Materialforschung ist ein entscheidender Innovationsfaktor

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Abstract (ENG) – The aim of this paper is to show the relevancy of materials to boost to the extreme of excellency invention and innovation in cross cutting fields of economic growth and development, as it is the case of Information and Communication Technologies, Energy and Biotechnology/Life Sciences, based on discussions that we have been within the European Materials Research Society, other Materials related societies and in particular with the Directorate-General for Research and Innovation of the European Commission. Moreover, we also aim to supply examples where new concepts should be thought to promote industry based on knowledge, able to answer to our future societal challenges. Therefore, this work is also our vision concerning what worthwhile to do within the materials sector as a whole and in particular to the energy sector. Of course, it is always a limited vision of what in the whole world of materials can be done. We do not have any pretension to exhaust all possibilities.

Keywords – advanced materials, photovoltaics, thin film solar cells, roof tiles, tiles, architectural aesthetics, plasma-enhanced chemical vapour deposition technologies

Auszug (GER) – Das Ziel dieses Papers ist es, die Relevanz von Werkstoffen zeigen, um das Äusserste an herausragenden Erfindungen und Innovation in den interdisziplinären Bereichen Wirtschaftswachstum und Entwicklung zu fördern, wie dies im Fall von Informations- und Kommunikationstechnologien, Energie und Biotechnologie, sowie Life Sciences zutrifft, basierend auf Diskussionen, die wir im Rahmen der European Materials Research Society, anderen Material bezogenen Gesellschaften und insbesondere mit der Generaldirektion für Forschung und Innovation der Europäischen Kommission. Darüber hinaus wollen wir auch Beispiele, in denen neue Konzepte ausgedacht werden, um die Industrie zu fördern, wissend, dass wir in der Lage sind, unsere künftigen gesellschaftlichen Herausforderungen zu beantworten. Daher ist diese Arbeit auch unsere Vision über das, was sich lohnt, im Rohstoffsektor als Ganzes und insbesondere für den Energiesektor zu tun. Natürlich ist es immer eine begrenzte Vision von dem, was in der ganzen Welt der Materialien durchgeführt werden kann. Wir erheben keinen Anspruch darauf, alle Möglichkeiten ausgeschöpft zu haben. (ch)

Suchwörter - advanced Materials, Photovoltaik-Dünnschicht-Solarzellen, Dachziegel, Fliesen, architektonische Ästhetik, Plasma Enhanced Chemical Vapour Deposition-Technologien

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Materials Research is a key factor for innovation

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1. Introduction

Today, the main difficulties for the Western countries are to identify the best social agreement to develop a strong sustainable society, offering jobs to nearly everybody. Many facts make this objective difficult to be obtained but, still for a large part of the world population, water, food, energy is major constraints. Materials play in both cases a critical rule, once they are considered the driven component to sustain innovation and critical areas such as the Information and Communication Technologies (ICT), Energy and Biotechnology, where it is expected to reach average values above 70% by 2020. That is, we real need materials to promote the required growth in Europe that clear passes by consolidating Europe knowledgment and by promoting to the extreme innovation based on ideas generated.

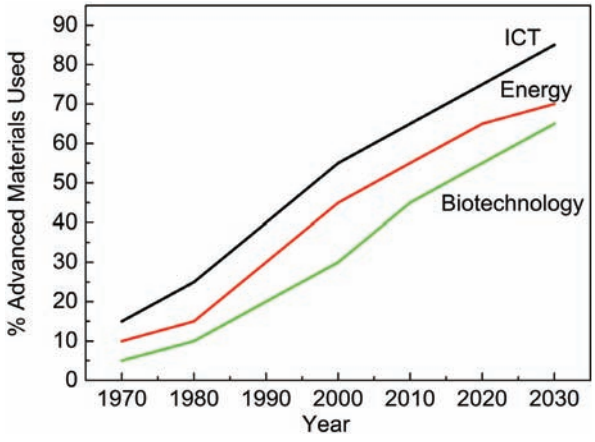

Fig. 1 Impact of advanced materials technology on ICT, Energy & Biotechnology
(% growth attributable to advanced materials. Source: Source: Sanford M. Moskowitz,
"The Advanced Materials Revolution", John Wiley & Sons Inc, 2009

Here, we are facing materials scarcity (both, raw and rare materials) and so, novel materials (by design, informatics supported) and eco-compatible are urgent need. Indeed, we approach the turn point of our unsustainability due to the explosion on use of materials and energy consumption, together with an exponential growth in population to which the society has to supply commodities, globally. Moreover, as far Europe is concerned, Europe is one of the poorest regions in the world concerning natural resources and so, all European growth should be sustained on the pillar of our knowledge and how this knowledge can boost innovation. (see Fig. 2a & 2b)

The orientations' Europe will select will be crucial for the population. Choices have to be done between high volume low added value industries or high added value goods. Moreover, it is necessary not to forget that the time scale between the discovery of novel materials and their use in industry takes more than one decade. Anticipation and short decisions makings are crucial in the world competition.

Since years the EU position was to consider that "Innovation" will keep our leadership over the emerging countries. This is no longer true and the BRICS countries (Brazil, Russia, India, China, and South Africa) are able to manage R+D at least as well as the Western countries. Progressively EU leading companies are losing positions in the world classification (ex. PV, ICT, …).

Globally, we have also to consider that since the American Industrial revolution (1820-1870), our main paradigm was to promote economic progress and societal comfort, that led us to change our energy resources from wood to fuel and to almost exhaust our natural resources: today we consume more than 1.5 times earths of resources every year (http://www.footprintnetwork.org), meaning that we are leaving in an non-sustainable world that is our main threatens in the years to come.

To return to sustainability, Materials Science and Technology is a key component since it is a cross cutting element of technology research, development and innovation in all critical areas such as a Energy, Food, Medicine, Electronics/ICT, Transports, Chemistry, Building Construction,… therefore strong actions in the field are required. In the following we will highlight only some cases as examples, to promote both, the research strategy we want and claim for EU future high level position in the field of Materials and what are the policy steps we think to be necessary to give to keep the required balance between a so structuring area as Materials are, to avoid to jeopardize the existing financial resources for research and development in Europe and so, a better use of them.

2. Advanced Materials For Future Challenges

The challenges that we are facing involves how Europe can be competitive in the future and how we can pro-

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mote simultaneously comfort to our citizens and generate/create the products that the market needs. Moreover, as we do not have the required natural resources, how this could be achieved? That is, how we can have a sustainable development able to promote highly innovative products to be integrated in high tech systems, either for long term use of for full disposable and recyclable applications. For all of this, three actions are urgent:

(1) optimize the use of the elements: this can be done by computer simulation (materials by design) but need availability of technical data as well as on eventual recycling and energy involved (should be preceded by studies…);

(2) recycle the various materials, which it means that from the concept to the recycling all development steps have to integrate this fact. Unfortunately, very few elements are really recycled in Europe, also because the legislations are not adapted.

(3) substitution solutions: will involve both simulations as well as experimental longer term work to identify replacing possibilities.

For sustainable development, a very wide range of materials have been under development for a short to medium term strategy. But now, before going to use them in practical applications we must consider its abundance (and so, costs related), if we can make them by design and how environment and human they are compatible (the so called eco-materials).

Examples are already numerous such as water purification, catalysts for the chemical/car industry; for CO_2 reduction etc ... but we cannot forget the building materials where novel light and highly strength materials are investigating for a broad range of applications. The same happens with the aerospace and car industry where novel materials are investigating, not only as substitutes of the ones up to now used but also to turn systems more secure and lighter, as a way to decrease energy consumption, besides the well-known effect in controlling pollution.

Other examples could be given related to future challenges such as the use of graphene, discovered in Europe, opening certainly a wide spectrum of applica-

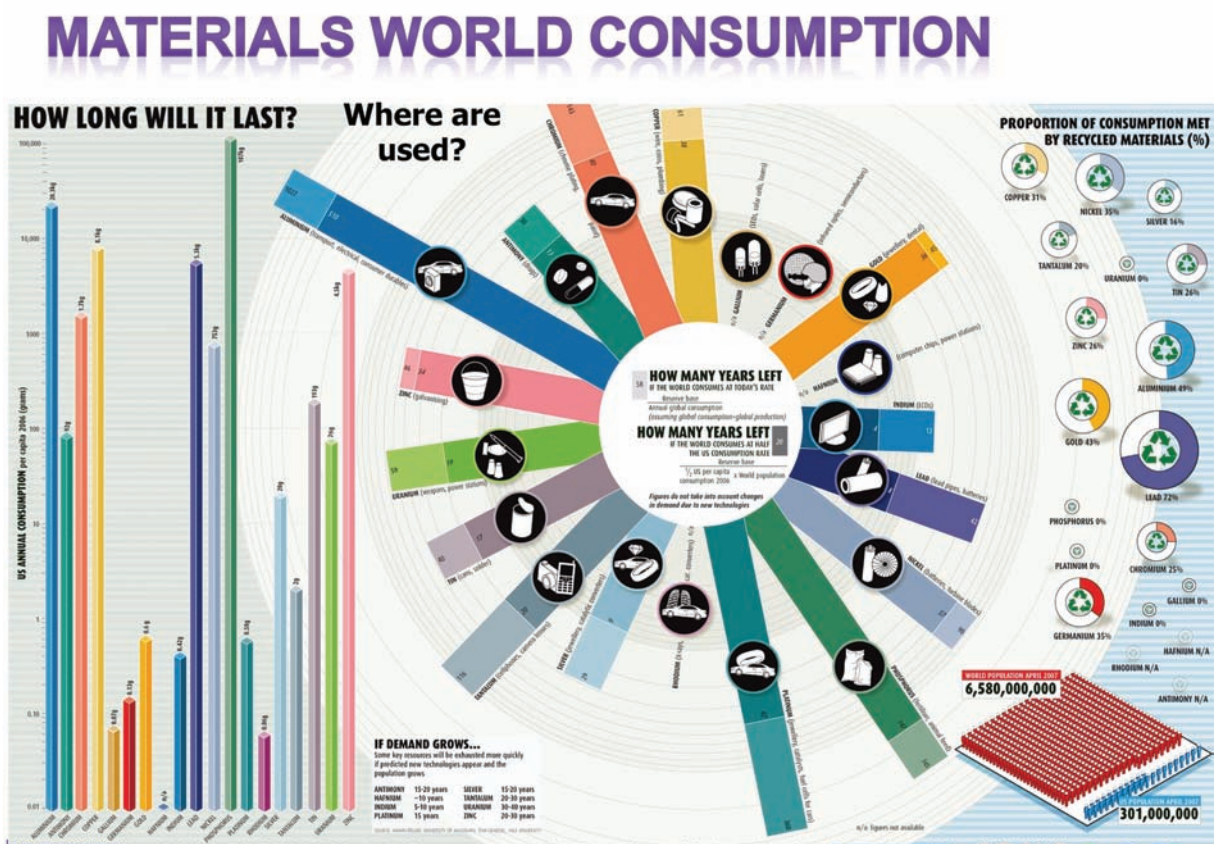

Fig. 2a Materials used in producing different commodities

tions, like in batteries or in ICT's (displays etc...). But, will Europe be able to support the needed innovative enterprises? Moreover, pressure is now put in different types of materials such as Graphane, a new carbon material, after fullerene, CNT and Graphene, corresponding to a full hydrogenation from both sides of a graphene sheet, able to lead to novel devices with exceptional properties, which is still in earlier stages of development.

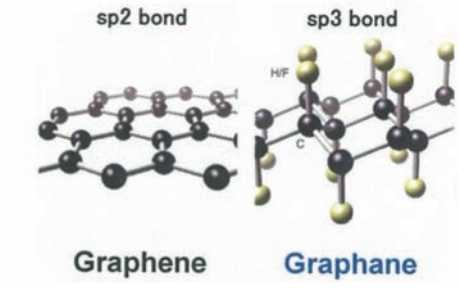

Fig. 3 Schematic of the structure of graphene and graphane

As other emerging applications targeting full disposable low cost flexible electronics is the use of cellulose paper to build up electronics, ranging from CMOS devices to logic gates. Indeed, the ability to process and dimensionally scale field effect transistors with and on paper and integrate them as a core component for low power consumption analog and digital circuits is challenging, opening the door to new applications ranging from smart labels and sensors on clothing and packaging to electronic displays printed on paper pages for use in newspapers, magazines, books, signs and advertising billboards. Moreover these paper CMOS constitute fundamental building blocks for analog and digital electronics, creating so the potential to have flexible form factor computers seamlessly layered onto paper. The holistic approach of merging low power circuitry with recyclable substrate poses an important step towards greener electronics.

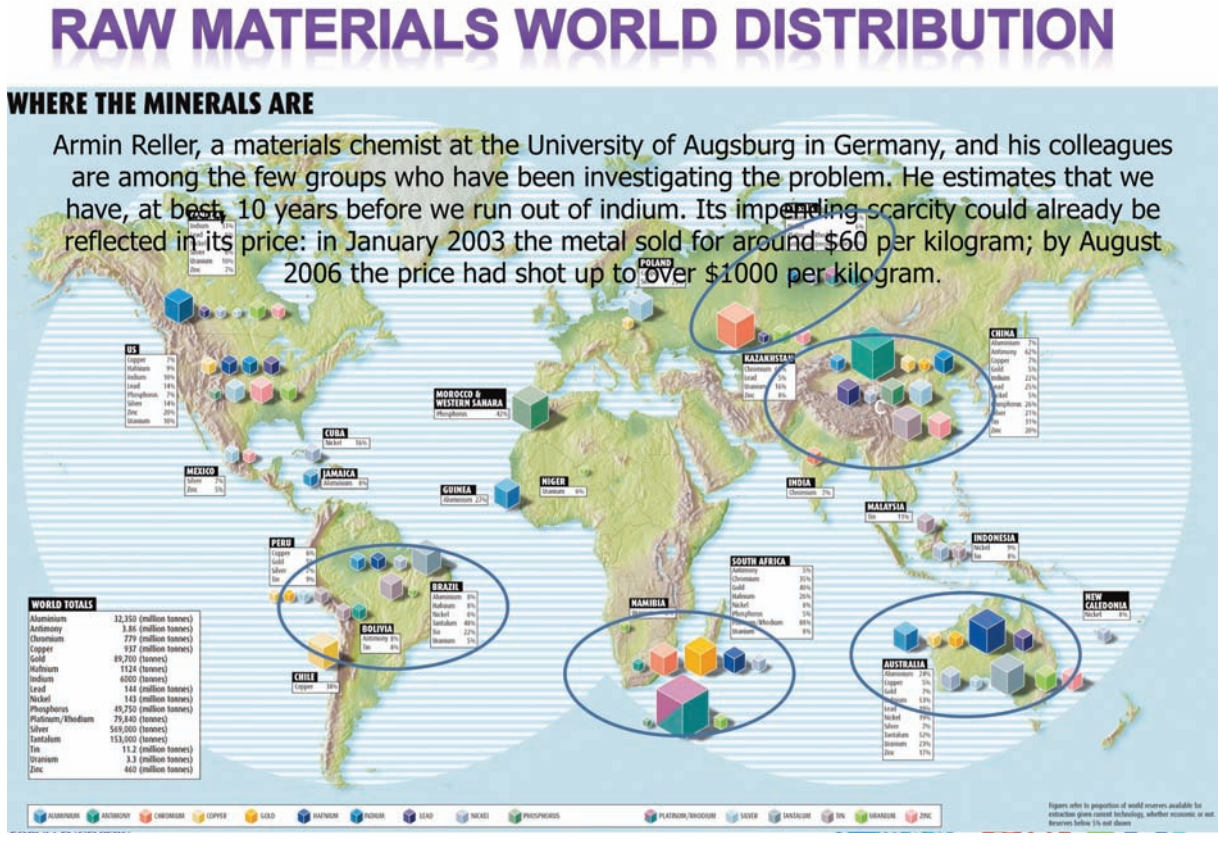

Fig. 2b Raw Materials word distribution

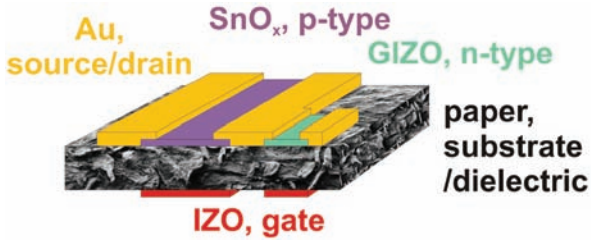

Fig. 4 Sketch of the structure of a CMOS based on paper and oxide materials (courtesy of CENIMAT)

Other examples where advanced materials are relevant are the ones need to be used in medical sensors for disposable diagnostic that can be paper made or the use of conformal radiation image sensors, involving mainly organic and hybrid materials. (see Fig. 5)

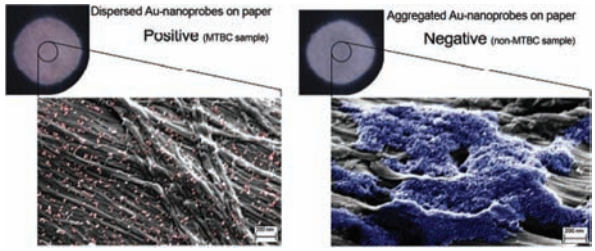

Fig. 6 Paper diagnostic platform for tuberculosis diagnostics (after Lab on Chip, 2012, DOI: 10.1039/C2LC40739F).

Another quite relevant field concerns the use of 3D conformal materials for tissue and proteases.

3. Materials for Energy

As far as materials for energy are concerned, for a short to medium term range, the house is a good example where pressure is put on new stable electrochromic materials with high transition speeds and using solid electrolytes; the use of light materials (composites); advanced insulation materials. (see Fig. 7)

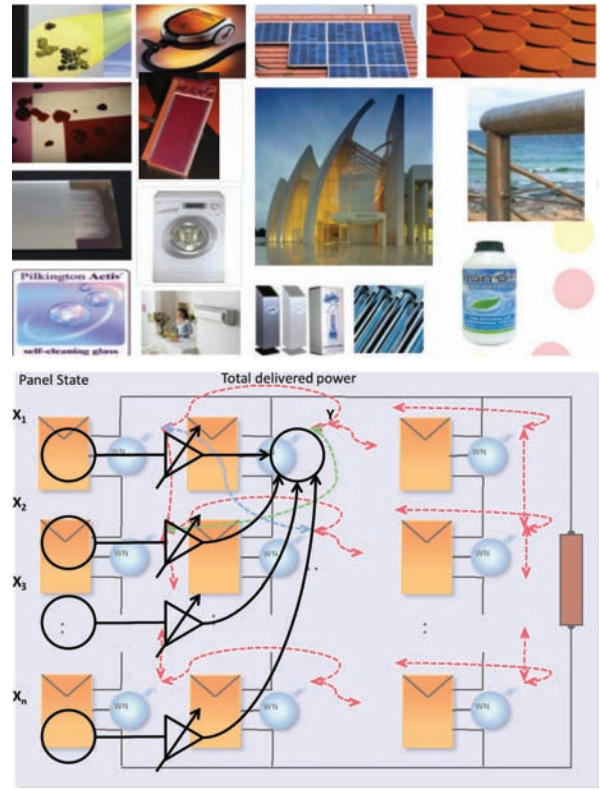

Fig. 8 Top: Different types of solar cells integrated in buildings; Bottom: Integration of transparent control devices on PV (courtesy of CENIMAT/ INESC, Portugal)

Apart from that architectonic building integration of photovoltaic with different designs or the use of solar cells embedded on tiles, are areas that should be looked at as ways to have ad-value to the product chain under development. Besides that, safe control of solar cells (both, inorganic or organic based) for avoiding hot spots and better energy management has to be taken into account, where full transparent power transistors (to avoid shadows and better full use of the all active area) is foreseen.

Also action should be taken towards materials beyond silicon, but also other parts of photovoltaics, such as transparent conductive oxides, metallic connects, antireflection coatings, interfaces, substrates, able to push efficiency beyond the present limits and to promote integration on wireless self-sustainable flexible power sources for a broad range of application, within the so-called key enable technologies.

As a way to push further todays efficiency of solar cells, novel approaches has been suggested going from the use of quantum dots, to nanowires or even exploiting the field of plasmonics. One of the emerged novel concepts concerns the exploitation of the light trapping approach to enhance the absorption of light by the semiconductor layer responsible for the generation

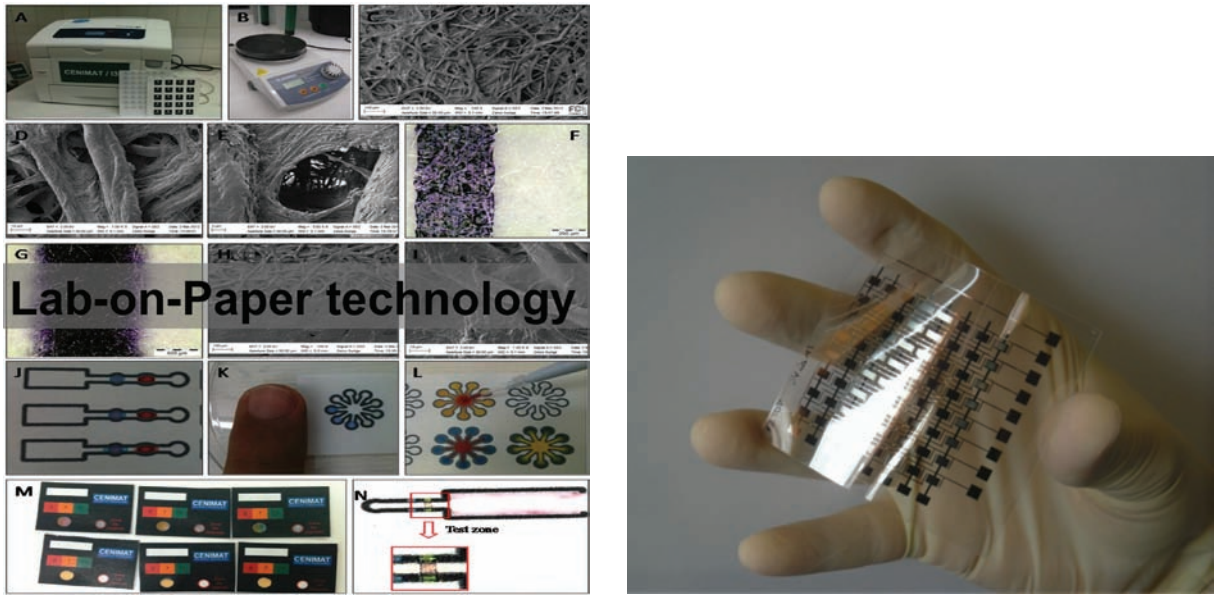

Fig. 5 Left: Steps used to fabricate microfluidic platforms on paper for DNA color detection (courtesy of CENIMAT); Right: X-ray conformal image sensor (courtesy of University of Bologna)

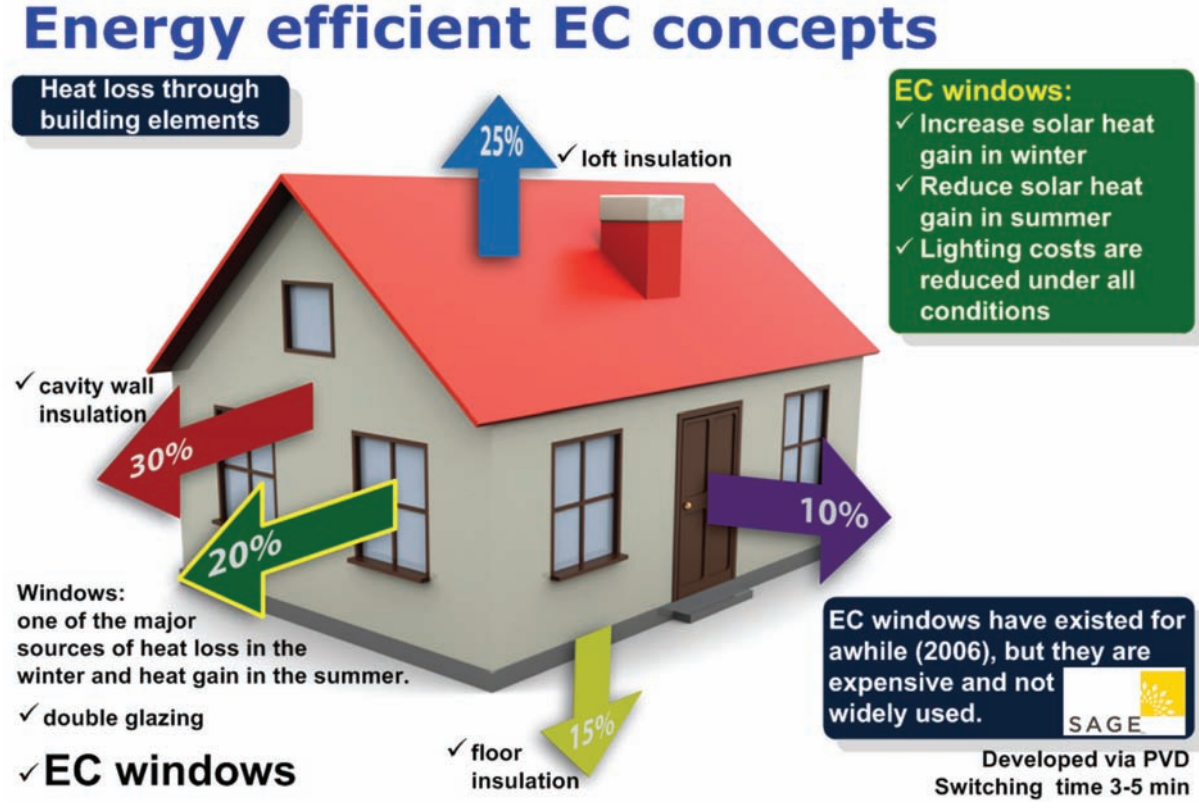

Fig. 7 Materials for house energy savings (courtesy of CENIMAT)

of free carriers (e.g. Si) in the solar cells using periodic arrangements of resonant dielectric micro-particles (DMPs) deposited on top of thin planar cells.

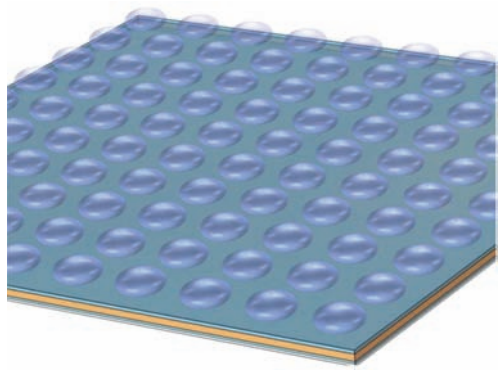

Fig. 9 Sketch of an array of transparent oblate spheroids deposited over the top TCO of a thin a-Si:H solar cell. The particles have sizes on the order of the wavelength (mesoscopic) of sunlight, therefore they are termed dielectric micro-particles (DMPs) (courtesy of M. Mendes, IMM, Catania/CENIMAT)

The aim here is to enhance the photocurrent of thin-film solar cells due to the action of light trapping produced by DMP structures. Since the DMP material is transparent (for instance, silica) such structures will be incorporated in the front of the cells, so that their forward scattered field can focus the light in the cell at the wavelengths that are poorly absorbed by its material.

The main challenges at medium to long term range as far as materials for renewable energy are concerned rely on enhancement of the efficiency of energy production, including sources beyond photovoltaics such as using fuel cells based on cheap and reliable membranes, active anode materials (now Pt), highly ion conducting materials, active electrodes. Besides production, we have to consider the energy storage [using super-caps novel electrodes and electrolytes for an increase cell voltage and batteries (materials for anode, cathode and electrolyte) for advanced Li-ion batteries with high voltage of e.g. 5 V, new types of Li-batteries or its substitutes or new concepts such as thin film batteries Li free] and energy distribution (super-conductors, energy control losses, etc.), where availability, costs and sustainability are key factors for all type of developments to be consistent made in these fields.

Other advanced materials to be pursued are catalysts able to keep activity and properties at high temperatures under highly contaminant-loaded gases (e.g. S); lightweight and highly resistance materials (new nano-composites) for turbine components;

At a long term strategy, we have also to consider materials for thermoelectric converters and for using CO2 raw material for chemical fuels or the use of paints for photovoltaics, based on nano-precursors to be sprayed, printed or brush painted. Here a strong work related to materials by design, involving nano precursors and their stabilization, by using proper binders' needs to be done.

4. Conclusions

Overall we conclude that materials are a crucial cross cutting element for sustainable and reliable development, to boost Science Excellency; Industrial innovation and so, to answer to societal challenges of the future. Moreover, we believe that it is time to institutionalize a platform dealing with materials for energy, aiming to boost European knowledge in the field as a way

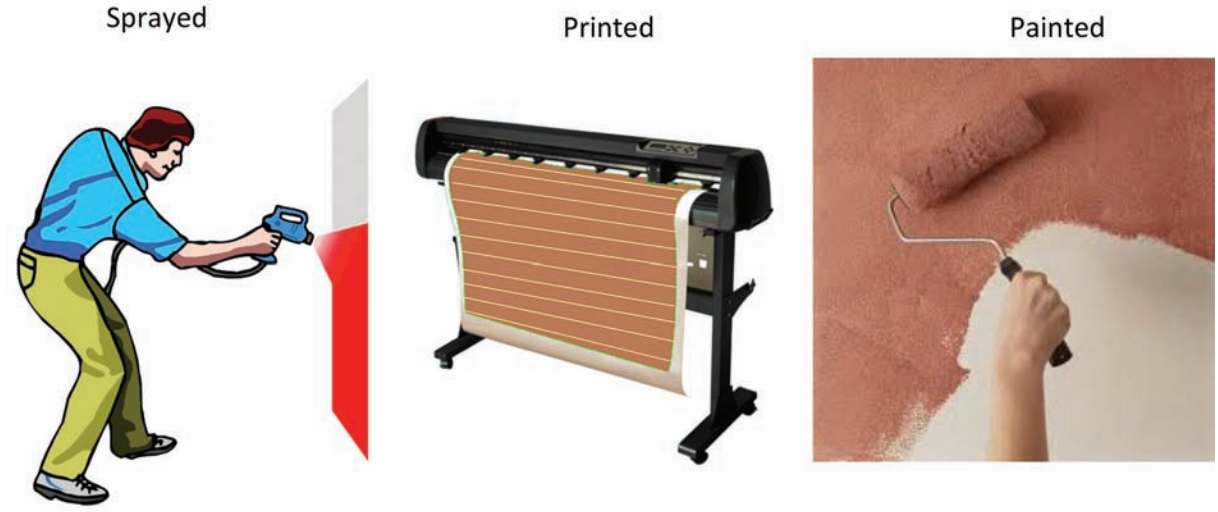

Fig. 10 Sketch of future solutions to paint solar cell panels

to promote the creation of a new European paradigm of positive growth, as far as jobs, economy and European citizen's comfort are concerned, by bringing together the promoters of knowledge (Academia) with the users of it, for practical ends (industry), allowing the creation or the renovation of today's Europe industry, in particular in the so demanded critical area of energy.

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