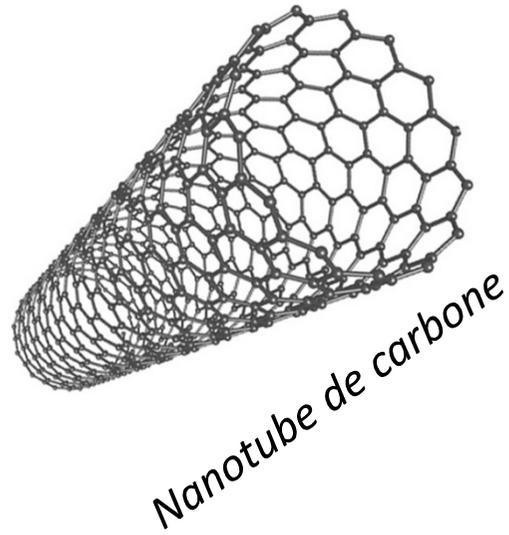
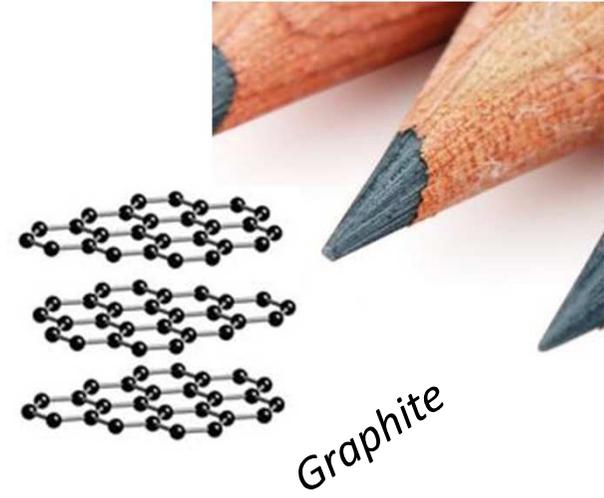


## Classification périodique des éléments

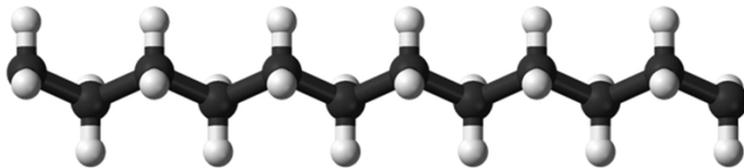
1 Hydrogène <b>H</b> 1s1 1,008 2,2	IIA																2 Hélium <b>He</b> 1s2 4,003 !
3 Lithium <b>Li</b> 1s22s1 6,941 1,0	4 Béryllium <b>Be</b> 1s22s2 9,012 1,6	Classification périodique des éléments										5 Bore <b>B</b> 1s22s22p1 10,810 2,0	6 Carbone <b>C</b> 1s22s22p2 12,011 2,5	7 Azote <b>N</b> 1s22s22p3 14,007 3,0	8 Oxygène <b>O</b> 1s22s22p4 15,999 3,5	9 Fluor <b>F</b> 1s22s22p5 18,998 4,0	10 Néon <b>Ne</b> 1s22s22p6 20,179 !
11 Sodium <b>Na</b> (Ne) 3s1 22,990 0,9	12 Magnésium <b>Mg</b> (Ne) 3s2 24,305 1,3	VIII										13 Aluminium <b>Al</b> (Ne) 3s23p1 26,982 1,6	14 Silicium <b>Si</b> (Ne) 3s23p2 28,086 1,9	15 Phosphore <b>P</b> (Ne) 3s23p3 30,974 2,2	16 Soufre <b>S</b> (Ne) 3s23p4 32,066 2,6	17 Chlore <b>Cl</b> (Ne) 3s23p5 35,453 3,2	18 Argon <b>Ar</b> (Ne) 3s23p6 39,948 !
19 Potassium <b>K</b> (Ar) 4s1 39,098 0,8	20 Calcium <b>Ca</b> (Ar) 4s2 40,080 1,0	21 Scandium <b>Sc</b> (Ar) 3d14s2 44,956 1,4	22 Titane <b>Ti</b> (Ar) 3d24s2 47,880 1,5	23 Vanadium <b>V</b> (Ar) 3d34s2 50,942 1,6	24 Chrome <b>Cr</b> (Ar) 3d54s1 51,996 1,6	25 Manganèse <b>Mn</b> (Ar) 3d54s2 54,938 1,6	26 Fer <b>Fe</b> (Ar) 3d64s2 55,847 1,8	27 Cobalt <b>Co</b> (Ar) 3d74s2 58,933 1,9	28 Nickel <b>Ni</b> (Ar) 3d84s2 58,939 1,6	29 Cuivre <b>Cu</b> (Ar) 3d104s1 63,540 1,9	30 Zinc <b>Zn</b> (Ar) 3d104s2 65,390 1,6	31 Gallium <b>Ga</b> (Ar) 3d104s24p1 69,720 1,8	32 Germanium <b>Ge</b> (Ar) 3d104s24p2 72,630 2,0	33 Arsenic <b>As</b> (Ar) 3d104s24p3 74,922 2,2	34 Sélénium <b>Se</b> (Ar) 3d104s24p4 78,960 2,5	35 Brome <b>Br</b> (Ar) 3d104s24p5 79,904 3,0	36 Krypton <b>Kr</b> (Ar) 3d104s24p6 83,800 !
37 Rubidium <b>Rb</b> (Kr) 5s1 85,470 0,8	38 Strontium <b>Sr</b> (Kr) 5s2 87,620 1,0	39 Yttrium <b>Y</b> (Kr) 4d15s2 88,905 1,2	40 Zirconium <b>Zr</b> (Kr) 4d25s2 91,220 1,3	41 Niobium <b>Nb</b> (Kr) 4d45s1 92,906 1,6	42 Molybdène <b>Mo</b> (Kr) 4d55s1 95,940 2,2	43 Technétium <b>Tc</b> (Kr) 4d55s2 97 1,9	44 Ruthénium <b>Ru</b> (Kr) 4d75s1 101,070 2,2	45 Rhodium <b>Rh</b> (Kr) 4d85s1 102,905 2,3	46 Palladium <b>Pd</b> (Kr) 4d105s0 106,460 2,2	47 Argent <b>Ag</b> (Kr) 4d105s1 107,870 1,9	48 Cadmium <b>Cd</b> (Kr) 4d105s2 112,410 1,7	49 Indium <b>In</b> (Kr) 4d105s24p1 114,820 1,8	50 Étain <b>Sn</b> (Kr) 4d105s24p2 118,710 1,8	51 Antimoine <b>Sb</b> (Kr) 4d105s24p3 121,750 2,0	52 Tellure <b>Te</b> (Kr) 4d105s24p4 127,600 2,1	53 Iode <b>I</b> (Kr) 4d105s24p5 126,904 2,7	54 Xénon <b>Xe</b> (Kr) 4d105s24p6 131,290 !
55 Césium <b>Cs</b> (Xe) 6s1 132,905 0,8	56 Baryum <b>Ba</b> (Xe) 6s2 137,330 0,9	57 Lanthane <b>La</b> (Xe) 4f15d16s2 138,900 1,1	58 Cérium <b>Ce</b> (Xe) 4f15d16s2 140,120 1,1	59 Praséodyme <b>Pr</b> (Xe) 4f35d16s2 140,907 1,1	60 Néodyme <b>Nd</b> (Xe) 4f45d16s2 144,240 1,1	61 Prométhium <b>Pm</b> (Xe) 4f55d16s2 145 ?	62 Samarium <b>Sm</b> (Xe) 4f65d16s2 150,360 1,2	63 Europium <b>Eu</b> (Xe) 4f75d16s2 151,960 ?	64 Gadolinium <b>Gd</b> (Xe) 4f75d16s2 157,250 1,2	65 Terbium <b>Tb</b> (Xe) 4f95d16s2 158,925	66 Dysprosium <b>Dy</b> (Xe) 4f105d16s2 162,500 1,2	67 Holmium <b>Ho</b> (Xe) 4f115d16s2 164,930 1,2	68 Erbium <b>Er</b> (Xe) 4f125d16s2 167,260 1,2	69 Thulium <b>Tm</b> (Xe) 4f135d16s2 168,930 1,2	70 Ytterbium <b>Yb</b> (Xe) 4f145d16s2 173,040 1,1		
87 Francium <b>Fr</b> (Rn) 7s1 223 0,7	88 Radium <b>Ra</b> (Rn) 7s2 226,020 0,9	89 Actinium <b>Ac</b> (Rn) 5f16d17s2 227,03 1,1	90 Thorium <b>Th</b> (Rn) 5f16d27s2 232,038 1,3	91 Protactinium <b>Pa</b> (Rn) 5f16d37s2 231,036 1,5	92 Uranium <b>U</b> (Rn) 5f36d17s2 238,029 1,4	93 Neptunium <b>Np</b> (Rn) 5f46d27s2 237,048 1,3	94 Plutonium <b>Pu</b> (Rn) 5f66d27s2 244 1,4	95 Américium <b>Am</b> (Rn) 5f76d37s2 243 1,3	96 Curium <b>Cm</b> (Rn) 5f76d47s2 247 1,3	97 Berkélium <b>Bk</b> (Rn) 5f96d47s2 247 1,3	98 Californium <b>Cf</b> (Rn) 5f106d47s2 251 1,3	99 Einsteinium <b>Es</b> (Rn) 5f116d47s2 254 1,3	100 Fermium <b>Fm</b> (Rn) 5f126d47s2 257 1,3	101 Mendélévium <b>Md</b> (Rn) 5f136d47s2 258 1,3	102 Nobélium <b>No</b> (Rn) 5f146d47s2 259 1,3		
I. U. T. - Département de Chimie - Cours & Travaux Dirigés de Chimie Générale (11CG2) - Première année.																	

Robert VALLS - septembre 2011.

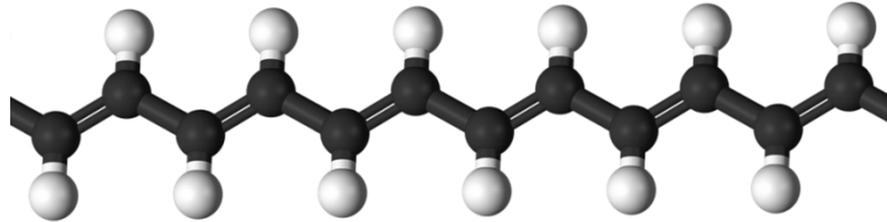
# Les formes du carbone



Polymère



# Des plastiques conducteurs d'électricités



Alan J. Heeger



Alan G. MacDiarmid



Hideki Shirakawa

The Nobel Prize in Chemistry 2000 was awarded jointly to Alan J. Heeger, Alan G. MacDiarmid and Hideki Shirakawa "for the discovery and development of conductive polymers".

- ✓ Matériaux aux propriétés optiques et électroniques proches du Silicium,
- ✓ Possible de les mettre en œuvre dans des encres imprimables.

# À la frontière entre 2 mondes



Microélectronique

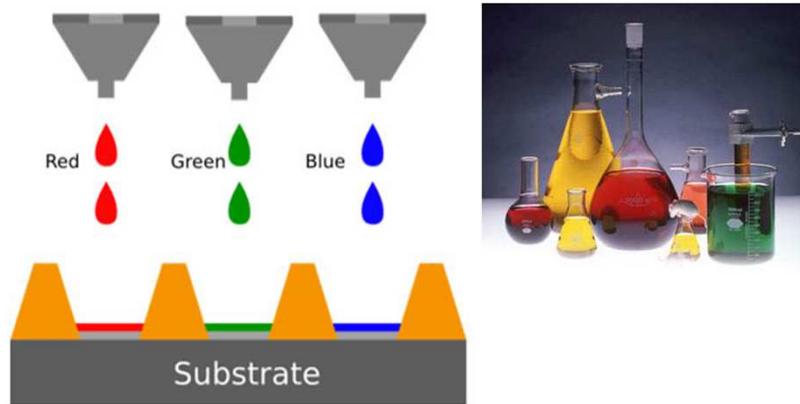


Impression

Electronique organique ou électronique imprimée

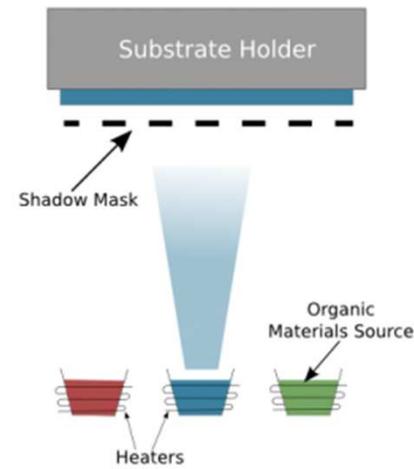
# Mise en œuvre des matériaux organiques

## Encres/impression



Machine jet d'encre

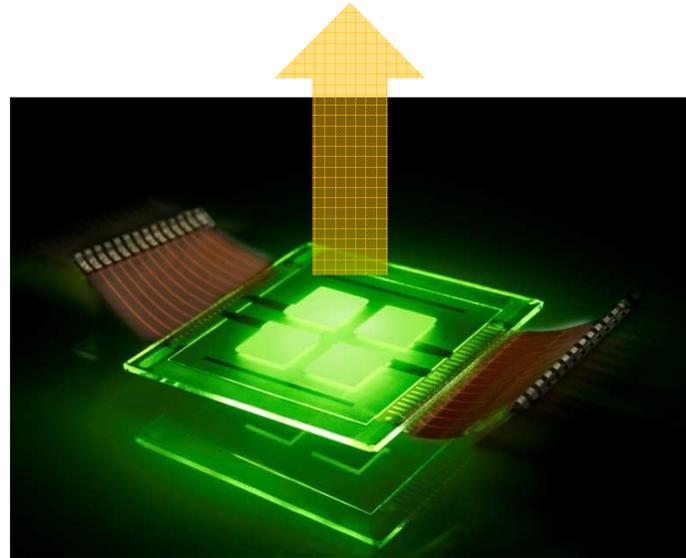
## Poudre/évaporation



Bâti d'évaporation

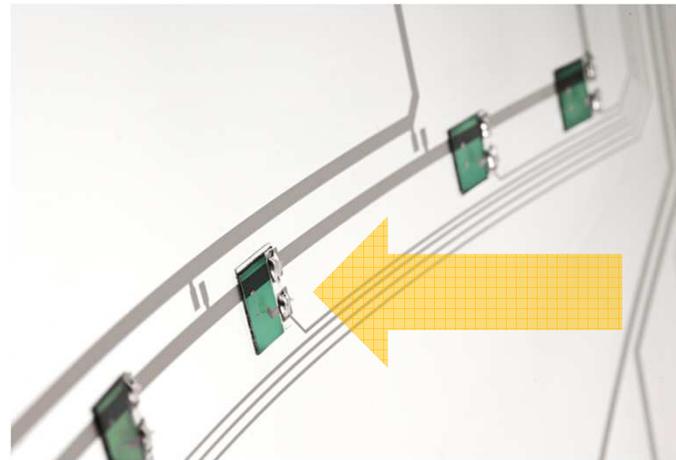
## Emission de lumière

→ OLEDs



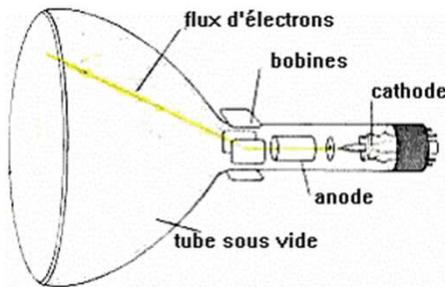
## Capture de lumière

→ Photodétecteurs organiques

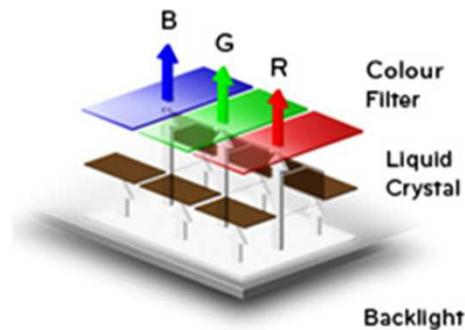


# Technologies des écrans

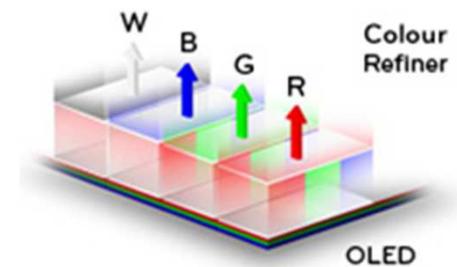
## Tube cathodique



## LCD

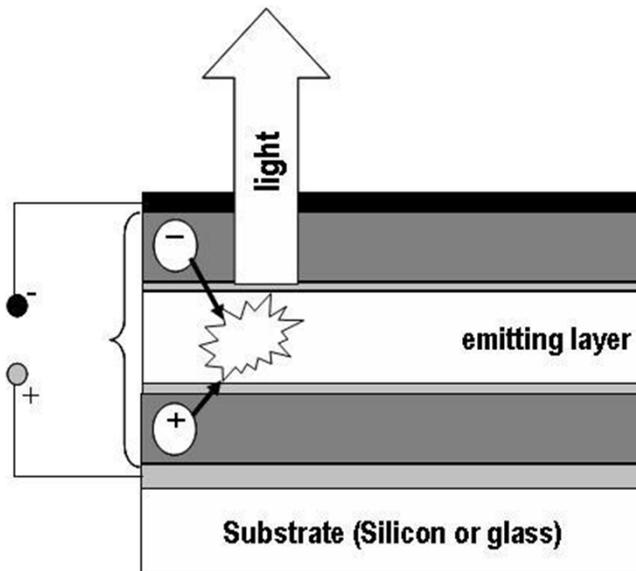


## OLED

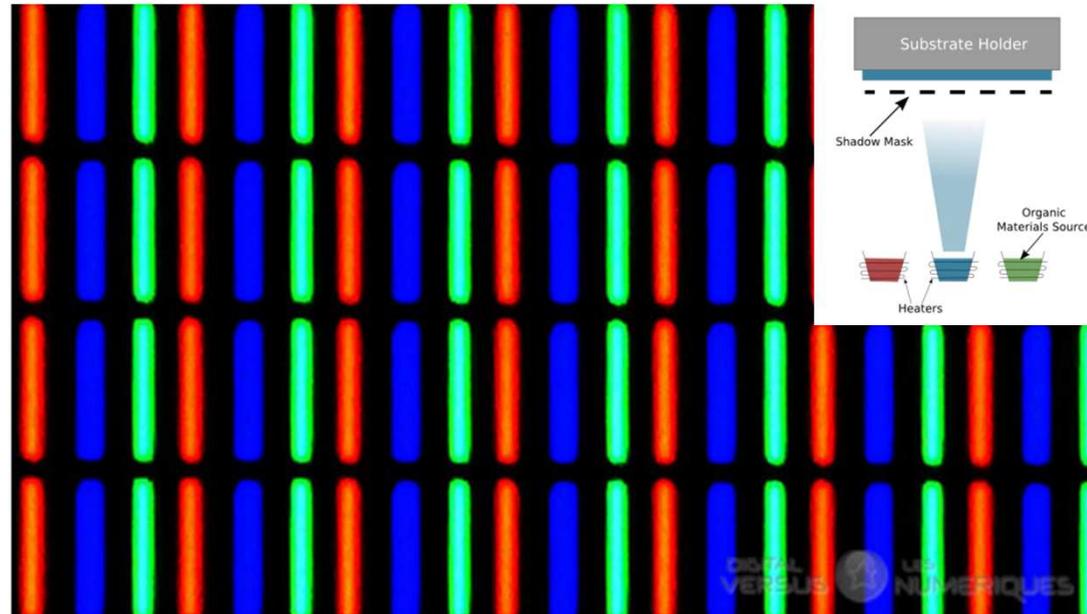


# OLED (Organic Light Emitting Diodes)

Principe basé sur l'électroluminescence ou l'électrophosphorescence de molécules organiques.

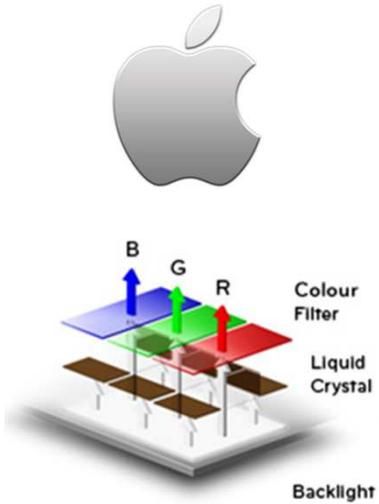


Transforme un courant électrique en lumière

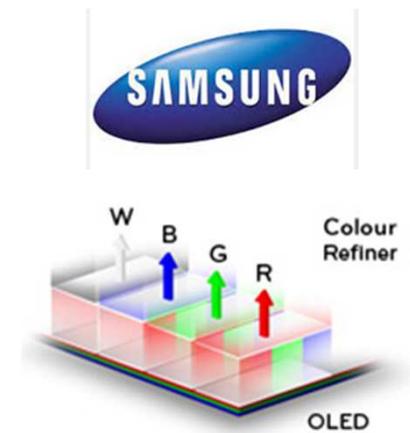


Zoom sur une série de pixels (RVB)

# 1<sup>ère</sup> « vraie » application: Smartphone



Technologie LCD

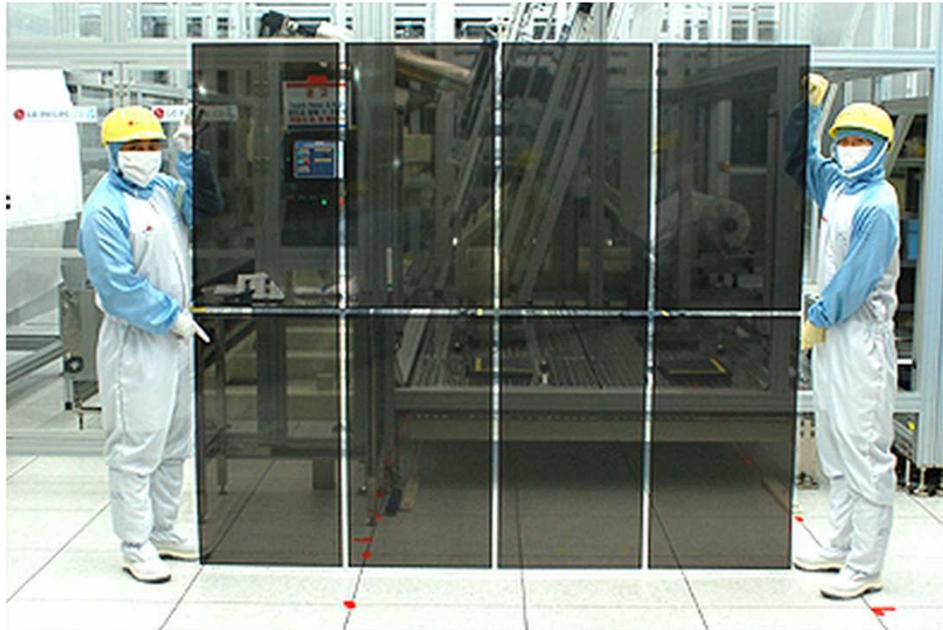


Technologie OLED

## Avantage des écrans OLED vs LCD:

- Pas de rétroéclairage,
- Consommation réduite,
- Noir plus intense,
- Image plus lumineuse,
- Écran moins épais,
- Possibilité d'avoir des écrans souples,
- Etc...

# Les écrans de télévision OLED



Génération 7 de taille de dalles de verre

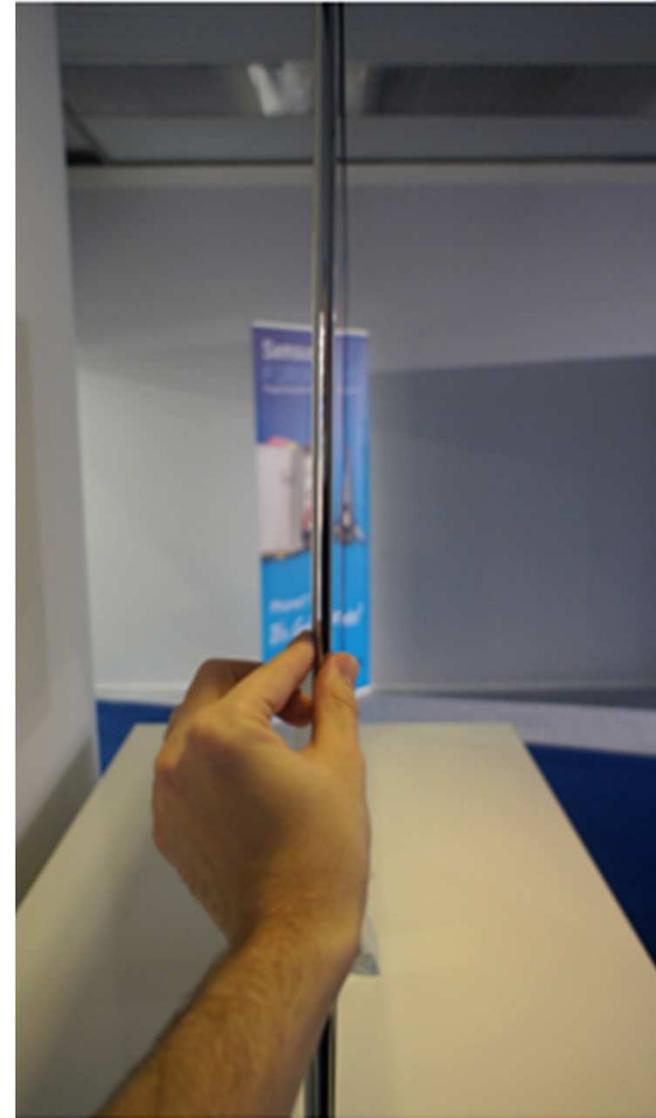


Panasonic



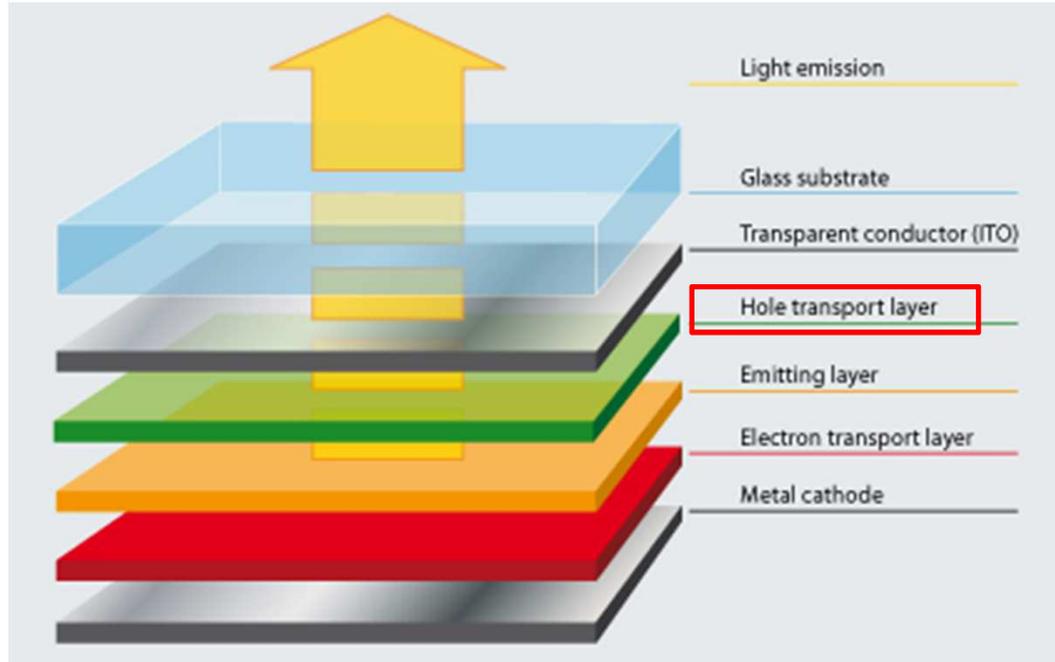
Usine OLED Samsung Gen8

# Les écrans de télévision OLED



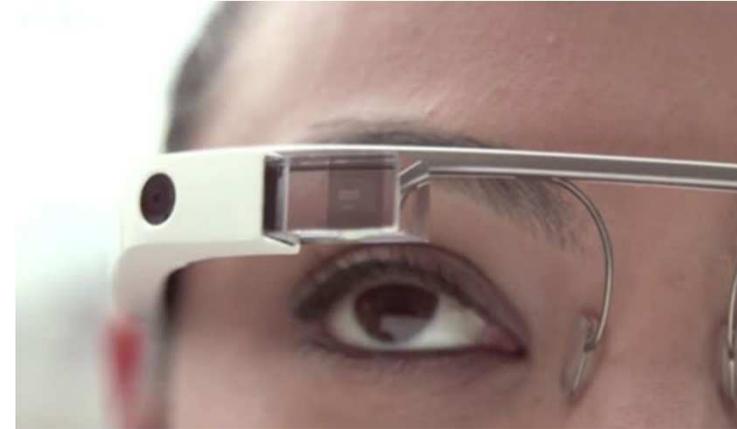
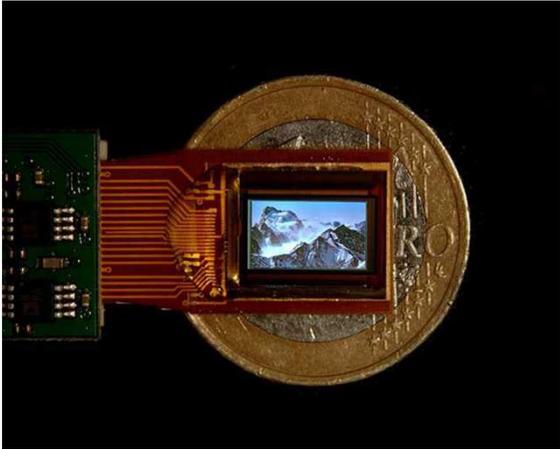


# Une couche qui vaut de l'or



Novaled racheté par Samsung 260M€ en 2013

# MicroOLED (start up du CEA Grenoble)



Concept Google glass

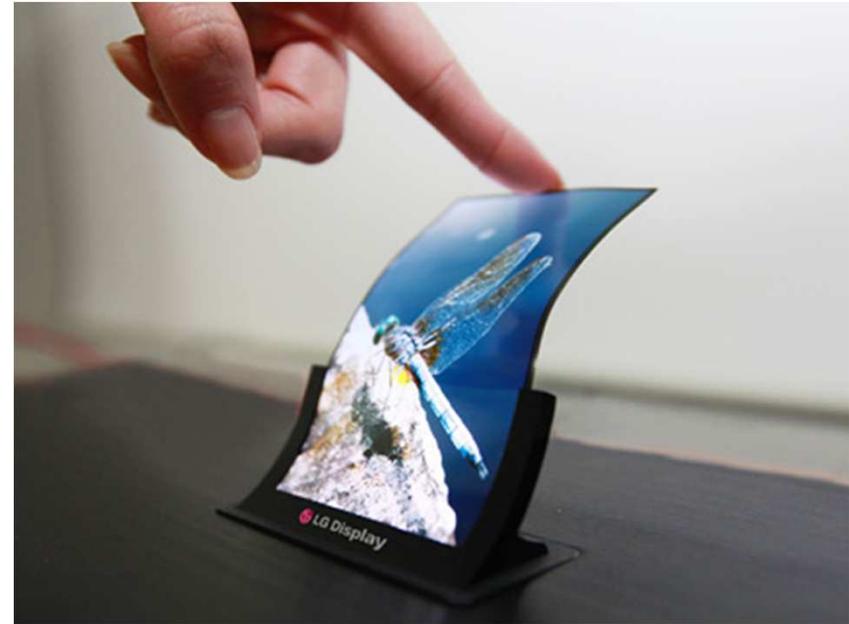


Viseur caméra

## À venir: les écrans OLED flexible

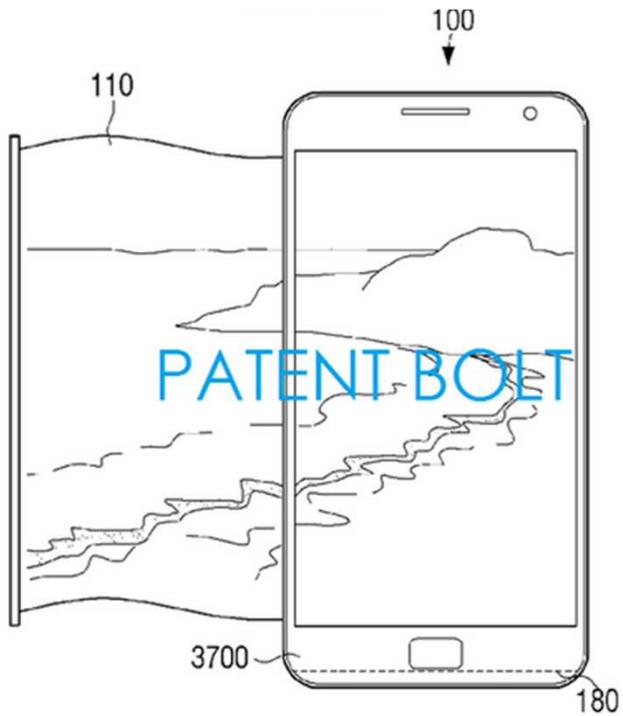


Ecran souple Samsung (YOUM 2015)



<http://www.youtube.com/watch?v=pzq0rKK5Kb0>

# Ecrans enroulables



Nombreux brevets déposés



# Ecran OLED transparent

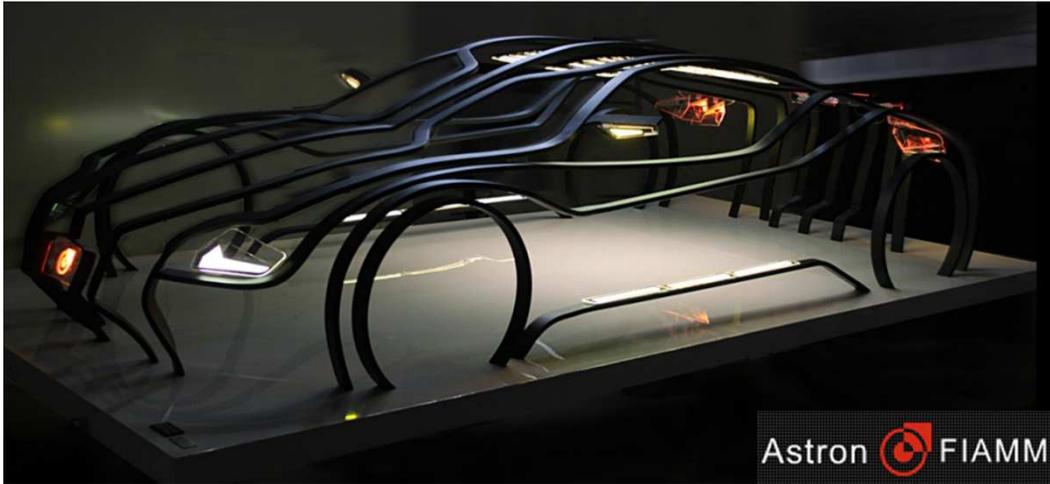


*Film Avatar*



*Démonstrations de concept chez LG et Samsung* 28

# OLED pour l'éclairage



*Automobile*



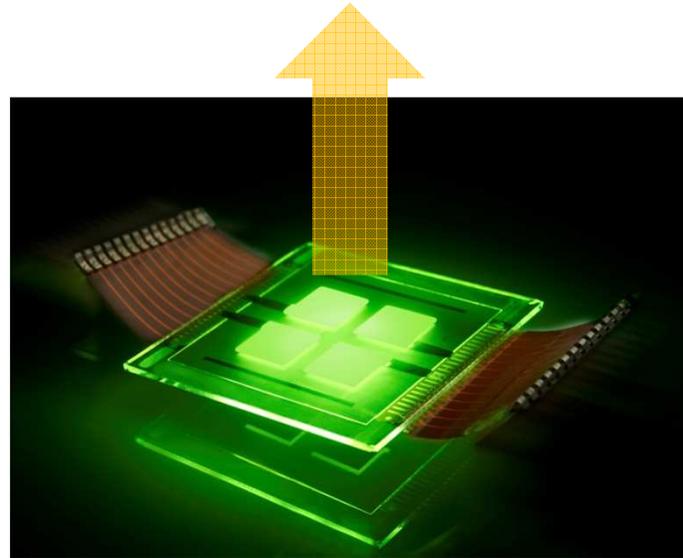
*Signalétique*



*Eclairage technique ou décoratif*

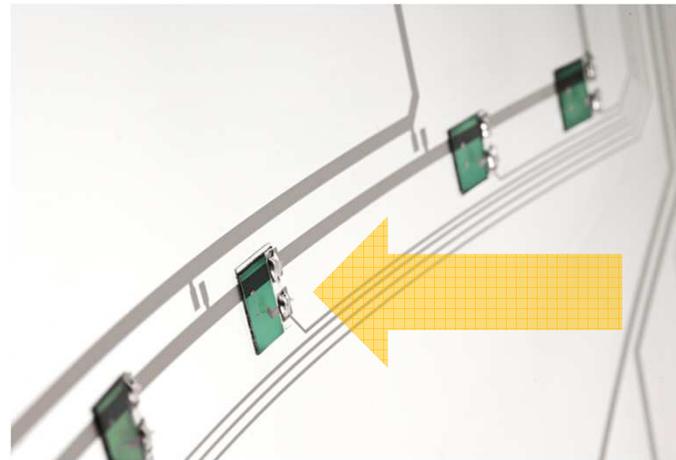
## Emission de lumière

→ OLED

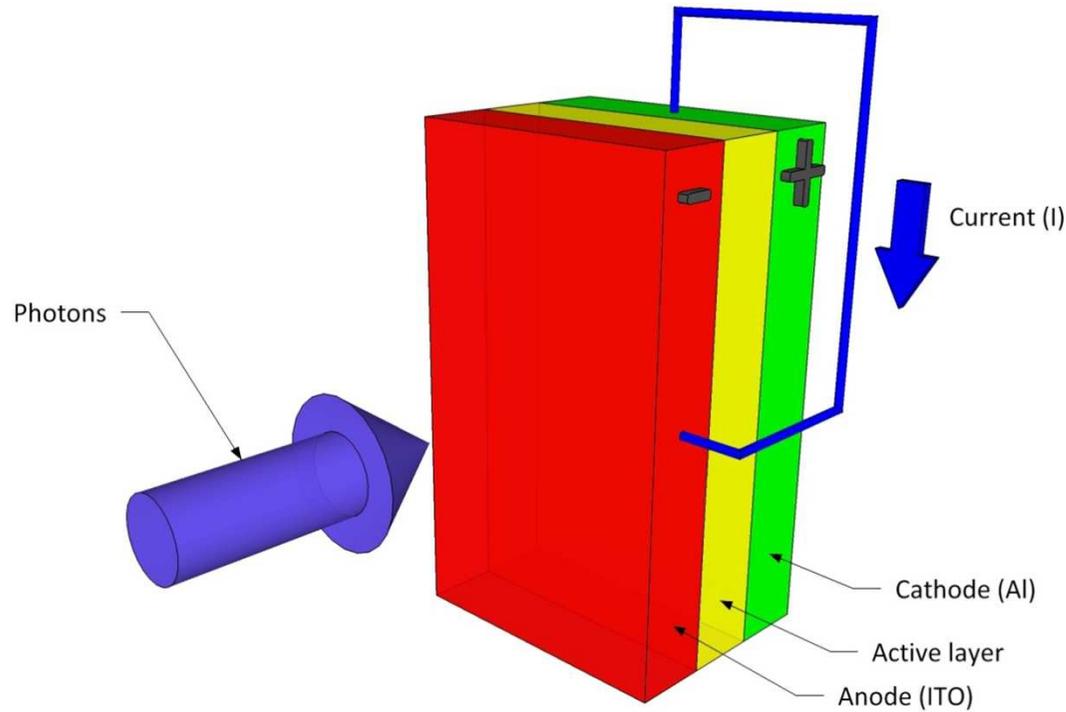


## Capture de lumière

→ Photodétecteur organique



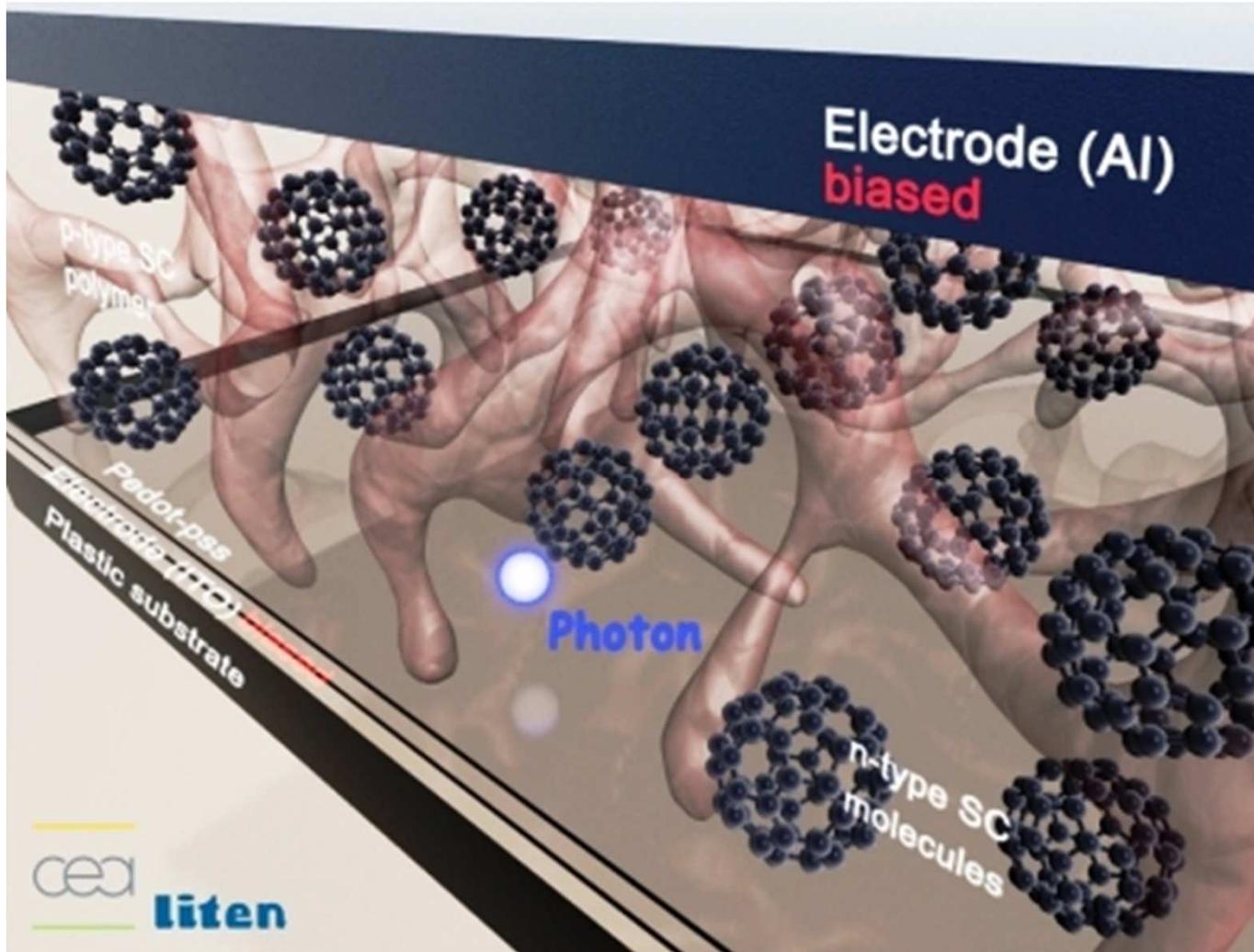
# Les photodétecteurs organiques



Transformer la lumière en courant électrique

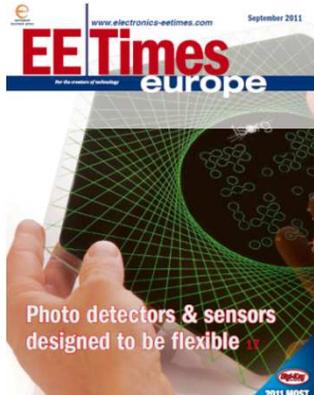
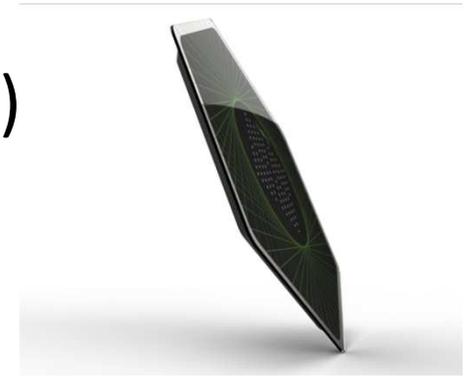


# Couche de photoconversion





# Start up ISORG (Image Sensors ORGanic)



Electronics Engineering Times



On Board magazine



**Silicon 60 EETimes (Electronics Engineering Times) :**  
the list of the 60 startups worldwide with the most promising technology

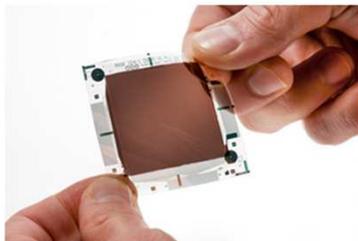
## ISORG in Silicon 60 since 2012



*"Take ISORG for example. For this French startup company, it was the first time at Printed Electronics USA. This was a good opportunity to see demos of their printed photo-detector arrays in action."*

New award for Plastic Logic and ISORG's sensor which promises to transform the way we interact with consumer devices

07/04/2014



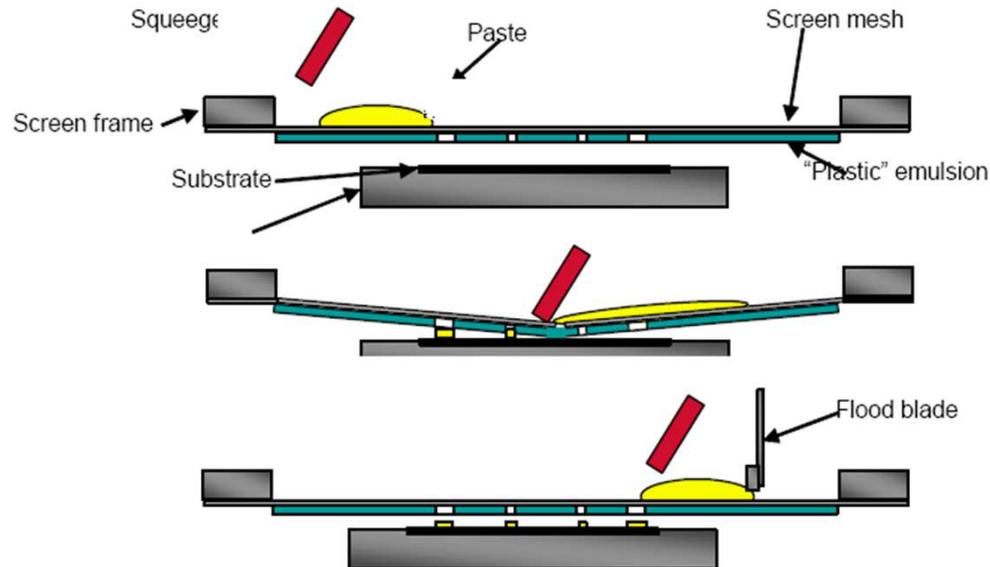
**ISORG selected as Cool Vendor 2013 for Imaging & Display as 1 of the 5 worldwide coolest suppliers**

« We find three specific things of coolness for ISORG :

- . New products
- . Cost effective
- . It works »

# Impression sous forme d'encres

## Sérigraphie



- Électronique grande surface
- Substrats plastiques souples et légers
- Temps de cycles courts

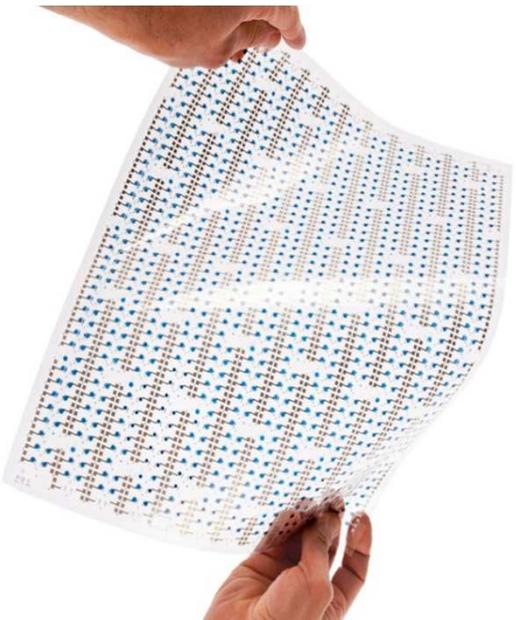
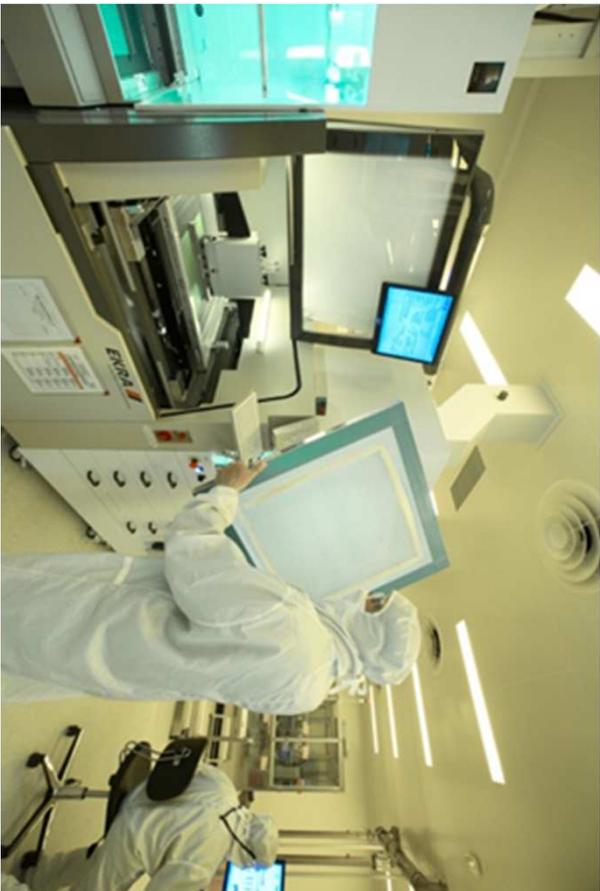
1960



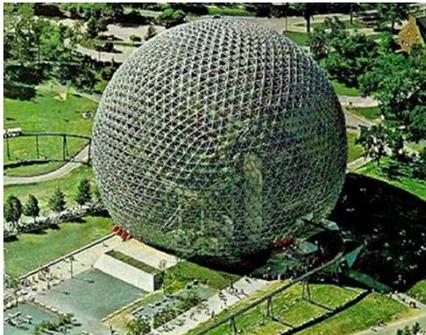
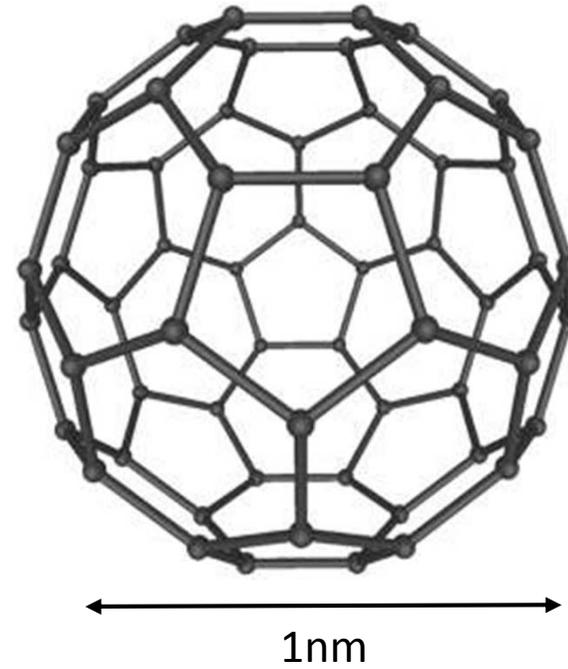
Andy Warhol



2014

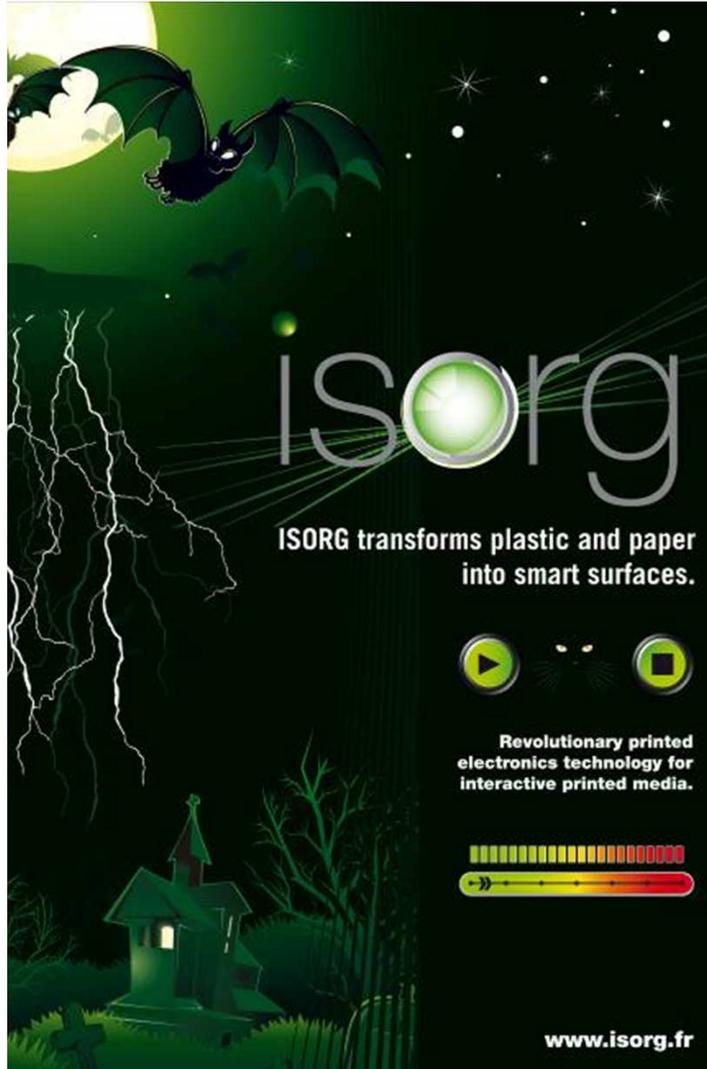


# Fullerène



Architecte:  
Buckminster Fuller

# Exemples d'applications

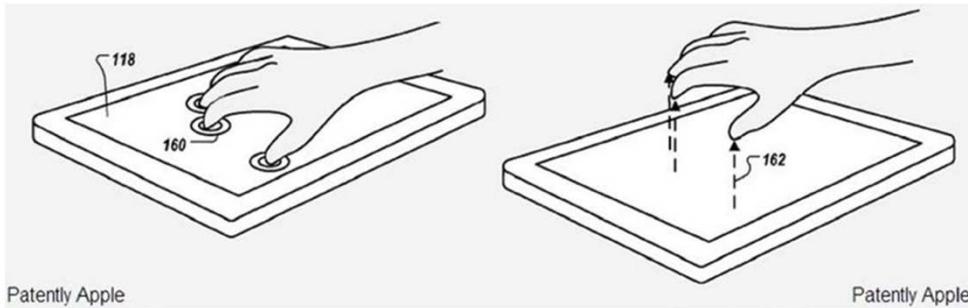


Affiches interactives



# Exemples d'applications

Prochaine génération de tablette et smart-phone avec Interface 3D



Imagerie médicale et contrôle non destructif



# Exemples d'applications

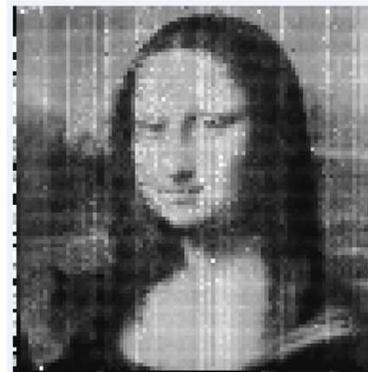
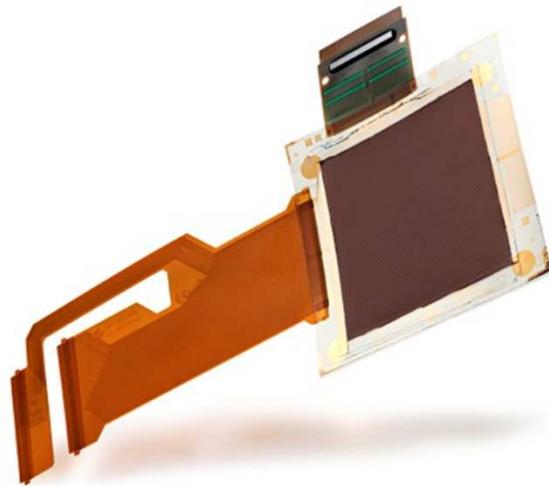
## Electroménager



## Contrôle industriel



# Scanners

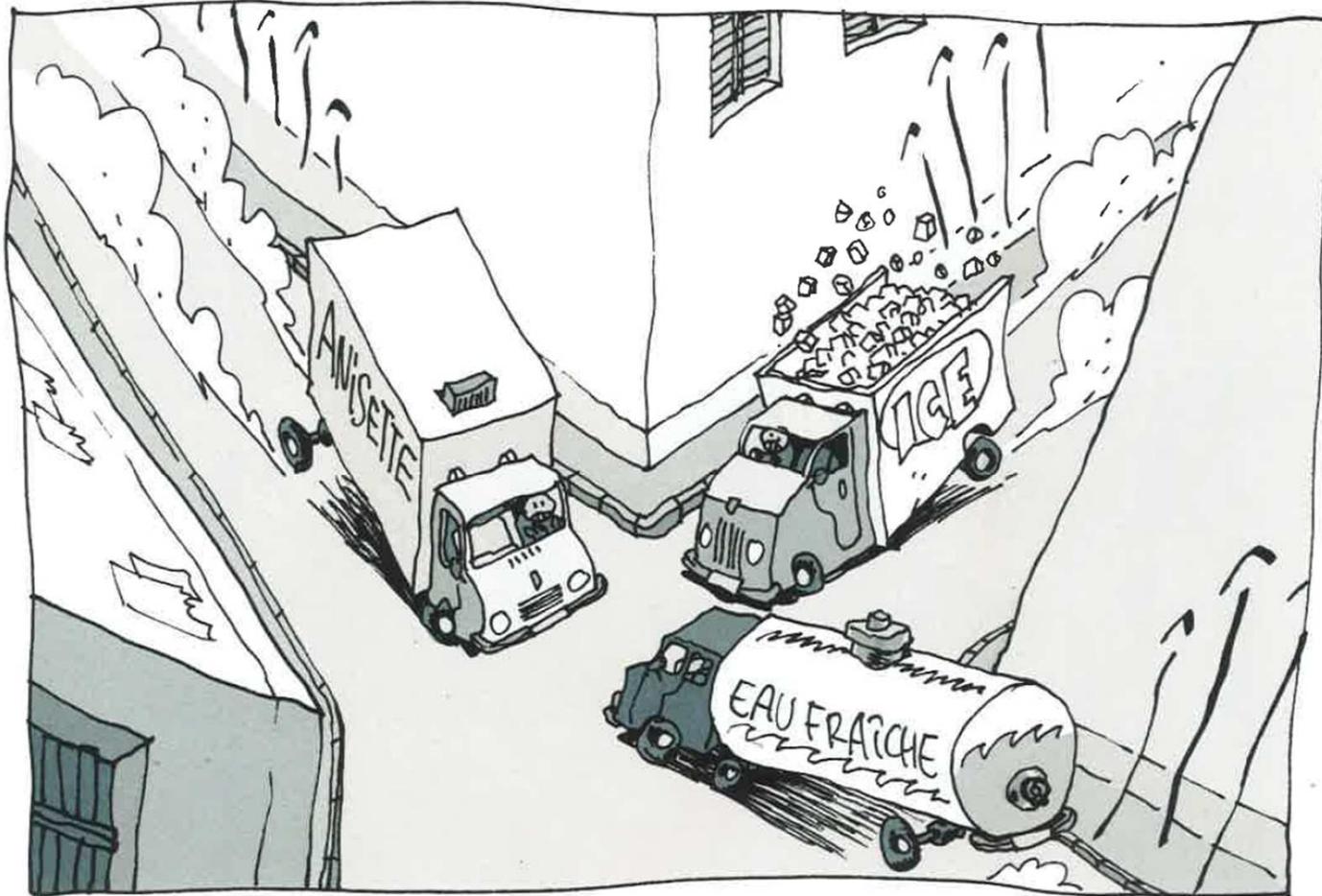


1<sup>er</sup> démonstration de scanner flexible tout imprimé



et bien d'autres applications à inventer...

# Conclusions



DEUX SECONDES AVANT L'INVENTION DU PASTIS



Merci de votre  
attention