Wearable, flexible or organic electronics

Field description and possible overlaps

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- Field description and technical features
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  - Flexible electronics (FE)
  - Organic electronics (OE)
- Synthesis and overlap opportunities
  - Case study 1
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- Prospect for further integration and technical barriers
  - Case study 1
  - Case study 2
- Conclusion

Wearable electronics

Definition and history

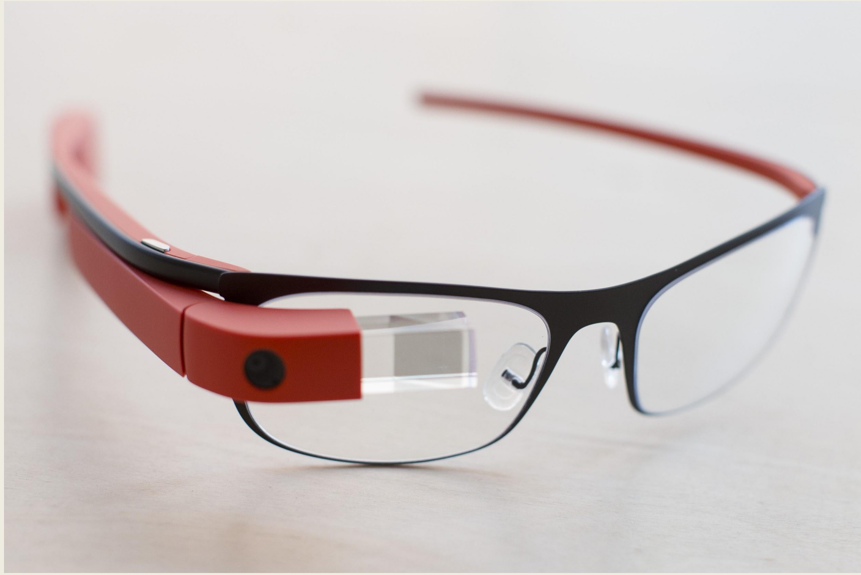
These are miniature electronic devices that are worn by the bearer under, with or on top of clothing.
In 1961, Claude Shanon and Edward Thorp used a timing device hidden in a shoe to predict with relative precision the winning number at the *roulette* in Las Vegas. The model on the picture was built in the early 70’s, still to cheap at the *roulette.*

Through the 80’s a wide range of ever smaller computer was with unequal success fixed to belt, wrists, or even necklace. The market has however seemed mostly reluctant to the mainstream adoption of portable computation units.

Source: http://www.eyetap.org/wearcam/eudaemonic/

WE: Chosen samples (1)

Google Glass



Fonte:http://www.tecmundo.com.br/google-glass/61138-mudanca-termos-venda-sugere-lancamento-comercial-google-glass.htm

Main features (from Google)

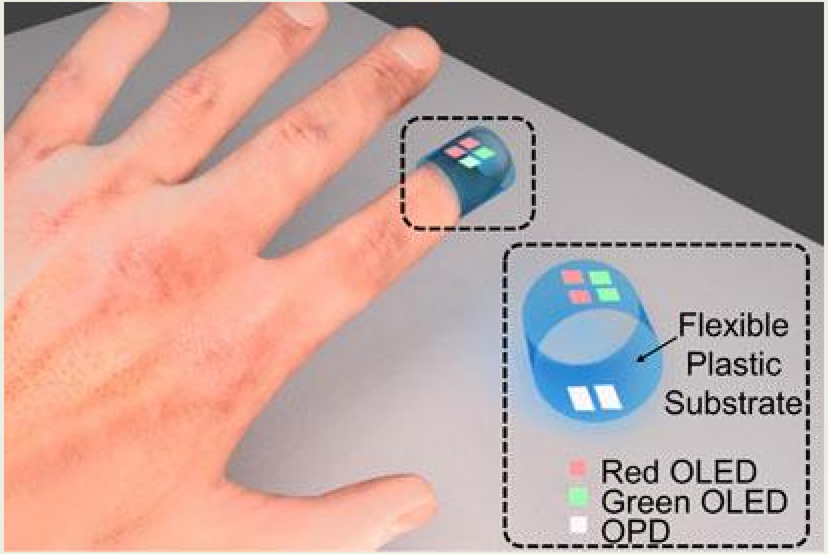
- Camera: 5MP (CMOS)
- Wifi: 802.11 g/g 2.4 GHz
- Storage: 12 Gb
- Price: US$ 1.499
- Weight: 43 g

Unofficial

- CPU: dual core OMAP 4430
- Memory: ~1Gb RAM (60% usable)
- Operating system: Android 4.0.4
- Clock frequency: 1-1.2 GHz

WE: Chosen samples (2)

Personnal O_2 blood content sensing system



Fonte:https://newscenter.berkeley.edu/2014/12/10/organic-electronics-cheap-wearable-medical-sensors/

Main features

- Green OLED (532nm)
- Red OLED (626nm)
- Organic photodiode sensible to those wavelength
- Operating frequency: 1 kHz
- Accuracy: 1-2%
- Bracelet: Commercial elastomer
- Lifespan: Descartable
- Potential cost at industrial production: Low to Very low.
- Weight: Very low

WE: Acceptable features

Frequency	kHz to GHz
Flexibility	Both are found
Price	Very Low (discartable) to Very High
Integration's caracteristic dimention	cm to nm
Weight	Tipically low
Manufacture	Potentially Easy to Very Complex

In general needs to be able to withstand moderate physical shocks, H_2O, and UV.

Flexible electronics

Definition and history

Field of electronic where the circuit components are mounted upon a flexible or foldable substrate as PEEK or Polyimide.

Early attempts and interests, with the first patent on the subject filed on 1903 for fine conductors. Widespread interest from the early 50’s.

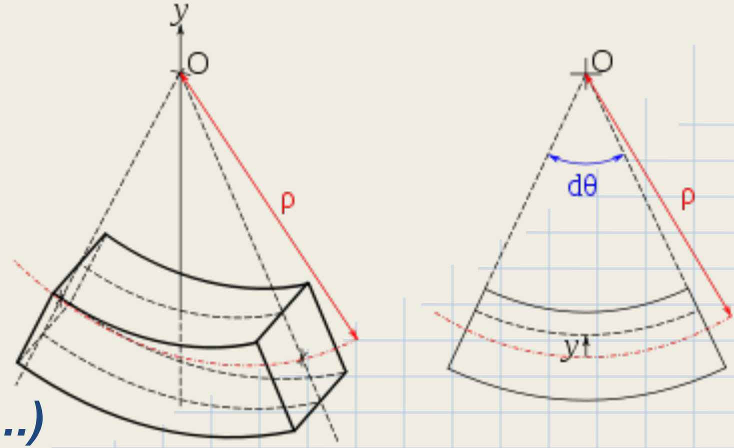
Recall: What is flexibility?

Capable of being bent

Repeatedly without dammage

$$M(x) = -EI\,\frac{d^2w}{dx^2}$$

$$\sigma = \frac{My}{I_x}$$

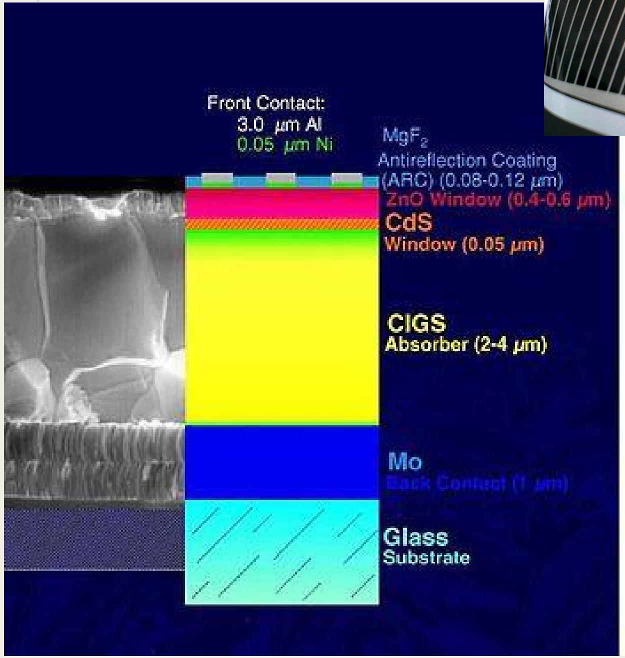


+Notion of fatigue strength

Every material is *Flexible (up to a certain point...)*

FE: Chosen samples (1)

Thin film CIGS PV cells



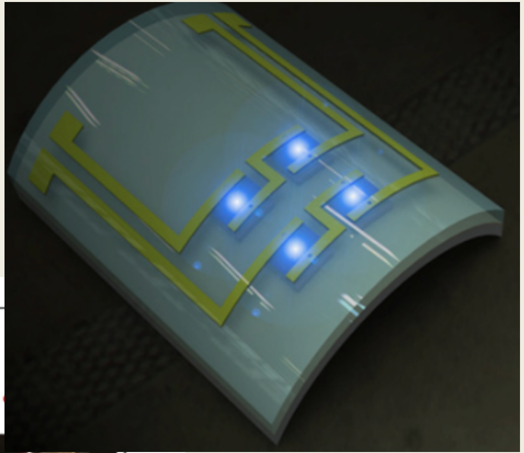
Fonte: http://en.wikipedia.org/wiki/Copper_indium_gallium_selenide_solar_cells

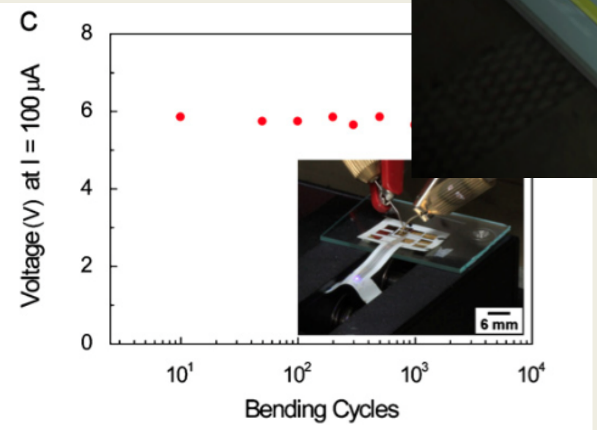
Main features

- Conversion efficiency max: 20.8%
- Manufacturing process: Involves high temperatures and vacuum
- Lifespan: +10 years
- Cost: Medium
- H_2O & O_2 Stability: Good
- Material abundance: Indium quite scarce (production linked to the one of zinc => Bottleneck)
- Weight: Medium

FE: Chosen samples (2)

GaN blue led for medical applications





From [1]

Main features

- Efficiency: Very High
- H_2O stability: Very Good
- Colour: Bright blue
- Mechanical tenue: Very High
- Biocompatibility: Very Good
- Lifespan: Very Long
- Cost: High
- Flexibility: Very Low (test up to 0.62% strain)
- Materials abundance: Medium

Note 1) OLED weak points are Lifespan and H_2O stability.
Biocompatibility is in general very good!

FE: Acceptable features

Chemical stability (H_2O, O_2)	High
Lifespan	From short to very long
Biocompatibility	High or irrelevant
“Flexibility”	High (through High performance material (low thickness) OR low E modulus)
Price	Very Low to Very High

Organic electronics

Definition and history

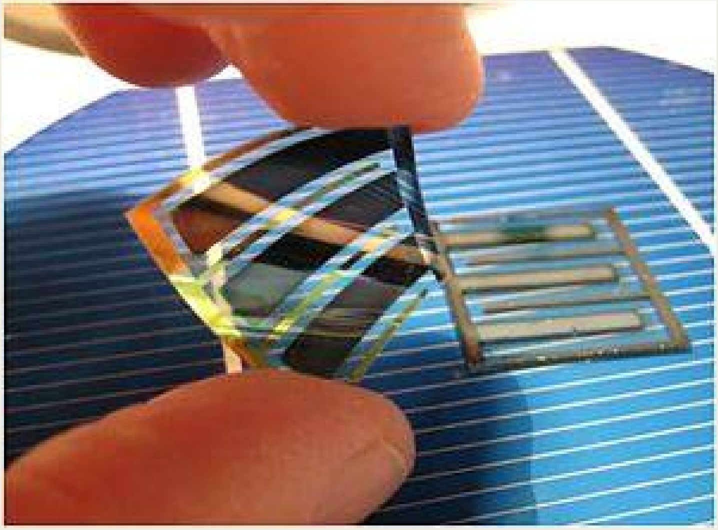
Organic electronics is a field of material science concerning the design, synthesis, characterization, and application of organic small molecules or polymers that show desirable electronic properties such as conductivity. (*from ref [4]*).

The very first observed organic conducting material was observed as soon as 1862, when Henry Letheby isolated *polyaniline* and measured its conductivity.

The very beginning of widespread research however occured in 1977 when Heeger, MacDiarmid and Shirakawa showed the conductivity in polyacetylene partially oxydized with halogens [5].

OE: Chosen samples (1)

Bulk heterojunction organic solar cell

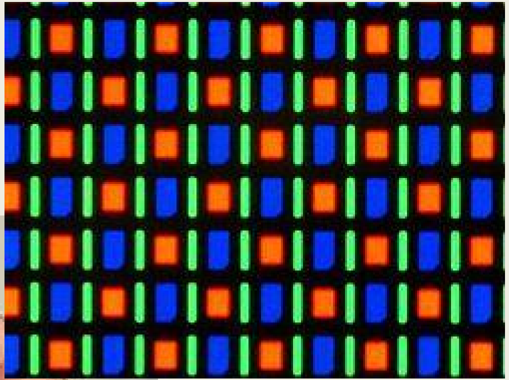


Main features

- Price: Potentially very low
- Material abundance: Very High
- Conversion efficiency max: 5%[7]
- Lifespan: mostly below 1 year with adequate encapsulation [6]
- Chemical stability: Low to Very Low
- Weight: Very Low

OE: Chosen samples (2)

AMOLED for smartphone display



Source: http://en.wikipedia.org/wiki/AMOLED

Main features

- Price: Potentially very low
- Material abundance: Very High
- Lifespan: Up to 50.000h in industrial production with adequate encapsulation [8]
- Chemical stability: Low to Very Low
- Weight: Very Low

OE: Desirable features

Price	Potentially very low
Material abundance	Very High
Lifespan	From very low (1h) up to very large (50.000 h)
Chemical stability	Low
Funcional performance	From very good (OLED) to poor (OPV)
Weight	Very Low

Summary of chosen features

	Clock frequency	Potential marginal cost	Lifespan	Material abundance	Weight	Overall performance	Mechanical stability
Wearable electronics (required)	Low to Very High	Low to Very High	Low to Very High	n.a.	Low	Low to Very High	High
Flexible electronics (applicable)	Low to Very High	Low to Very High	Low to Very High	Low to Very High	Low	Low to High	Medium
Organic electronics (Provided)	Very Low	Very Low	Low to Very High	Very High	Low	Low to Very High	Medium to High

Ready to use, washable, stretchable, conductive ink for the textile industry (22/09/2014)

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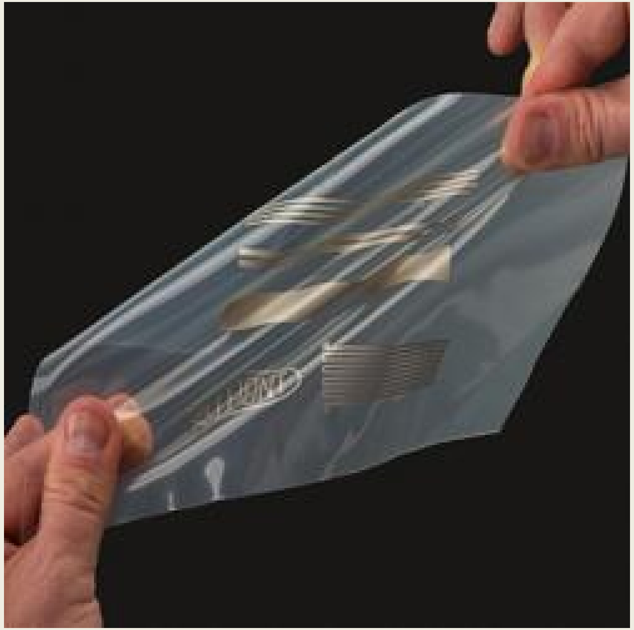

Source: http://www.plusplasticelectronics.com/smartfabricstextiles/dupont-launches-stretchable-conductive-inks-to-target-smart-garment-market-124624.aspx

Features

- Stretchable at least 100%
- Conductive
- Washable resistant (100 cycles)
- Chemically stable over time

Ready to use, washable, stretchable, conductive ink for the textile industry (22/09/2014)

Technical implementation

No patent filed for the producer of the ink (*DuPont Microcircuit Materials*) **BUT**

Patent presenting very similar features filed by *Xerox Corporation, Norwalk (US)* [10]. Might have been licensed or adquired later…

Latex particles of fluoropolymer (Tecnoflon TN for example) *uncured* filled with organic conductor such as carbon black.

The high contact angle between water and the fluoropolymer enhance greatly the water tenure as well as overall heat and chemical stability.

It is not mentioned in the patent that any curing agent (such as amines) has been added to the blend prior to application to the textiles. It would however make sense as virtually all other commercial versions of the Tecnoflon actually containt some kind of initiators [11].

To date only conductive inks are availaible in the field of stretchable electronics

OLED display for smart packaging

	Clock frequency	Potential marginal cost	Lifespan	Material abundance	Weight	Overall performance	Mechanical stability
Wearable electronics (required)	Low to Very High	Low to Very High	Low to Very High	n.a.	Low	Low to Very High	High
Flexible electronics (applicable)	Low to Very High	Low to Very High	Low to Very High	Low to Very High	Low	Low to High	Medium
Organic electronics (Provided)	Very Low	Very Low	Low to Very High	Very High	Low	Low to Very High	Medium to High

OLED display for smart packaging

Source: http://www.oled-info.com/sti-group-shows-worlds-first-package-organic-solar-cell-and-oled 2010

Features

- First of its kind *active packaging* by STI
- Low autonomy
- Low efficiency
- At this stage, still very costly
- Do not bring added information
- Standard green OLED

OFET based disposable sensor for hazardeous vapors

	Clock frequency	Potential marginal cost	Lifespan	Material abundance	Weight	Overall performance	Mechanical stability
Wearable electronics (required)	Low to Very High	Low to Very High	Low to Very High	n.a.	Low	Low to Very High	High
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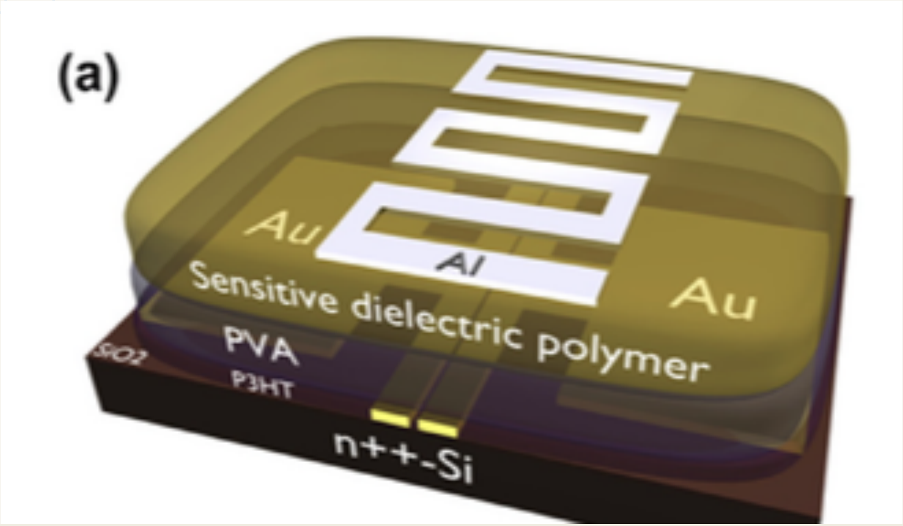
OFET based disposable sensor for hazardeous vapors



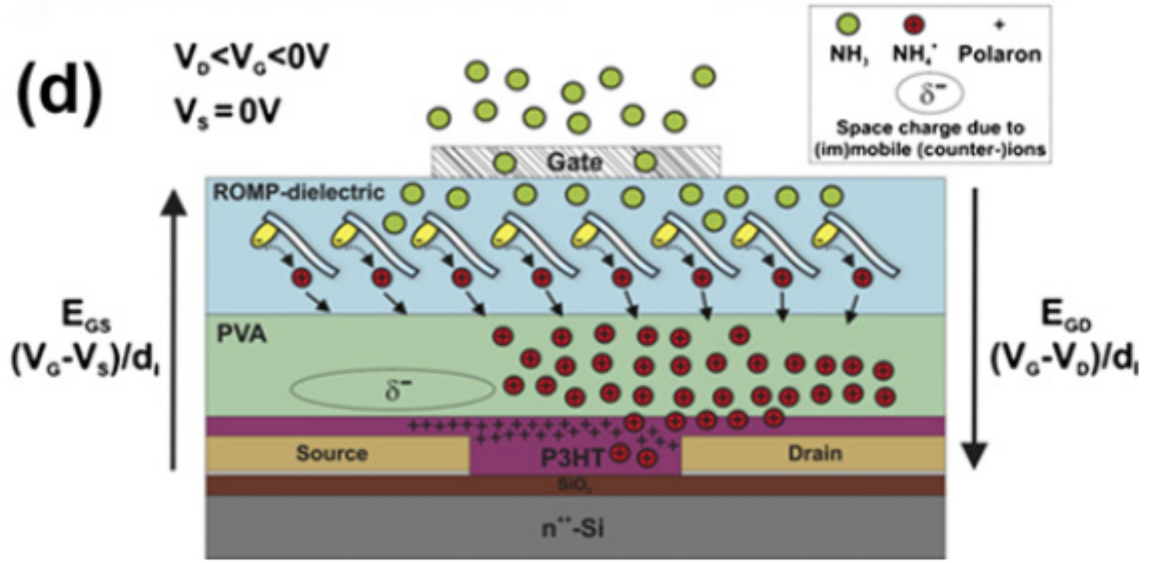
From [2]

Features

- I_{on}/I_{off} = 10^3-10^3
- Operating frequency 1 kHz
- Detection Threshold: 1ppm
- Operating $V_{S\text{-}D}$ = 15V
- Induced E field = ~10^5V/cm
- Disposable

OFET based disposable sensor for hazardeous vapors

Technical implementation



From [2]

- Configuration: Top gate staggerd thin film transistor [9]
- Functionalized dielectric (ROMP) allow generation of ions upon NH_3 exposition
- PVA buffer layer (intermixing+encapsulation)
- Ions brought near the SC reduce the operating voltage (through double layer enhanced capacitance and redox processes)

Proper choice of the dielectric make the system very versatile!

Summary of features

What if..?

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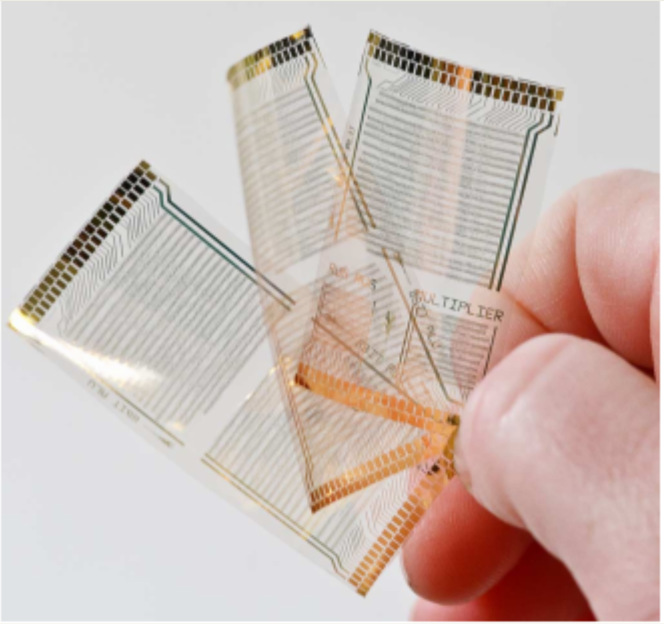
Organic electronics (Provided)	~~Very Low~~ High	Very Low	Low to Very High	Very High	Low	Low to Very High	Medium to High

What if...Higher mobility materials was available

Low cost printed processor



Both from [3]

Features

	Plastic microprocessor	Intel 4004
Transistor-count	3381	2300
Area	1.96 x 1.72 cm^2	3 x 4 mm^2
Pin-count	30	16
Power supply voltage	10 V	15 V
Power consumption	92 μW	1 W
Operation speed	40 operations/second	92000 operations/second
Semiconductor	Pentacene	Silicon
P-type mobility	~0.15 cm^2/Vs	~450 cm^2/Vs
Logic family	P-type	P-type
Operation	accumulation	inversion
Technology	5 μm	10 μm
Bus width	8 bit	4 bit
Production year	2011	1971
Wafer scale	6″	2″
Substrate	flexible	rigid

What if...Higher mobility materials was available

Technological barrier

Clock frequency is a function of the **gate delay** wich describes the *speed* to wich a signal is allowed to cross an electronic device.

Such *speed* is itself proportional to the mobility of the carriers in the material in use.
Pentacene mobility for organic crystals is close to the state of art of achievable mobilities...

	Plastic microprocessor	Intel 4004
Transistor-count	3381	2300
Area	1.96 x 1.72 cm^2	3 x 4 mm^2
Pin-count	30	16
Power supply voltage	10 V	15 V
Power consumption	92 μW	1 W
Operation speed	40 operations/second	92000 operations/second
Semiconductor	Pentacene	Silicon
P-type mobility	~0.15 cm^2/Vs	~450 cm^2/Vs
Logic family	P-type	P-type
Operation	accumulation	inversion
Technology	5 μm	10 μm
Bus width	8 bit	4 bit
Production year	2011	1971
Wafer scale	6"	2"
Substrate	flexible	rigid

As the transistors' numbers are in the same order of magnitude...

We might expect
40/0.15~92000/450
or
266.6a.u. ~ 204.4 a. u.

Summary of features

What if..?

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Organic electronics (Provided)	Very Low	Very Low	~~Low to~~ Very High Only	Very High	Low	Low to Very High	Medium to High

What if...Longer lifespan organic devices were available

OLED and OPV could reach truly low cost mass production

Source: http://www.techfever.net/iphone/?cat=10908&paged=2

Features

- High quality lightning
- High cost
- Low lifespan
- Relatively lightweight
- Helps the OLED industry to grow

What if...Longer lifespan organic materials was available

Technological barrier

- Encapsulation techniques to prevent H_2O, O_2 infiltrations
- Growth of non radiative recombination center during use
- Radical creation and disproportionation of the active components of the blend

Conclusion

What we will remember…

- Some fields present natural shared features
  - A systematic screening can help spot particular technological applications
- Every technological advance in a particular field can potentially unlock new applications for that field in another one *a priori* unrelated
- ...

Q&A

Thank YOU for

YOUR ATTENTION!

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