WELCOME TO THE NANOWORLD
EPISODE 2
... NANOS, NANOS, EVERYWHERE
ENGLISH SCRIPT

TC IN
10 00 00
<u>OPENING TITLES - NANOWORLD</u>

LA COMPAGNIE DES TAXI BROUSSE
PRESENTS

WITH THE PARTICIPATION OF
FRANCE TELEVISIONS

IN PARTNERSHIP WITH
EUROVISION SCIENCE AND THE EUROPEAN COMMISSION, DG RESEARCH

A FILM BY
CHARLES-ANTOINE DE ROUVRE
JEROME SCEMLA

PRODUCED BY
LAURENT MINI
KARIM SAMAI

10 :00 : 00
COMM
All around us, around you, and me… the worlds of media, science and economy are resounding with the prefix « nano ». All I hear is references to this invisible scale, a billionth of a metre, just a few atoms wide…

The frenzy is global. Thanks to nanos, science and technology foresee a fascinating new world, infinite new research fields, and miraculous new possibilities.

From materials to energy, the environment to medicine, via electronics and agriculture… nanos should make everything more efficient, more resistant, cheaper and less polluting…

Nothing in our world will be free from nanos… a prospect which sometimes appears quite alarming…

Welcome to the Nanoworld.. to the Nanoworlds…

10:01:07:00
TITLE :

WELCOME TO THE NANOWORLD
... NANOS, NANOS, EVERYWHERE ...

30
01:07
COMM
Welcome to our journey of discovery, exploring the materials and technologies at the heart of our daily lives.

01:15
VLADIMIR BULOVIC
PROFESSOR OF COMMUNICATIONS AND TECHNOLOGY
MIT
I'm an electrical engineer I like physics, we have absolutely no idea why things work on the Nano scale, this is the field to be in, this is the field in which I can hopefully learn a great deal and from there expand the knowledge into other understandings

01:34
COMM
The end of the 20th century saw computers revolutionising work, leisure and industry.
The 21st century begins with an understanding of the nanometric mechanisms at the very core of matter, and the possibilities of manipulating them on an atomic scale.
The new nano-sciences and technologies upset the existing order and enable us to envisage materials with completely new properties, and the manufacture of objects that are ever smaller, more efficient and more ecological.

02 03
A brief reminder… The prefix 'nano' signifies a scale of ten to the minus nine metres – a billionth of a metre. And thus everything else is on the same scale. A few main principles give nano-sciences and technologies their particular characteristics.
First of all, working with matter on a nano scale rather than a macro scale, (our « normal » world) means working directly on the very components of matter, and no longer on a mass that's already been composed. Since the end of the 20th century, scientists in every discipline – physics, chemistry, biology - have been using their shared knowledge to manipulate atoms individually and to assemble them like simple building-blocks.
You no longer need a tree to make a tooth-pick. In theory, one can assemble the atoms making up the tooth-pick to reach the same result.
Acting directly on the constituents of matter also enables different properties to be exploited. Because the size is different, the materials react differently… In this way, on a macro scale, gold is a conductor ; on a nano scale ; it's an insulator.

03:14
COMM
Other characteristics and properties are also revealed on the nano scale, such as the effects of quantum physics.
Our reality, defined by classic physics, is no longer valid in the nano-world.
For example, if I take a ball, and throw it against a wall, it will bounce off it. But if I am very small, and the ball is of nano-metric size, when it hits the wall, it will bounce, but it will also pass through it… it will be here, there and nowhere.
If you're a little lost, don't worry… so am I. And the leading scientists are still wondering…

03:56
COMM
A quick glance via a search engine will provide 18 million hits concerning nano subjects. And the presence of nano sciences and technologies around us is already evident in the most unexpected fields.

SYNTHE :
FLORENCE
04:10
COMM
In Italy, for starters, I visit Professor Baglioni, a Renaissance enthusiast.
He is working on saving the beauty of the past using techniques with a bright future.
In his lab, he has devised a nano-technological solution which ushers in phenomenal progress in the restoration of artworks ravaged by time.

04:28
PIERO BAGLIONI
CHEMIST
UNIVERSTY OF FLORENCE
Why you clean so..if you clean. These people, I say that the French TV is coming and they clean completely the lab, this is not a good impression, I mean. It's totally clean, terrible (RIRES) unbelievable.
So here, in this lab, they reproduce mainly nanoparticles for conservation or for other purposes.
So we produce these particles that are calcium hydroxide particles. Calcium hydroxide are exactly the same chemical composition used by the artist.

04 :53
So we produce these particles that have calcium hydroxide particles, calcium hydroxide are exactly the same eh chemical composition used by the artist

If you want to drink, it's OK, it's not toxic…. If you want to try, maybe you need to visit the restroom after but it's not toxic at all

05:35
COMM
It is in the impressive Pitti Palace, in the heart of Florence, that he shows me how his nano-particles are used. The demonstration concerns the salvage of some recently discovered 17th century frescoes.

05:49
PIERO BAGLIONI
This was the first room that we started restoring after the discovery of these apartments. The ceiling is a fresco painting and when we discovered this, it was in very poor condition. There was a contamination by solphate, lots of nitrate because we are below the garden so there was a water infiltration. So we show just one part of the process and maybe I can show you here some part. This part is very delicate, paintings, these particles are in organic solvant, isoprophanol and basically, we need some paper, just to avoid direct contact with the part we want to treat so we don't remove the pigments. I will treat just a small area so..correct treatment now is to add as much as particle as you can and, when the wall does'nt accept it anymore it means it is saturated with particles, you don't need to

do anything else. And just to finish, we cover this with cellulose and let dry. With these nanoparticles of calcium hydroxide, basically, we replace what has been lost during there. We don't change any chemical physical properties, we bring back the painting to the original state.
07:50
COMM
The nano-particles developed by Baglioni have the same chemical composition as the materials used by Renaissance painters. By penetrating the very heart of the fresco, these nano-particles stimulate a chemical recombination of matter. The atoms and molecules present in the solution replace those lost over time.
Contrary to the processes used previously, the pigments and the support are neither modified nor deteriorated.

08:15
JOURNALIST
And how long does it last ?

08:18
PIERO BAGLIONI
Oh, it depends, if it doesn't rain in this place, 400, 500. if there is no smoke, for ever.

08:29
When you scale down and you have this em small particle, this at the fundamental constituent in certain sense, of the what we call supra molecular structure of nature so these are the brick of nature and the same particle can be used for different purposes.
Now we have a certain number of methodology that can be apply for fisco paintings, for oil paintings, to preserve painting and codex

09 :04
COMM
Progress linked to nano-technologies is not limited to the restoration of ancient artworks, however…
From museums to supermarkets… lab tests lead to practical applications. Several hundred consumer products are already available, from tennis rackets to window coatings, via socks, shirts and ties with original qualities…
For beyond the scientific and technological issues, what's at stake is above all commercial, and the textile industry has been quick to understand the benefits it can reap from the progress already made.
By modifying the surface of fibres, on a nano-metric scale, scientists have succeeded in creating some astonishing properties.
I, myself, can appreciate them, as a guinea pig, on a Pacific beach…

SYNTHE :
SAN FRANCISCO

10:31
COMM
My hair, face and skin are soaked and salty. But the water has merely slid off the material, without penetrating the fibres.
To understand the scientific explanation for this phenomenon, I go to see an expert in the field, on America's west coast.

10:50
WILLIAM STOCKTON
CHEMIST
NATIONAL TEXTILE CENTER
we’re adding things but at such a small scale at the Nano scale
It’s enabled us to make fabrics that have performance features, that existed in the past, but never without changing the natural feel or breathability of fabric.

11:07
JOURNALIST
Today, cotton is still cotton

11:07
WILLIAM STOCKTON
cotton is still cotton, silk is still silk, wool is still wool. But it has a performance feature that you might not expect
Performance is changed because of this Nano scale treatment

11:21
COMM
It doesn’t look like much, but the ability to add these qualities on a nano-metric scale has fundamental consequences. With these textiles, there’s no need to wash them as often. And so there’s less waste, less water, less detergent, less pollution. Ultimately, we save time, a fair amount of money, and above all, energy.

11:41
WILLIAM STOCKTON
A lot of Nanotechnology claims that you are imitating nature and a good example on our case is Peach fuzz. The Peach fuzz is you can think of little whiskers on the surface of a peach that makes it somewhat hydrophobic

12:13
COMM
As they slide and fall, the water droplets conserve their spherical shape, rejected by the super-hydrophobic surface.
This nanoscopic phenomenon is also called the lotus effect. The leaves of the lotus are always dry and clean. The water slides off, removing any particles of dust that are present. The leaves are self-cleaning.
On the nano scale, the lotus leaf has a very particular structure. It has a multitude of protrusions, covered with tiny hairs, on which the water droplets cannot find purchase, or spread out.

But the scientists are going even further. After the hydrophobic and self-cleaning effects, applied to windows, in imitation of the lotus leaf, they are able to manipulate the surface of various materials to create coatings with new properties… fire resistant, anti-bacterial, or, one day soon, the ability to change colour.
Of course, the military is by no means the last to invest in research into these new capacities. Imagine a super-light synthetic material, inspired by a spider’s web, both solid

but flexible, which could resist bullets…
Imagine uniforms, covered in sensors able to detect chemical and bacteriological products on a molecular scale.

All this is coming soon, if we believe Alain de Neve, who welcomes me to the Royal Naval Academy in Belgium.

SYNTHE :
BRUSSELS

13:35
ALAIN DE NEVE
ANALYST
ROYAL HIGHT INSTITUTE FOR DEFENSE
The basic idea, in the textile field, and notably in a military context, is to create intelligent materials. Which means textiles that can react in some way. Textiles which could acclimatise themselves to the terrain where combatants are in action, and which may itself change. In such a case, we could see a new generation of camouflage systems which would guarantee a maximum of unobtrusiveness for combatants.
We can also imagine concealing somewhere within these textiles a certain number of nano-agents which would help reduce a combatant's inhibition on the ground.

And then there's the possibility of creating what we call invasive systems.
We shall use nano-technologies to create materials which enable much more thorough monitoring to be done, for example, agents on a nano-metric scale which will be distributed in a combatant's body to provide real-time monitoring, concerning the combatant's aptitudes, his degree of fatigue, his stress levels, and, for example, to decide which unit is best suited to carry out a particular mission… and all this is done in real time.

15:08
COMM
And why not clothing that can provide food or medical care… ? The food industry and pharmaceutical laboratories are studying such potential markets very closely. For myself, such prospects are both a dream, and something of a nightmare…

15:20
ALAIN DE NEVE
Let's say that the applications in a military context will essentially concern, to begin with perhaps, the resistance of such materials. We'll no doubt produce materials that are more effective, and much more resistant. Their life span will be markedly increased.
This is what the first types of applications involve. I would say the resistance aspect… the creation of nano-structured materials.

15:47
COMM
Creation is the next step. It's no longer merely a case of coating the surface of a material with a layer of nano-particles, but actually modifying its internal structure, or even creating completely new composite materials with exceptional qualities.
But what qualities exactly ? And why ?

16:06
On the East coast of the United States, I have an appointment at MIT, the Massachusetts Institute of Technology, the place with the highest concentration of Nobel Prize winners in the world.

10:16:21:00

SYNTHE :

BOSTON

10:16:30:00

COMM

Krystyn Van Vliet runs a lab specialising in material sciences. Her greatest pleasure comes from pushing materials to breaking point, in order to find out how to improve them.

10:16:38:00

IN

Hello, I'm Charles
Krystin...

16:45

KRYSTYN VAN VLIET
PROFESSEUR EN SCIENCE DES MATÉRIAUX
MIT

There's two main reasons why people bother to spend so much time studying materials at the Nano scale one is that you could see emergent properties, very new properties that don't exist in the micro scale at all.
And the other reason why people study materials at the Nano scale is that's the very fundamental limit of atoms and molecules.

Every object in the world, is made of something, so you know if I look at a camera, or I look at a watch I'm immediately drawn to what are the materials made out of, is that is that an alloy or is that a pure metal, is it resistant to corrosion, is it going to be hard, how much energy is it gonna take to process your watch plate compared to my watch plate, those things just become natural ways of looking at objects, breaking them down into what materials are they made out of, how can I process them to be better, cheaper, less energy consumption.
It's fine to be able to understand how steel in a bridge deforms at the macro scale, but if you want to make that steel ten times stronger and ten times more resistant to corrosion, you need to understand how the atoms are moving around at the Nano scale.

18:00

COM

Scientists know the properties of materials. They have the technological ability to manipulate them. They can now imagine creating new composite materials in the laboratory by combining the advantages of different materials, molecule by molecule, atom by atom…
For example, the more a material is composed of small, concentrated grains of matter, the harder it will be. The more the grains can change their shape, the more flexible the material will be. One can imagine combining the advantages of metal and plastic in a new material, a nano composite, flexible and hard…

18:38
KRYSTYN VAN VLIET
Cars are a nice example of how all different classes of materials have been used to make something useful we've hit polymers, ceramics, glasses, metals; developing all of these is completely driven by Nano scale research right now and it would make the car safer and better for the the environment
So in a car you have metal the chief thing that keeps you from being hurt in a car accident is the ability of that metal structure to resist impact.
So, Nano structured materials ah Nano structured metals have been developed as one way to do that.
so you need to make something that has low density, so it's a lightweight material, so it doesn't require as much fuel and yet also very resistant to mechanical defamation; very strong and also quite stiff.
In principle, that technology already exists but can we scale it up to the level of making a car? Um glass, a lot of the ways that glass is processed already make it very strong.

19:53
KRYSTYN VAN VLIET
I may never be allowed to do that again ! Thank you very much !

19:59
KRYSTYN VAN VLIET
People are working now on glass that could do more than just allow you to see through it, it could have Nano particles in it, there are able to break down some of the noxious gases in the atmosphere, for example produced by the car exhaust itself, so that the glass can serve an environmental role besides just a role for viewing

20:33
KRYSTYN VAN VLIET
The good thing is that cars are such huge volume items as you see here, is we'll be making enough of that
so people will be able to make a profit, and that's one of the things that helps drive research, there's clearly a market for improvements in cars.

20:54
COM
The conception of more efficient cars entails different ways of consuming energy and the use of alternative propulsion methods.
This story also concerns fuel cells, or batteries, which produce electricity from hydrogen and oxygen.
To do this, they require a catalyst : platinum. By taking advantage of the increased surface-volume ratio on the nano scale than on the macro scale, nanotechnology enables previous production limits to be substantially extended.

SYNTHE :
GRENOBLE

21:21
COM
In France, Nicolas Bardi's department at the Technology and Energy Innovation Laboratory is working on this very question.
21:32
NICOLAS BARDI
ENGINEER
HEAD OF PEM FUEL CELL COMPONENTS LABORATORY
CEA
It's not the arrival of nano-technologies which has brought about the invention of fuel cells. We're still using a principle invented by an Englishman who soaked plates in acid in 1800 and something.
But it's the capacity to manipulate, and quite simply see, nano-objects, which enables us to do more efficiently and with less matter what we did before at a much higher cost.

In a car, you need several dozen kilowatts of electrical power, so that means several dozen grammes of platinum. The market price of platinum is something in the range of 30 euros a gramme. So, at 30 euros a gramme, if you need, for example, 100 kilo-watts, you'll need 3,000 euros worth of platinum in your car.
So we can see it's not viable…

And ultimately, what's active is not the core of the platinum, but just the surface. So we'll take a surface of carbon, which is not expensive, and then we'll add some small grains of platinum, and it's the surface of these small grains of platinum that is active… so we can attain the same performance levels with a much smaller quantity of platinum.
Our research objective, therefore, and that's what we're working on today, is to reduce by a factor of ten the quantity of platinum.

22:54
This is an electron microscope image, of what it looks like when it's applied. You can see all the white points, they're the grains of the catalyst. And the slightly bigger circles are grains of carbon. And you have the scale here… that's 100 nanometres.

23:26
COMM
The introduction of increasingly effective tools for studying these complex chemical reactions and the behaviour of matter on nano scale has brought about enormous progress.
But the more scientists move forward, the more their research requires powerful, rapid machines, capable of astoundingly delicate simulations. Their limits today are perhaps right there : in the potential for calculations and data storage.

23:48
KRYSTYN VAN VLIET
PROFESSEUR EN SCIENCE DES MATÉRIAUX
MIT
You're trying to study a process of a material, that's going on in seconds or less than five minutes, you've missed it, right, so how fast we can apply these images em is one of the rate limiting steps of what we do and what we study right now, and that's somewhat due to the hardware we're using, it's somewhat
due to how fast you can store a lot of information on a chip, right now, so things more to do with electronics. So that speed of information is one of the limiting ah features of our kind of work.

24:30
COMM
And yet… Ever quicker, ever smaller, ever more powerful… These were the objectives of computer science even when the first transistors filled entire rooms.
The computer revolution was the result of the miniaturisation of these transistors, the basic component of electronics, as they enable a signal's amplification to be controlled. Miniaturisation has made computers increasingly accessible to all, and ultimately, indispensable.

25:09
COMM
Today, the microprocessor, or chip, the tiny square of silicon, barely a centimetre wide, is at the heart of all our machines. Thanks to the millions of transistors it contains, it can perform several million operations per second. And the more transistors there are on a chip, the greater its capacity for calculations.
Today's microprocessors contain 500 million transistors, but this is nothing to what lies in store. According to the theory of Gordon Moore, one of the founders of Intel, the size of chips will be halved every 18 months, while their power will be doubled.

25:25
COMM
In practice, however, this theory comes up against a brick wall. Manufacturing potential has reached its limits : the potential of silicon. Scientists will soon no longer be able to cram in any additional transistors.
Ever keen to pursue its progression, the industry is therefore counting on nano-technology to find a solution.

SYNTHE :
GRENOBLE

25:44
COMM
Still in France, Jean Christophe Gabriel is seeking innovative responses to these questions.

25:52
JEAN-CHRISTOPHE P. GABRIEL
PROGRAM LINE MANAGER « BEYOND CMOS »
LETI
Scientists have never before found themselves in a situation where there are so many red lights in such a short time-frame. We've been working on silicon-based electronics for fifty years, but we're reaching the limits of silicon. The chip you have in your computer, which is about one centimetre square, contains around five hundred thousand transistors, and in a year or two, we'll be at more than a billion. At the present time, it's really hard to reduce the size, so what people are doing now, is piling them up, they're making several levels, what we call three dimensions.

They are structures where you have wires, one on top of the other, one, two, three wires. Each wire is, in fact, a transistor, so now we have a transistor structure with dimensions.

You can say that this will increase the density, but not on a flat level – in three dimensions. We have to realise that structures like these, we can make them with wires that are about ten nanometres thick. We foresee, therefore, that we'll have structures of this type around 2020-2025.

27:11

We're now using wires that are so small that the insulation we put around them is only a few atoms thick. What does this mean ? It means that we have electrical leaks. And these small electrical leaks, when you have a billion little wires like this, or billions of little wires, they cause heat. I don't know if you've noticed, but your laptop, when it's on your knees, it's almost burning hot. There are some people who think that in order to avoid the heat problems, we'll replace electrons, we won't use electronics any more, but something else, and that could be what we call spin… spin is the fact that when an electron turns, basically, as there's a charge, it creates a small amount of magnetism, which we call spin. Spin can generally be directed up or down, like the earth's magnetic field, so we could say that up and down equals zero and one, if I can measure it. So here we have much less energy being deployed, and we'd have much fewer problems with heat.

28:07

COMM

Electron spin, nano-wires and nano-tubes used as transistors, quantum computers… Whatever possibilities are envisaged, each new solution for continuing to develop computer performance is now the result of nano-science and technology.

SYNTHE :

PASADENA

28:29

COMM

In California, Jim Heath is also tackling this problem. Along with his team at Caltech, he has succeeded in making transistors with molecules… molecular transistors… and in assembling them to form a « chip » barely the size of a white blood cell, but which can store an equivalent amount of information as the entire university's fund of knowledge.

28:49

JAMES HEALTH
CHEMIST
CALTECH

Nanotechnology implied a bottom up fabrication, just like your body, you start off with just two cells, one from mum one from dad, and out comes you. Nanotechnology represented that kind of manufacturing And so we tried to make a computational platform that sort of did all the stuff that a normal computer does, but um was a symbol together at a scale that was more molecular in nature than it was the way that we would make a computer chip now, much much smaller.

29:25

JOURNALIST

Do you mean you were using molecules instead of silicone

JAMES HEATH

Well we use in fact I had some silicon components but the silicon components were wires that are about as the diameter is about as wide as a molecule,

they're spaced, by the spacing's about as wide as a molecule, a good sized molecule but a molecule, and then the switches were actually molecules
and so using these kind of molecular switches , coupled with these really small wires and this grid like network, uh we made a memory circuit
it was a hundred and sixty thousand bits, so, big, you know it was big enough to store like a small book on it but it's no bigger, it's actually smaller than a white blood cell.

30:08
JAMES HEATH
More than is that we developed this manufaction approach, that lets us really make things with sort of electronic precision at molecular scale
so if you ask who would a company like Intel if they kept in their path to make it, they would make that chip in about twenty twenty or twenty twenty one, we demonstrated that we could keep going to almost twenty thirty, we could actually make them a fracture of ten smaller than what what we did

30:36
COMM
But Jim Heath's research doesn't stop there… his aim is to give his electronic components the same complexity and robustness as a living being…

10:30:50:00
IN
Okay
So you wanted to give us...

31:02
JAMES HEATH
Well it's an idea, and it's a very general idea and it's one that nature uses it's to build redundancy into the system. If we take it currently as example take an Intel Pentium chip and you you know stick a screw driver on a part of it and break part of it, the whole thing's gonna fry, it's no good, on the other hand if you um, take a human body and you you know pluck out a bit of skin from the finger, you're gonna continue, you may say ouch but you're gonna continue working just fine, because you have a bunch of redundant systems, it doesn't you're not hing hinging you're you're success as a person doesn't hinge upon every single aspect of the body working.
And so, something that we wanted to do was to take advantage of the architecture that's similar to the street roads of Los Angeles. And it turns out that Los Angeles is sort of unique in that the streets are, in a rather non imaginative way, they're laid out like this, just a cross, cross hedge grid. And so if I wanna go from you know the inner section of this finger and that finger to somewhere else on the finger I have lots of different pathways I can do it, and the idea that we had was that; if the wires and the switches were cheap enough, if you could make enough of them, then even if you had some broken wires, and broken switches you could find alternative routes for getting from one point to the other, alternative ways to do the computation or destroy the information, and uh and that's something Nanotech can give us is cheap parts coz you may make somethings highly engineered you may be able to make a whole bunch of it, but some of them might be defective and not work, you had the ability to have it be robust even in the in the presence of defective components.

32:48

COMM
As I leave Jim Heath and California, I'm less worried about the electronics industry. Our computers still have fairly healthy future prospects.
Wanting to imitate nature is all well and good…Using the architectural models around us, is perhaps even better…
I return to the East coast, to see once again what we're already capable of doing, electronically, on a nanoscopic scale.

SYNTHE :
BOSTON

10:33:19:00
IN
So that's the place, the miracle of science ?... »
Yes, it's supposed to be nice... »

33:24
JOURNALIST
So that's the place, the miracle of science ?... »

33 38
VLADIMIR BULOVIC
PROFESSOR OF COMMUNICATIONS AND TECHNOLOGY
MIT
Yes, it's supposed to be nice...

33:30
COMM
Vladimir Bulovic, a professor at MIT, has a good example to satisfy my appetite for knowledge…

33:38
VLADIMIR BULOVIC
For the first time we are able to go ahead and start from the macroscopic scale all the way down to Nano and have a coherent picture why things happen, and once we have that really worked out we'll be able to make things that we have never thought of before.
If I wanted to make let's say a TV that's the size of this table I need to be able to put a few molecular layers over the entire area in a precision that

34:14
COMM
An LED screen (light emitting diodes) is made up of three layers. The first, in the middle, is a layer of material that produces light when it is stimulated, for example, by electricity. Above and below are two other layers which constantly maintain the stimulation. They are connected to the energy source through another two layers which provide the electrical contact.

34:40
VLADIMIR BULOVIC
Now the thing though that changes when you start talking about Nano scale is what is the functional operating unit, you know what works in this device?
Well it's the middle layer of molecules that's doing the work, the middle layer of

maybe five to ten molecules when I see an LED that's the only part that's glowing and what's mind boggling about it, I mean that whole middle layer, um is on the order of ten Nano metres, now how big is that? Now you're hair, the thickness of your hair might be fifteen microns, so ten Nanometres is one five thousandth of your hair thickness, that's the only part of your device that works.
And you need to put it down over this large areas with a precision that will allow you to have uniform TV display.

35:28
VLADIMIR BULOVIC
The colorant in side this particular pickle is also a molecule and it turns out these particular molecules just like any other molecules you can think of them as semi conductors they have an excited state and a ground state if I can come up with a way to excite this pickle, molecules inside this pickle maybe I can come up with a way for those excited states to relax and give me light. It turns out if you apply enough excitation you can excite nearly everything through luminous.
So if I excite you high enough with lights with electricity you will start glowing ha ha ha.

36:12
COMM
Creating light with a pickle... it's hard to believe. Using organic molecules to make a screen ? An OLED, with an « O » for organic ? What's the point ? It would be more efficient, thinner, and consume less electricity. Here's a demonstration…

36:25
VLADIMIR BULOVIC
This is uh what we're gonna light up, all we now need to do is appy a hundred and ten volts of alternating currents accross this pickle LED and see if we can light up.
so here we go... let's turn the switch on... look at that...
You're seeing light emission yellow light emission at times which is the excitation of organic molecules inside the pickle.
Now if you would like a different colour for your TV display, um ha ha you need to use different molecules. There are many many many molecules inside there, um for every cubic centimetre there are ten to twenty one molecules and each one can glow over a million times, billion times sometimes, that gives you a lot of lifetime.
Now in this particular display, LED we need to apply a hundred and ten volts, because the LED itself is very very big, in order to make a five volt LED what I need to do is take the pickle and slice it really really thin and put electrodes in top and the bottom and now I can generate the same kind of electric fields I have inside here except in much much smaller structure roughly speaking, ha.

37:46
COMM
These screens, based on organic molecules just a few nanometres across, are quite impressive. Detailed images, bright colours, and just a few millimetres thick… The research scientists are promising whole walls of images for the very near future…

38:00
VLADIMIR BULOVIC
The brilliance of Nanotechnology really is that we change the paradigm of the way we build structures and organic LED displays are now becoming a reality.

If you go ahead and look at the image that you can generate the thinness of the display, you can make it in a flexible display one that you can roll up, you can come up with ways of making a transparent display a display that looks just like a piece of glass until you turn it on.

Imagine one day I would like to coat my entire whiteboards for example with this, so I don't have to have a little TV display but a huge TV display and I need to do it with a precision of a few molecular layers, well how do I do that, how do I make a bigger TV than this one and make it not cost very much, printing we think might be a way of doing that.
And it could be that you get a flexible sheet of fabric or plastic that's coated with uh organics and then you go ahead and cut it to size that you want and you go ahead and use a staple and mount it onto the wall, that's your TV from then on. One day...

39:03
COMM
The Holy Grail that OLEDs promise, is the flexible screen. And it already works in the lab. But for large-scale manufacturing, there's just one problem…air must not come into contact with the layers. It damages them. A surface material has to be found, with the same qualities as glass, but as supple as plastic.

39:23
COMM
And what's next ? Why not imagine any and every type of screen, even one we could paint on a wall. Anything is possible, because OLEDs also enable another problem to be side-stepped ; that of energy.
One percent of American energy today is guzzled by TV screens, and another one percent by computer screens… That makes two per cent. And this will only get worse. We can't go on in this way…

39:57
COMM
The best way, perhaps, would be to find a solution, a durable solution to the energy problems we face in the 21st century.
Nanotechnologies have a future role to play in these technical questions… issues with a broad social relevance.

40:22
JAMES HEALTH
CHEMIST
CALTECH
Nanotechnology will step in and make technologies for converting energy from one form the other much better, for storing energy they'll make that much better, for harvesting energy, sunlight which is the ultimate solution, ah it's gonna make that much better and maybe that the Nanotechnology solution's gonna be fundamentally enabling it's gonna be the key component, it might just be something that uh gives added value to stuff that we've already uh made, but makes it twice or three times more efficient.

JOURNALIST
Hum and this is far away or is this?

JAMES HEATH
No, no, no, it's happening now, it's happening now.

41:00
COMM
Fine promises… but in practice ?
The practice, perhaps, comes through photovoltaics.

SYNTHE :
SANTA BARBARA

COMM
Scientists can well be encouraged by the Californian sun. It's not just by chance that Alan Heeger, A Nobel Chemistry prize winner for his work in the field, has settled on the west coast.
It's a relaxed atmosphere, as usual, but that doesn't mean promising progress isn't being made.
At the dawn of a post-oil society and an imminent climatic apocalypse, the solution – a miracle, according to Heeger – is apparently within reach. It's merely a question of using a technology that we already know, which exploits solar energy.

41:44
IN ALAN J.HEEGER
That's a good view...

41:53
ALAN J. HEEGER
PHYSICIST
NOBEL PRIZE IN CHEMISTRY 2000
UCSB
So we what we do in this lab is uh, focus on this goal of improving the efficiency.
These these solar cells are laboratory made here with new materials, new architecture, ah trying to ever increase the the efficiency.

42:15
JOURNALIST
In which way the Nanotechnology is improving the efficiency?

ALAN J.HEEGER
Well when you, if we try to do it on ah a micron scale we would never collect any of the charges, uh the materials are just, require that we use Nano scale technology.
Self assembly is critical here because the length scale is ten Nano meters, too small you can't do it, it has to create that structure, that Nano structure, by itself, it has to self assemble into that Nano structure.
If you look at this with very high magnification you will see that this is really two materials that are mixed on a Nano scale.

What we're doing is just mixing two materials in a solvent that dissolves both of them and then when the solvent evaporates away they form this remarkable Nano structure that allows us to separate the charge and then to collect the charge.
But you can't always be lucky, you have to get it right, you have to engineer the materials so they give you the right ah Nano scale structure.

43:32
COMM
Alain Heeger believes in solar power. We head for his home. He decides to show us his own installation, in the hills above Santa Barbara.

43:44
ALAN J.HEEGER
We put the solar cells on aproximatly two years ago and it's been terrific, our cost for electricity is droped basically zero.
We receive from the sun in one hour we receive enough energy to cover the entire needs of the planet for one year. It's amazing right?
And this is our electric meter and as you can see the meter is running this way I'm selling electricity to the grid. At night, it would be going the other way, and I would be buying electricity from the grid.

44:34
ALAN J.HEEGER
We're working on a new generation of solar cells basically plastic solar cells that are of this kind that are very light weight they're very flexible they will be very low cost compared to what ah we have available today.
These plastic solar cells are basically printed from solution, we make a solution containing the semi conductor ink, so the cost is like that of of printing.
This technology is one of the best examples of Nano science, nanotechnology.

45 28
COMM
Printing a solar panel, the structure of which assembles itself. Nano-technology provides the solution and the practicality. It's the perfect solution. Everything becomes possible. It's light, cheap and simple to make.
There's just one problem to solve… the efficiency.
For the output of these supple solar panels today is only half that of rigid solar panels, which themselves have a limited capacity.

45:50
ALAN J.HEEGER
Right now the efficiency that we can get in small ah laboratory scale is about six percent compared to this is fifteen or eighteen percent ok? So we have we really have to improve the efficiency.

46:25
ALAN J.HEEGER
One day, we'll have this plastic built right into the tiles for the roof. So when tyou install the roof tiles the dream is everything will come together at the same time.
Let's dream, that's gone happened...
If we have ten percent efficiency solar cells we can get a hundred watts from every square meter ok? What's a hundred watts? Well, you know a hundred watts will

light alight bulb, ok? A hundred watts for a family off the grid, will change their life, a hundred watts would allow them to have light at night would allow them have a radio or a small TV, so one of the one of the dreams that we have with these plastic solar cells is to be able to put low cost lightweight simple units of order of a hundred watts to the billions of people who are off the grid.

47:30

COMM

Cities like plants… feeding off the sun, through photosynthesis… It's a nice dream, no ? But we're a long way from managing to do what photosynthesis does… which enables a plant to transform light from the sun into energy so efficiently. And another thing… we have to know how to stock the energy. Because at night, there's no way I can recharge my telephone using this little solar panel.

In any case, according to another chemistry Nobel-prize winner, Water Kohn, the use of photovoltaic cells should alone satisfy up to 35% of our energy requirements by the year 2050.

And soon, large-scale solar cell factories will see the light of day, as it were. It is forecast that some will have a production capacity of around 200 million solar cells per year, equivalent to a total power output of 430 megawatts, or enough electricity for some 300,000 homes.

48:17

JAMES HEALTH
CHEMIST
CALTECH

If we talk about trying to move the world economy from where it is now with the few first world countries and a whole bunch of third world countries, you know there is nothing that you can look at that tracks the standard of living oth more than energy you know if energy consumption goes up the standard of living goes up.

48:35

PIERO BAGLIONI
CHEMIST
UNIVERSTY OF FLORENCE

We can say that Nano science is a sort of Renaissance of of
science because it its eh it brings together different fields and is a real eh eh measure of shift in the knowledge we have
A sort of new industrial revolution when Nano science will be fully in a certain sense, right now it's just the beginning.

49:04

VLADIMIR BULOVIC
PROFESSOR OF COMMUNICATIONS AND TECHNOLOGY
MIT

Now the lat the latter part of the twentieth century and twenty first century now, we finally realised by breaching the disciplines by learning the language of each other we're gonna be able to do many many more things we haven't imagine before.

49:16

ALAIN DE NEVE
ANALYST
ROYAL HIGHT INSTITUTE FOR DEFENSE

There’s just so many exciting things, so many new uh ideas, new new concepts ah and the tools to deal with them that uh, gee, I wish I was twenty five again.

49:36

COMM

This future is therefore quite appealing. The exploration of the nanoworld is still in a very early stage. And what we are doing today is so primitive, compared to what nature can do. Nanotechnologies are a tool, not an end in themselves.

At the centre of this universe, where anything is possible, stand us : human beings. And it is our bodies which will no doubt be the most directly affected by nanotechnology. For medicine, or nano-medicine as it will become, offers fabulous future fields of experimentation… into life itself.

TC OUT 50 25
<u>END CREDITS (ROLLING)</u>

A FILM DIRECTED BY
CHARLES-ANTOINE DE ROUVRE
JEROME SCEMLA

PRODUCED BY
LAURENT MINI
KARIM SAMAÏ

WRITTEN BY
CHARLES-ANTOINE DE ROUVRE
JEROME SCEMLA
ANNE FRANCE SION

MUSIC COMPOSED BY
JOSEPH GUIGUI
DAVID DAHAN

NARRATION BY
GARY GRANVILLE

ADDITIONAL VOICES
SANDY BERNARD
FRASER MACNAUGHT
JERRY DI GIACOMO

CHIEF EDITOR
DELPHINE DUFRICHE

ASSISTANT EDITOR
BENOITE DORLACQ

SOUND EDITOR
CLAIRE JOUAN

PRODUCTION MANAGER
BENEDICTE RICHARD

POST- PRODUCTION MANAGER
NOËL MORROW
SÉVERINE CAPPA

TRAINEES
CHANTAL RUFFIN
SOUADE SAMAÏ

RESEARCHERS
LAURENCE PIVOT
BENJAMIN TURQUET

DIRECTORS OF PHOTOGRAPHY
REMY REVELLIN
CHRISTOPHE LEMIRE
BORIS CARRETE
JEROME SCEMLA

SOUND
VINCENT MAGNIER
ODILE DARMOSTOUPE

GRIP
YOHANN TROUBAT
GRÉGORY DAUBAS

CASTING
LISA FACHAU

MAKE-UP ARTIST
STEPHANIE FIORILE

LOCATION MANAGERS
LAURENT AIT BENALLA
WAI YIM WONG CHARMES
AYA ASAKURA, YOKO ISHITANI
FLORENCE ROUDAUT, LUCAS DELOFFRE
LYN MARKEY
VERONIQUE GARA

DOCUMENTATION
VALERIE COMBARD
VALERIE FRENE
XAVIER BRILLAT

TRANSLATION
FRASER MACNAUGHT

COLOR GRADING
THIERRY LERAY
PASCAL FAIVRE CHALON
PAUL- HENRY ROUGET

DUBBING
SPARKLE STUDIO

2D ANIMATIONS
TCHACK

2D 3D ARTISTIC DIRECTION
LUCIANO LEPINAY

STORY-BOARD 2D 3D
DANIEL KLEIN

ANIMATION & COMPOSITING
DENIS VAUTRIN
SANTINE MUNOZ
ARMEL FORTUN

PRODUCTION
MATTHIEU LIEGEOIS

TRAINEES
LOUISE CAILLEZ
VIRGINIE GUICHAOUA

3D ANIMATION
CREATIVE CONSPIRACY

PRODUCTION
LUC VAN DRIESSCHE, KOEN VERMAANEN

ANIMATION
BART BOSSAERT, BRUNO HANSSENS,
TOM NEUTTIENS, WANNES AELVOET, JEREMIE LOUVAERT

COMPOSITING
GERRIT BEKERS, JEREMIE LOUVAERT

SFX
MITCHEL SMITH

TRAINEES
EVELYN BEKAERT, JEROEN BOURGOIS
PIETER DEPANDELAERE, XAVIER VANYSACKER

ADDITIONAL MUSIC
SONG « ESSAYE » INTERPRETED BY ALARASH
SONG « NANOBOTS » & « EPILOGUE »INTERPRETED BY PAR JAMES HEATH

ARCHIVES
ANGELS AGAINST NANOTECHNOLOGIES
APARCHIVE
ATELIER DES ARCHIVES
BBC
CALTECH ARCHIVES
CERIMÈS
CHICAGO T.H.O.N.G.
FRAMEPOOL
GAUMONT-PATHE ARCHIVES
GEDEON PROGRAMMES
IBM
INSERM
NEC

NICK PAPADAKIS
PAUL W.K. ROTHEMUND
PILKINGTON FRANCE
PROGRAM33
SONY
SVT
TRANSPARENCE PRODUCTION
WORLD TRANSHUMANIST ASSOCIATION

WE WOULD LIKE TO THANK

LIRMM
PHILIPPE POIGNET / DAVID GUIRAUD / GUY CATHEBRAS / FABIEN SOULIER

MINATEC / CEA
LORENE FERRANDES / CLEMENT MOULET

FRANÇOIS TARDIF
MANAGER - ULTRACLEAN PROCESS LABORATORY

SEBASTIEN NOËL
PHYSICIST

GUILLAUME SAVELLI
PHYSICIST

NICOLAS BARDI
ENGINEER

DENIS TREMBLAY, PAULINE LEGRAND, DIDIER LOUIS

PASCALE BAYLE-GUILLEMAUD, PIERRE-HENRI JOUNEAU, VIOLAINE SALVADOR
NANOCHARACTERIZATION PLATFORM

FABRICE NAVARRO
BIOLOGIST

THOMAS DELMAS
PHYSICAL CHEMIST

ELODIE SOLLIER
ENGINEER

JEAN-CHRISTOPHE P.GABRIEL
PROGRAM LINE MANAGER « BEYOND CMOS »

F.BERGER
PHYSICIAN - RESEARCHER

CHRISTINE PEPONNET
HEAD OF DEPARTMENT - BIO SYSTEM-ON-CHIP

RAPHAEL SALOT
PHYSICIST

JEAN-YVES LAURENT
CHEMIST

HARVARD UNIVERSITY
QUAN QING

CORNELL UNIVERSITY
MARGARET FREY / GEORGE G. MALLIARAS / MICHAEL SKVARLA

M.I.T.
VICKY DIADUCK / LUIS FERNANDO VELASQUEZ-GARCIA
MARC A. BALDO / JESUS A. DEL ALAMO / KARL K. BERGGREN

IBM WATSON RESEARCH CENTER
JOERG APPENZELLER

CALTEC
MARK DAVIES / ERIK WINFREE / PAUL ROTHEMUND

UCSB
WALTER KOHN

THE HONG KONG POLYTECHNIC UNIVERSITY
ANNE HON

NATIONAL SCIENCE FOUNDATION
JOSHUA A. CHAMOT

FORESIGHT
CHRISTINE PETERSON

NBCI
MASAO WATARI

UNIVERSITY OF TEXAS NANOMEDECINE TEAM
ENNIO TASCIOTTI / ALESSANDRO GRATTONI / RITA SERDA / ROHAN BHAVANE / ALI BOUAMRANI / SILVIA FERRATI / BING XIA / JIANHUA GU / ROBERT CAHILL

ETH CENTER ZURICH
VAHID SANDOGHDAR / PHILIPPE KUKURA

IRENE CAMPOS / DEUTSTCHES MUSEUM MUNICH
EVA TIETZ
LADY MARGARET KROTO
CHRISTOPHER RADIC
GUY FORESTIER
GUNTER OBERDORSTER
DANIELA DINI
SANTA CROCE / PALAZZO PITTI

PHILIPPE LEMOINE
MINOO DASTOOR
ROLAND HERINO
DANIEL OCHOA
ILARION PAVEL
ISABELLE MURMURE
JEAN-ERIC WEGROVE
MARJORIE THOMAS
PAOLA, KIM, CHIARA, ILARIA, FEDERICA AND GIACOMO FERRARI
MASAYO ENDO / SONY CORP.
KONARKA
COMPUTER HISTORY MUSEUM
LE TELEPHERIQUE DE LA BASTILLE A GRENOBLE
RESTAURANT LE PER’GRAS
ATOMIUM DE BRUXELLES
STEPHANIE GIRAUD / URBASOLAR
ARKEMA
SAGEM DEFENSE SECURITE

A PRODUCTION
LA COMPAGNIE DES TAXI BROUSSE
LAURENT MINI
KARIM SAMAÏ

IN PARTNERSHIP WITH
EUROVISION SCIENCE
PHILIPPE JACOT
LAURA LONGOBARDI
KAREN SIMHA

COPRODUCED WITH
THE FINANCIAL PARTICIPATION OF THE EUROPEAN COMMISSION,
DIRECTORATE-GENERAL FOR RESEARCH"
(PROJECT 'SCIENCE IN EUROPE 2020’)

EUROPEAN COMMISSION
European Research Area

WITH THE PARTICIPATION OF
EUROPE IMAGES INTERNATIONAL

WITH THE SUPPORT OF
LA REGION LANGUEDOC-ROUSSILLON
CENTRE NATIONAL DE LA CINEMATOGRAPHIE
ANGOA AND PROCIREP
SOCIETE DES PRODUCTEURS

PRODUCT WITH THE COLLABORATION OF
LA RTBF –TELEVISION BELGE –CLAIRE COLLART
UR- NINNIE KÜLLER
TFO, LA CHAÎNE ÉDUCATIVE ET CULTURELLE DE LANGUE FRANÇAISE DE L'ONTARIO

WITH THE PARTICIPATION OF
FRANCE TELEVISIONS

FRANCE 5 DEPARTMENT

DEPARTMENT DOCUMENTARIES
PIERRE BLOCK DE FRIBERG
CARLOS PINSKY
HERVE GUERIN

PHILIPPE LE MORE
VALERIE VERDIER FERRE

PRESS FRANCE 5
ANNE-SOPHIE BRUTTMANN