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RESEARCH ARTICLE

SIGNIFICANCE OF VALUE ADDED MATERIALS (VAMS) FOR MODERNITY AND DEVELOPMENT

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ABSTRACT

Materials science developments are often invisible to users of technology, but they are at the heart of so many important advances. Materials research and development is a global pursuit. It covers a broad set of science and engineering disciplines and engages researchers across academia, industry and government laboratories. Value added materials (VAMs) are products whose worth is based on their performance or functionality, rather than their composition. They can be single entities or formulations/combinations of several materials whose composition sharply influences the performance and processing of the end product. Products and services in the materials industry require intensive knowledge, innovation and commodities due to technological developments. The frontiers of materials research have been taken to the next level by the availability of technologies allowing the tailoring of material structure at the nanoscale and by the development of material systems made up of components with nanoscale dimensions. Materiomics takes a materials science perspective toward complex biological systems, explicitly accounting for feedback loops that link functional requirements (and changes thereof) to altered material components and structure, at different scales in both time and length. Materials research seeks to understand fundamental physical and chemical properties, and then use that understanding to improve the technology base that we count on to meet our needs for energy, national security and defense, information technology and telecommunications, consumer products, health care, and more. This means investing in the leading-edge research and educating the next generations of scientists and engineers needed to secure the VAMs for emerging technologies for 21st century is requirement for modernity and development.

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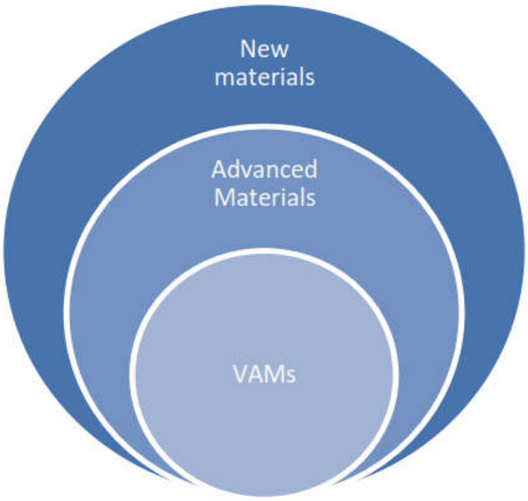
INTRODUCTION

The world's ability to meet the rising demand with limited natural resources is increasingly coming into question. Value Added Materials (VAMs) are products whose worth is based on their performance or functionality, rather than their composition. They can be single entities or formulations/combinations of several materials whose composition sharply influences the performance and processing of the end product. Products and services in the materials industry require intensive knowledge and converged innovation. VAMs are normally produced by a complex, inter-linked industry. Similarly, most advanced materials are called a 'new generation' of materials (Fisher, et al. 2008; Weng et al., 2011; Pinciotta, 2011; Waqar and Jackson, 2009) that display physical attributes substantially different from the generics (Weng et al., 2011; Krueger et al., 2010; Kelsall, 2005) and provide superior performance capacities. Advanced materials are materials that are early in their product and/or technology lifecycle, that have significant room for growth in terms of the improvement of the performance characteristics (technology lifecycle) and their sales volume (product lifecycle).

Advanced materials refer to all new materials and modifications to existing materials to obtain superior performance in one or more characteristics that are critical for the application under consideration. Added value materials with higher knowledge content, new functionalities and improved performance are critical for industrial competitiveness and sustainable development; the materials themselves represent a key step in increasing the value of products and their performance, including design and control of their processing, properties and performance. Moskowitz (2009) elaborates on advanced-material families based on properties, production methods and applications, as well as the classical materials .The key for tailoring material properties is to understand how the microstructure influences macroscopic properties such as physical and chemical behave our in different applications, how better performance is achieved and how these properties can be modified and controlled by means of material and manufacturing technology (EuMaT, 2012). Apply scientific understanding to advance our ability to design, improve, and scale service systems for business and societal purposes using raw materials development. Service-dominant logic may be the philosophical foundation of service science,



Source: Wessel and Renzo, 2012.

Figure 1. VAMs as a part of advanced and new materials

and the service system may be its basic theoretical construct for six 'key enabling technologies' (advanced materials, advanced manufacturing, nanotechnologies, photonics, industrial biotechnologies, and micro-and nano-electronics) can provide the instruments to accelerate the creation of innovation and the deployment of technology-based products and services, and so induced faster economic growth in Africa soild mineral driven economies and the world.

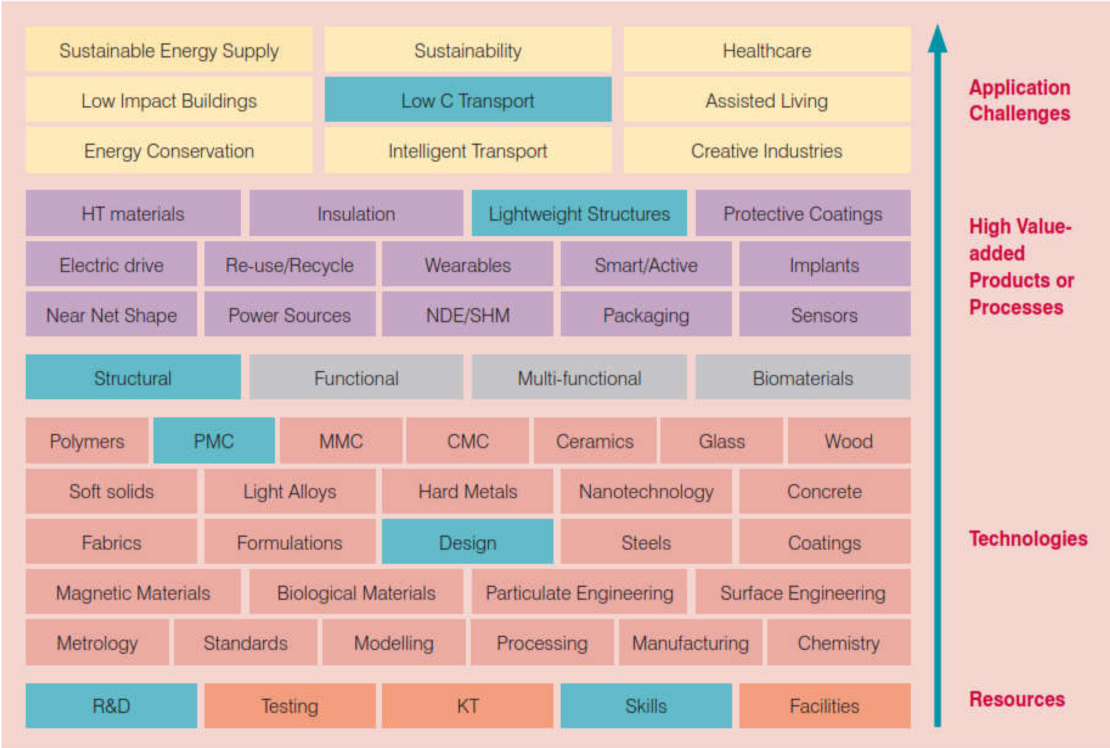
The rapid expansion in the scope of materials science and engineering has led to incorporation of such fields as experimental and computational biology, biomedical engineering, and genetics in the context of natural and synthetic materials. Recent progress provides insight into biological mechanisms and enables us a peek into how biology works at the ultimate, molecular scale and how this relates to macroscopic phenomena such as cell mechanics, tissue behaviour, or functions provided by entire organisms (EuMaT, 2012). Value Added Materials (VAMs) aimed at improving the effectiveness of public-and private-sector research partnerships through cooperative investments, expanding interactions among personnel, and increasing opportunities for technology transfer in its broadest sense and stimulate new research and development (R&D)business models that may be scalable to a national and regional level. Future technology mapping will provide a more comprehensive visualization of the entire production technology landscape that will take account of technology subcategories that have varying readiness levels in different production contexts, and varying levels of diffusion and adoption within different sectors. The evaluation of the significance of value added materials (VAMs)aregap analysis; solutions; impacts on materials science on state-of-art technology development and applications:

- The conception or creation of new knowledge, products, processes, methods and systems and development of value added services by collaborative research for VAMs.
- VAMs Cross-Discipline Education : Trans-diciplianry Applying Artificial Language (AI) and Machine Language (ML) methods to materials discovery and design effort requiring experts from many fields, including materials science, chemistry, mathematics, and computer science. Cross-disciplinary education and training are needed at the university and graduate levels;
- Design and develop dual core value added materials for military and civilian applications;
- Develop an interdisciplinary and intercultural approach to service research of raw materials ; build bridges between disciplines through grand research challenges; establish service system and value proposition as foundational concepts; work with practitioners to create data sets to understand the nature and behaviour of materials systems create modelling and simulation tools for advanced materials;
- The training requirements for the future of Value Added Materials.

The internet of things (IoT) encapsulate VAMs application of products development is often presented as a revolution, but it is actually an evolution of technologies developed more than 15 years ago. Operations and automation technologies are now blending, albeit conservatively, with sensors, the cloud and connectivity devices of the information technology (IT) industry Information Handling Services (HIS) projects the number of those devices to grow to almost 80 billion by 2025, up from 17 billion today[1].The immediate opportunities for producers are in smart enterprise control, asset performance management in real time and smart and connected products and services. Cyber-security and interoperability challenges are hindering producers from embracing IoT on the factory floor and in their supply chains, with 85% of assets still unconnected. Materials science and engineering drastically intensified in the 1960s, when applications of materials became increasingly based on scientific principles rather than the empiricism that prevailed prior to World War II.[2] Materials science and engineering today can be described as 'the study of substances from which something else is made or can be made; [and] the synthesis, properties, and applications of these substances.'[3] This definition covers both natural, traditional materials as well as synthetic, designed materials, Figure 2.

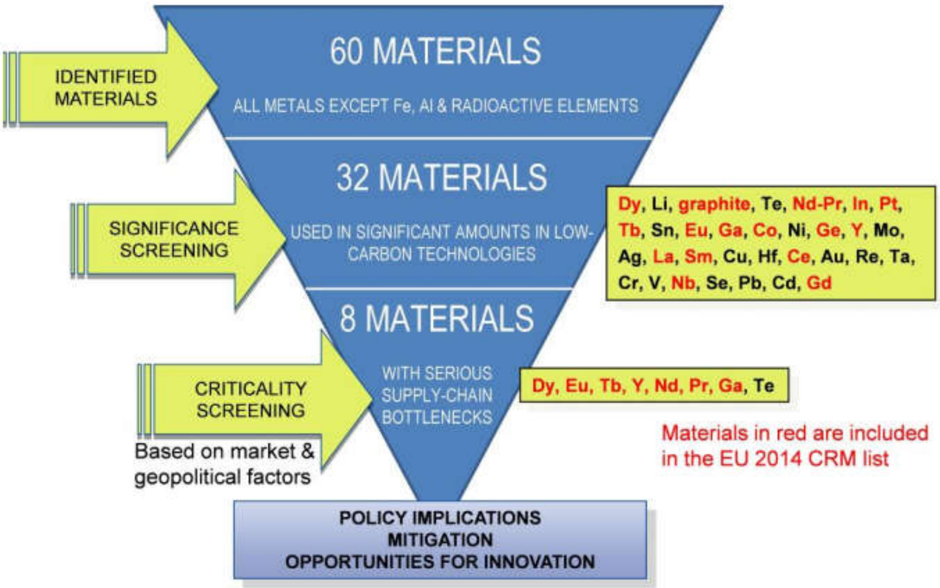
Environmental sustainability: Sustainable electronics brings to mind images and concerns about energy efficiency, resource use, and waste disposal or recycling - that is, building an electronic world that enables sustainable management of natural resources. For example, how can electronic devices be built that operate more energy efficiently than today's silicon-based devices? Chemists and other scientists and engineers are using organic materials to steer electronics into the future in a more environmentally sustainable way than is possible in today's electronic world, for example by using carbon-based material instead of precious earth-mined resources and by relying on safer and less energy intensive manufacturing methods than silicon-based electronic processing methods(CS3,2012).

Technology sustainability: Sustainable electronics implies that electronics itself is long lasting - not just the actual devices, but also organic electronic technology in general. Chemical, materials, and other scientists and engineers have only just begun to tap the vast potential for innovative functionality made possible through the use of organic materials in electronic devices. The way that organic electronic structures with biological systems opens up a vast world of possibility with respect to medical, sensing, and other human interface applications. The versatile nature of organic electronics, combined with the promise the field holds forth for environmental and social sustainability, point the way to a very long-lived set of technologies (CS3, 2012).



Source: www.innovateuk.org. UK Technology Strategy Board

Figure 2. The advanced materials landscape



Source: JRC, 2013a

Figure 3. JRC assessment for the identification of raw materials as a potential bottleneck in the future European energy system

Source: Hagelüken, 2013

Plate 1. Significance of critical raw materials/technology metals

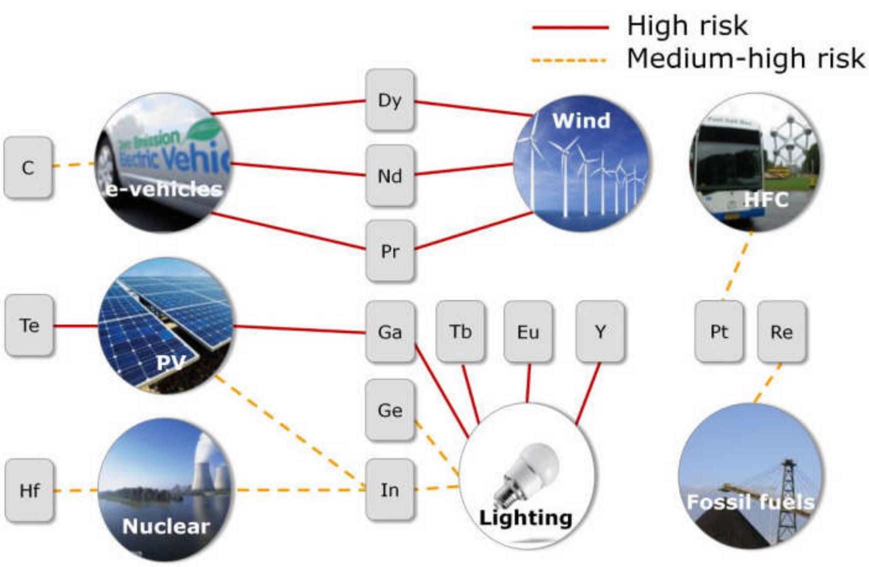
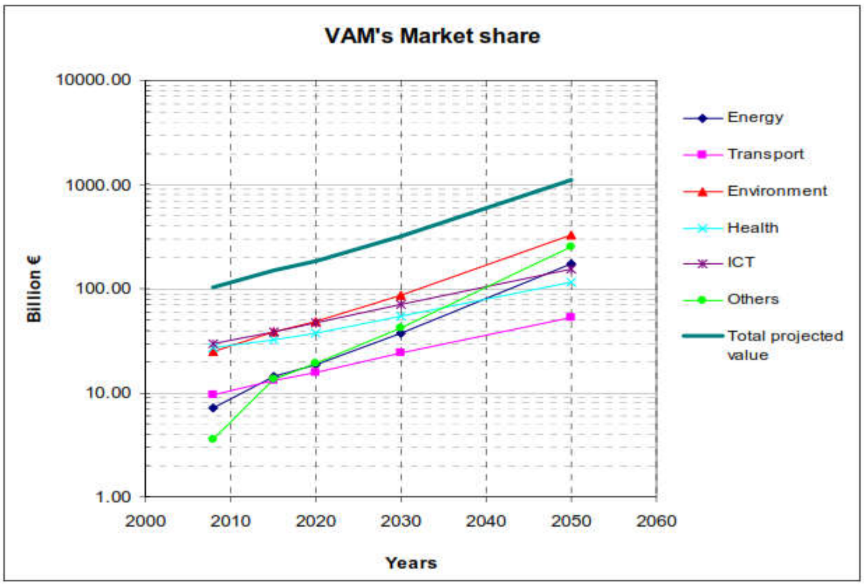


Figure 4. Low-carbon energy technologies at risk due to potential bottlenecks in the supply chain of critical raw materials (JRC, 2013a)



Source: ISQ Instituto de Soldadura e Qualidade

Figure 5. Market of Added Value Materials[5]

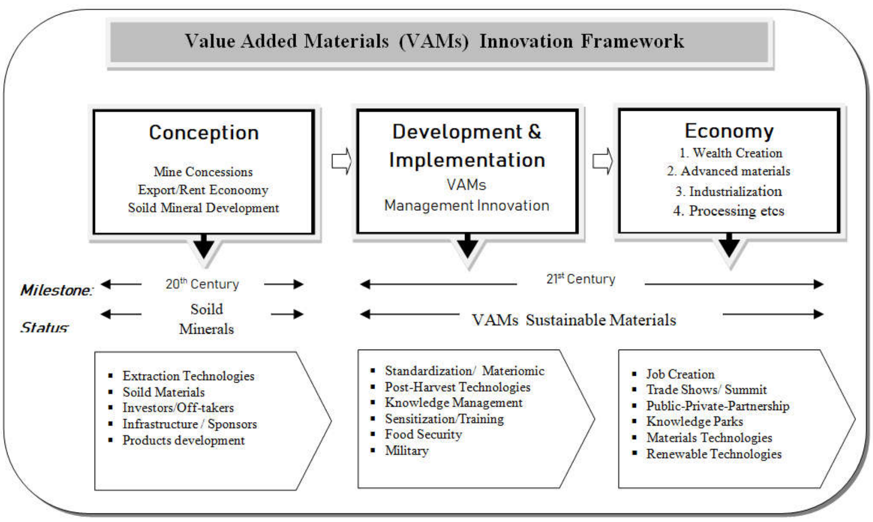
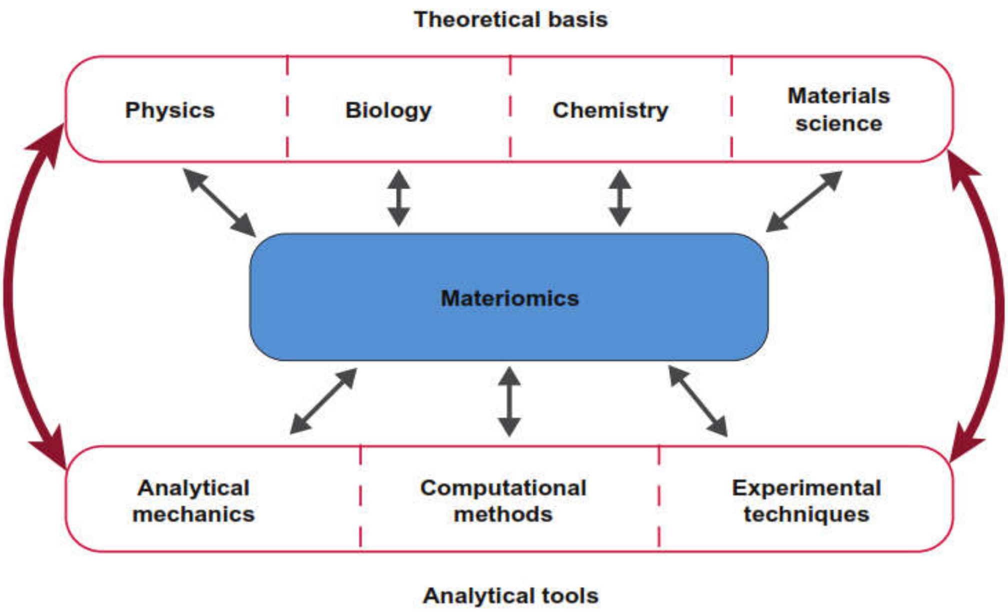


Figure 6 . Value added materials innovation framework for 21st century



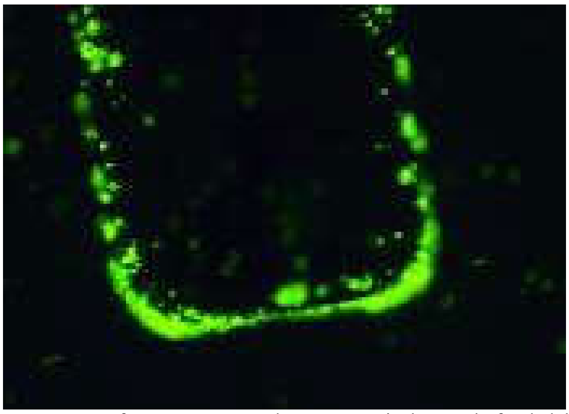
Source: Cranford and Buehler , 2010.

Figure7. The studyofmateriomicshasamultidisciplinarytheoretical,computational,andexperimentalfoundation resulting from the historical progression of physics, biology, chemistry, and materialsscience cross-discipline 'collective' approach

Figure 8. Self-Assembling Materials [6].Demonstration of self-assembly and molecular chirality, or right-handed and left-handed patterns of attraction. Opposing attraction patterns in the self-assembly units allowed for the parts to sort themselves when combined and shaken randomly. The yellow units and black units eventually self-assemble into two distinct structures, demonstrating error-correction throughout the assembly process. The molecular structures in this exhibit were based on the Polio Virus capsid

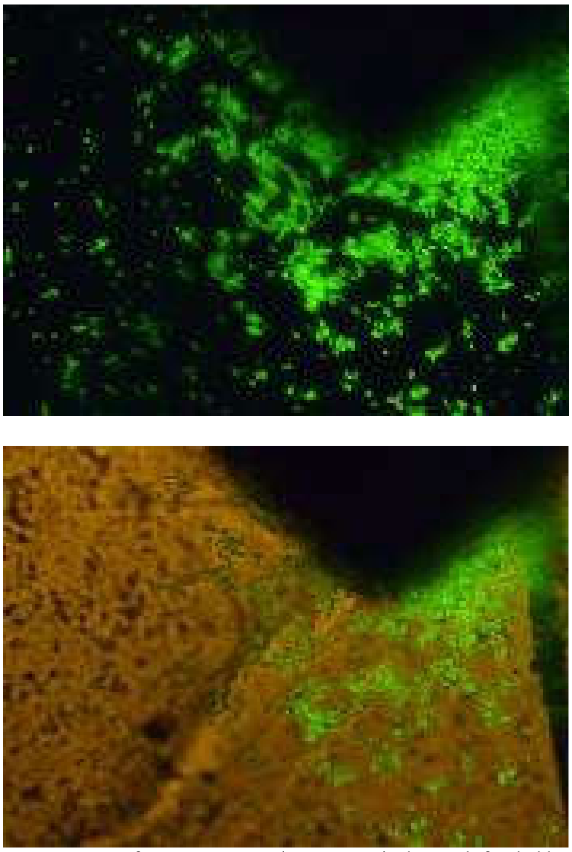
Sources: Sekitani et al., 2010; Zschieschang et al. 2011; Sun et al. 2011.

Figure 9. OTFTs make for good anti-counterfeiting features in banknotes. Left: Polymer substrate with functional OTFTs wrapped around a cylinder with a radius of 300 µm.



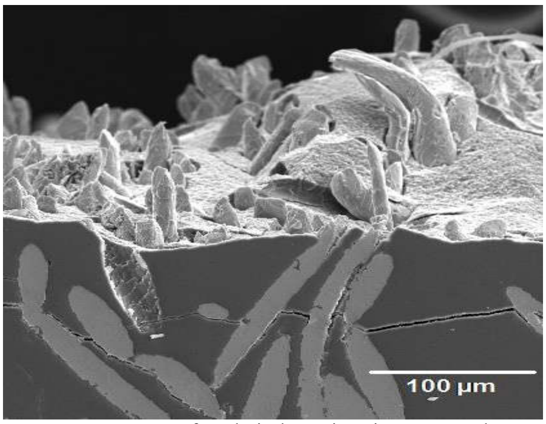
Source: Courtesy of ISMN-CNR and BSMU, Minsk. Work funded by the Magister Project– NMP, FP7

Figure 10. Stem cells loaded with magnetic nano particles - Cells are attracted by a magnetized scaffold for tissue engineering



Source: Courtesy of ISMN-CNR and BSMU, Minsk. Work funded by the Magister Project– NMP, FP7

Figure 11. Cell attraction to magnet placed below culture dish



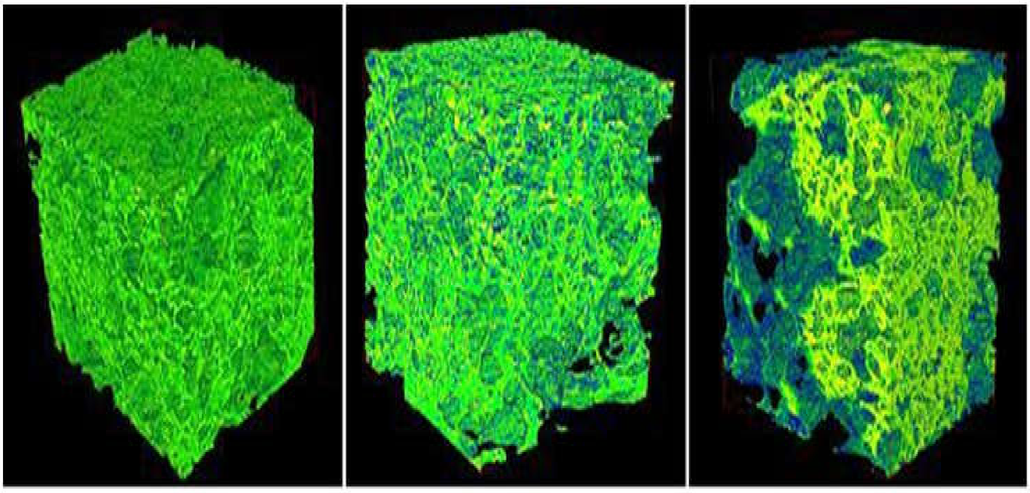
Source: Courtesy of Technische Universität Darmstadt

Figure 12. Crack bridging in a ceramic-metal interpenetrating phase composite

Justification: The European Commission claims that 14 critical raw materials used for high tech products such as mobile phones, laptop computers and clean technologies are in danger of shortage. Increased recycling of products containing these materials will be needed in the future. The list includes cobalt, gallium, indium and magnesium. They are increasingly used for 'emerging technologies' but are mined in only a few countries such as China, Russia and Mongolia, where Africa has not started to mined these developmental minerals (WWF, 2014). The difficulties of replacing critical raw materials which sets the stage for development of Value Added Materials (VAMs') market, especially in the field of catalysts and materials for energy storage. Technological breakthrough it will not be possible to fully reduce the market need for critical raw materials. The experts identified another approach: increased recycling of raw materials to reduce demand side of the market. Therefore, one response to the raw materials challenge is more research on how to recycle technically-challenging products and improve collection.

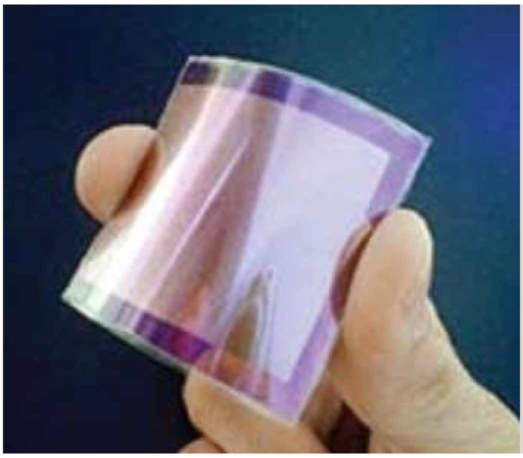
Here again ,VAMs will be use in the design of such advanced recycling systems(Figure 3).Among various technological, financial, market and policy challenges, the large-scale deployment of low-carbon energy technologies will lead to a significant increase in the demand for raw materials. Concerns about the supply of raw materials being insufficient to meet the growing demand of these technologies have increased considerably in the past few years. Previous studies conducted by the JRC have shown that several lowcarbon energy technologies could be at risk because of potential bottlenecks in the supply chain of certain raw materials [JRC, 2011, 2013]. The recent JRC report entitled 'Critical metals in the path towards the decarbonisation of the EU energy sector' identified 32 materials that are significant in terms of amounts requested compared to their global supply. When market and geopolitical factors were taken into account, eightof them were given a high criticality rating, namely: dysprosium, europium, neodymium, praseodymium, terbium, yttrium, gallium and tellurium (Plate 1). Furthermore, six additional materials are considered to have a medium-to-high risk and should be monitored closely: graphite, rhenium, hafnium, germanium, platinum and indium. Similar challenges to the material supply that may affect the US' clean energy technologies in the short to medium term were found by the Department of Energy (DOE, 2011a). The technologies of particular concern to the most critical materials listed in the JRC report were as follows: fluorescent lighting, wind energy, electric vehicles, and solar photovoltaic (Figure 4).

GAP Analysis: The fact that the technology and R&D investments in Europe are sufficient and balanced so that all essential industrial areas can be maintained competitive is becoming more important than ever before. Usually, technologies support each other by synergistic effect. Their combined use and concurrent engineering is today a self-evident approach in creating breakthrough innovations in all areas of technology and industry. Higher research volume, as such, produces typically more innovations than lower research investment, and more interfaces with different actors (competitors, research institutes, and other competencies) increase the probability of innovations to take place. Life cycle management has the goal to establish the relationship between plant and equipment investment costs, maintenance/inspection work and availability requirements, and to control these in an optimum way to minimize life cycle costs and environmental impacts.



Source: Courtesy of Technische Universität Wien

Figure 13. Microtomographic reconstruction of glass-ceramic scaffold (scaffold – green, new phase - blue).



Flexible solar cell[11]

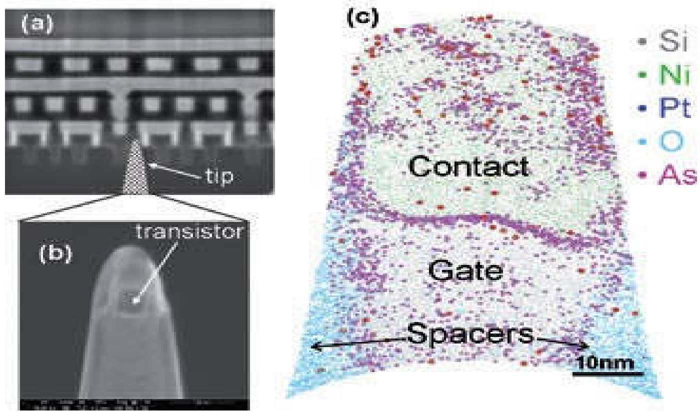


Figure 14. Analysis in 3D and at the atomic scale of a MOS transistor by atom probe tomography [14](APT): A transistor has been extracted from SRAM memories (a) using focused ion beam and shaped into a tip (b) to be analysed by APT (c). In (c), the atoms drawn as points define the transistor parts: contact (NiSi), gate (poly-Si) and spacers (SiO2). The arsenic atoms (dopants) have been enlarged to show the segregation at the NiSi/Si interface that changes the electrical properties

Source: DARPA, 2018*

Key R&D areas are the development of improved understanding of material degradation mechanisms in applications for process and energy industry, development of materials for improved friction and wear, corrosion and high temperature performance, Figure 5 **"**Fundamental discoveries in physics dominated the first half of the 20th century, whereas discoveries in molecular biology, such as the structure of DNA, dominated the second half. The 21st century may well bring forth a new era, one of revolu- tionary discoveries in materials research that result in far-reaching changes for society and how we live…".[4]

Environmental threats and resilience: The global climate is changing, affecting agriculture. Environmental change, water availability, soil degradation and biodiversity loss threaten food security. The price spikes of recent years highlighted the vulnerability of international food markets to adverse weather events. Less predictable weather patterns are likely to become more common. Agriculture and food production will have to adapt to these changing conditions to increase the resilience of food systems.

The sector will also have to make a concerted effort in helping reduce greenhouse gas emissions and meeting climate change commitments for sustainability by developing more efficient materials today. Materials Science and Engineering (MSE), basic research into final products and applications in the field of MSE involves certain MSE-typical motifs and specific issues, as well as certain aspects that are that are lacking today in industries and academia. In comparison with underlying traditional (or basic) disciplines such as physics, chemistry or biology, MSE involves a range of aspects that are more characteristic of applied science, where relevance has equal importance to curiosity in order to drive the research effort and justify expenditure– the defined goals often being a proven innovative technology or indeed a particular product. MSE and the related transfer of knowledge and technology includes consideration of factors such as materials and product life cycles, the abundance of materials, the technical, ecological and economic feasibility of materials engineering and processing, as well as the trans-disciplinarity of the 'background' knowledge and the efficiency of the academic effort involved (Figure 6).The societal impact of VAMs is, therefore, hugely significant and depends on the effective interconnection of three key aspects conception development and implementation and economy. Knowledge generation through basic and applied research, academic education and later career training

- Knowledge transfer within academia and from academia into commercial and industrial sectors, but more importantly here the transfer from industry into academia, something that is currently chronically neglected in academia; and
- Development of new technologies to produce new products and services.

The innovation chain is the chain going from (a) basic research, to (b) applied research, to (c) demonstrator projects and prototyping, to (d) early stage commercialisation and, finally to (e) mass production.

Thomson Reuters (2011). Global Research Report Materials science and technology. http://sciencewatch.com/grr/materials-science-technology

To overcome this problem, action is required to give a new thrust to competitiveness and to effectively move through the following scheme in VAMs (Figure 6):

- Foster the transformation of scientific results into a new technology.
- Provide proof-of-concept for the new technology by prototyping.
- Ramp up prototyping into large-scale production.

VAMs innovation framework addresses issues that are at the core of each of these steps. Progress can only be made if academic and industrial partners act closely together during the first two stages: transforming science into technology and facilitating demonstrator and production-driven projects. On the other hand, an optimised value chain implies favouring the transition from (a) raw or semi-processed materials, using (b) adequate equipment, into (c) devices, into (d) products and (e) services, and finally into (f) solutions to societal challenges. Another negative issue, which may be related to the previous one, is a weaker entrepreneurial mind-set among African/Nigeria scientists and engineers. Several Africa universities offer entrepreneurship education, but more and original initiatives have to be promoted to provide dedicated entrepreneurship training for engineers and scientists. Measures to strengthen technology and knowledge transfer are particularly important in the light of the paradox in the innovation chain of VAMs.

Materiome-The future of materials science research: Materiomics is the study of asystem's materiome or the 'complete' material system–its constituents and structure, properties and processes, function, failure, and behaviour–initsentirety. The goal is to link the disparate nature of the physical description of a material (ie, components and structure) with the related phenomenological functionalities (ie, strength and robustness). The approach is partially motivated by macro scale engineering techniques such as structural analysis in Figure 7by Cranford and Buehler (2010). In other words, the materiome provides not only the answer to what the material system is in terms of components, structure, and properties, but also to why the system is the way it is and how it is and/or how it can be manipulated. The consideration of the complete materiome of a material system allows a fundamental bottom-up design of purpose-specific materials from the atomistic to the continuum levels where the role of the relationship between processes, structures, and properties of materials in biological organisms is thus far only partially explored and understood. The objective is to ultimately bridge hierarchical levels and piece together not only material properties and structures at the nano- and microscales, but also the ultimate effects on both the mechanical properties and function of the entirematerial system.

A complete understanding of the materiomeeluci dates not only the cross-scale relations between hierarchies and mechanical properties, but also offers clue show to assemble new materials with disparate and mechanical properties from few constituent building blocks. The use of organic materials to build electronic devices holds the promise that future electronic manufacturing methods will rely on fewer, safer, and more abundant raw materials. The vision is for resource-efficient synthetic methodologies, whereby both the devices themselves and the manufacturing of those devices use less material than today's silicon-based electronic methodologies require. The same study also suggests a simpler approach to classification, grouping new materials as follows: Bioengineered materials, advanced ('super') alloys, advanced ceramics, engineering polymers, organic polymer electronics (OPEs), advanced electronic materials (other) advanced coatings, nanopowders, nanocarbon materials, nanofibers, thin films and advanced composites. Materiomics takes a materials science perspective toward complex biological systems, explicitly accounting for feedback loops that link functional requirements (and changes there of) to altered material components and structure, at different scales in both time and length. Materiomics provides an exciting opportunity for the analysis and engineering of complex biological systems based on quantitative insight into their fundamental physical and chemical features. A rigorous understanding may enable us eventually to integrate concepts from living systems into engineering materials design, seamlessly (Cranford and Buehler, 2010).

The incentive for materiomics is fourfold:

- Primarily, to amalgamate the advancing knowledgebase of chemistry, biology, materials science, and mechanics to a single, holistic description of a material system from nanotomacro. This complete description, the materiome, contains the information required to manipulate mechanical function and properties and development of new, predictive materiomic theories and models, which specifically include the hallmark of living systems feedback loops that facilitate an autonomous sensing, structural change, and as a result, adaptation to altered environmental conditions and functional requirements.
- Investigative methods developed from a multidisciplinary perspective for multiscale analysis can be applied to a vast amount of material systems, both current and future, offering new insights and theoretical formulations unavailable to past biochemists, medical engineers, and materials scientists.
- The application of materiomics can unlock fundamental design principles of Nature's materials based on high-throughput computational, theoretical, and experimental methods and utilize this insight in the development of advanced materials, biological and synthetic, micro- and macroscopic. This harnessing of Nature's 'trade secrets' could usher in new technologies that are currently unattainable without the integrative approaches a materiomics perspective provides. Indeed, such integrative approaches are already being implemented as discussed above, albeit by different research groups with disparate goals.
- Materiomics highlights the similarities and promotes a mutually beneficial relation between all researchers and scientists concerned with biomimetic materials, advanced composite design, nanotechnology, medical engineering, tissue engineering, mechanisms of disease, genetic defects, and any field requiring the complete description and understanding of a specific materiome (Cranford and Buehler, 2010).

By unlocking the complete materiomic information, efforts have been made to utilize gene regulation in the self-assembly and organization structural DNA materials (Seeman, 2007; Andersen et al., 2009; Lin et al., 2009). The field of materiomics provides a powerful integrated theoretical framework for complex hierarchical materials, which enables us to define future scientific hypothese sin the field of biological and synthetic materials and nanotechnology in a systematic way. Such hypothesis must be proved through a unified approach that combines theory, experiment, and simulation, leading to a detailed understanding of how Nature successfully links structure, processes, properties, and functions simultaneously over many length scales, from nano to macro. With the aim of maintaining academic excellence and at the same time reinforcing the capacity to innovate, national funding agencies and European institutions must consider coherent and compatible long-term strategic research plans covering the entire span from exploratory research to market implementation. This should be performed on a well-defined set of the topics presented above and especially on multifunctional and bio-based materials which are still in a nearly development stage and show potential for meeting numerous if not allgr and societal challenges. In addition, the following cross-cutting topics were confirmed as being of critical importance to improve the research process across the material sciences' board : analytical tools and characterisation methods; combinatorial materials science; data storage and processing tools; simulation ; surface science as an enabling technology; multi functionality; availability of natural resources and recycling.

VAMs Case Studies

Self-Assembling Materials: There is fairly good knowledge of biological systems which is translated into the ability to fabricate sim- ple objects with self-assembly processes. The first milestones towards more complex structures are the modelling of assembled objects and the development of concepts for assembly from individual building blocks (Figure 9). These should be made at the nanoscale as the starting point. Progress in self- assembling materials is subject to three conditions: cost reduction; development of dedicated instru- ments on atomic level; and the biological production of the building blocks for self-assembly. Mid-term milestones deal with 3D structures, whose assembly are protein-directed or are obtained from self-fold- ing polymers. Once such structures are assembled, a barrier would be their integration into devices, with a subsequent challenge on the modelling and the simulation of assembly processes. Self-assembly in different scales is a long-term milestone, with challenges here to engineer stable, macroscopic structures and, ultimately, to assembly complicated objects.

Biodegradable Stents: The principal motivations for R&D in biodegradable stents are children's diseases and the need for short-term treatments, e.g., aneurisms. Current research focuses on tailoring chemistry and topography. Short-term barriers are cell banks and stem cells, i.e., the availability of relevant cells, and understanding of the impact of degradation products and of deg- radation process on the control of the degradation rate. Milestones are the development of appropriate design, surface functionalisation and improvement of the mechanical properties, namely the stability of the stent (Figure 8). At that point, motivation for further research would be the decrease of throm- bosis risk, and the use of non-metallic stents so as to avoid artefacts in magnetic resonance images. Mid-term challenges are Mg-based alloys or biodegradable polymers and the controlled release of various drugs, e.g., from multi-layered structures. Manufacturing techniques and corresponding processes are required to meet these challenges and this is a mid- to long-term milestone, together with stent miniaturisation for brain applications. A corresponding challenge at this point is the ability to produce biodegradable stents with predictable behaviour, namely degradation rate. As is the case for previous case studies on biomaterials, long-term barriers are clinical trials, regulation and product (market) approval.

Organic Display Technology: Organic light-emitting diodes (OLEDs) are built from one or more layers of organic and hybrid material (either small molecules or polymers) sandwiched between two electrodes (e.g., indium tin oxide), all on a plastic or other substrate. Unlike other display technologies, which require a backlight in order for the display to show, OLEDs generate their own light via electroluminescence and therefore they do not require backlights. They require less power and are more energy-efficient than backlight-dependent display technology. OLEDs are already widely commercialized in many Samsung and other smartphone models[6]. The Samsung Galaxy line of OLED-based smartphones occupies a significant portion of the global smartphone market. Additionally, Samsung and LG Electronics have both announced forthcoming launches of large-screen OLED TVs. The new TVs are expected to not only be more spectacular than today's TV technology, with respect to crisper colours and sharper contrasts, but also lighter, thinner, and more energy efficient.

Transistor Technology: Transistors are considered a fundamental "building block" of modern electronic devices, either amplifying signals or operating as on-offs witches. There are many different types of transistors. Most organic transistors are organic field- effect transistors (OFETs). OFETs have several uniquepropertiesnot shared by silicon transistors, most notablytheir flexibility. Because OFETs can be manufactured at or near room temperature, they enable the manufacture of integrated circuits on plastic or other flexible substrates that would otherwise not withstand the high-temperature conditions of silicon-based device manufacture. OFETs are also highly sensitive to specific biological and chemical agents, making them excellent candidates for biomedical sensors and other devices that interface with biological systems (Sekitani et al., 2010; Zschieschang et al. 2011;Sun et al., 2011) and see Figure 9 below. Organic materials give electronic devices unique propertiesim possible to achieve with silicon-based electronic structures, enabling abroad range of innovative "out-of-the-box" applications. Theseproperties include sensing, biocompatibility, and flexibility. Because of the unique structural and functional variation oforganic materials, arguablyone of thegreatest are as for innovation in the field of organic electronics is in sensing that is, the use of electronic devices to sense chemical or biological substances in the environment, in or on the human body, in food and water, or elsewhere. For example, chemical scientists envision diagnostic sensors that detect changes in biomarker levels (e.g., changes in glucose levels in people with diabetes); environmental sensors that detect toxins in food or water; and national security sensors that detect trinitrotoluene (TNT) or other explosives. Biosensors are among the most exciting near-future applications of organic electronics.

Biomaterials: Biomaterials are synthetic or modified natural materials such as polymers, metals, ceramics, biological materials, and composites. Of particular interest to nanotechnologists are RNA, DNA, peptides, and proteins, because they allow scientists to build large numbers of fairly large, atomically precise three dimensional structures. Although these biomolecular structures are not as stiff and strong as carbon nanotubes are, they can provide great specificity for self-assembly by offering many degrees of freedom in designs (EuMaT, 2012). Scientists have already developed complex designs of nanomotors and nanotweezers using biomolecules. Health and life-science areas that use biomaterials include lab-on-a-chip diagnostic devices, orthopaedic implants, dentistry, urology, gene therapy, growth and repair of organs, tissue engineering, ophthalmology, drug delivery, cardiology and treatment of vascular disease, and cosmetic products. The use of biomaterials will continue to expand in health and life sciences as well as in mechatronics to fabricate functionalized biomolecular machines and biomolecular tools. Functionalized biomolecular machines include synthetic biosequencers or bioassemblers that scientists make from ribosomes. Biomolecular tools include nanomotors, nanotweezers, and nanobiosensors, all of which comprise DNA sequences, peptides, proteins, or other types of biomaterials and see Figures 10 and 11(EuMaT, 2012).

Intermetallics: Intermetallic materials are distinct chemical compounds comprising two or more metals and have crystal structures that are different from those of the constituent metals. Strictly speaking, intermetallics have been in use since the beginning of metallurgy in the ancient times. The intermetallics that were used in that period derived from low-melting alloy systems of copper. The applications relied on the hardness and wear resistance as well as their decorative aspect. Examples are the coatings of Cu_3As for bronze tools used by the Egyptians and $Cu_{31}Sn_8$ used as mirrors by the Romans and the Chinese. Intermetallics generally exhibit an ordered arrangement of mixed atom species of metal-metal or metal-semi-metal (in silicides) types in near-stoichiometric composition, including Ni_3Al, FeAl, TiAl, $MoSi_2$, etc. In these examples, Ni, Fe, Ti and Mo take on the role of the metal, while Al and Si take the role of the other metal or semi-metal. The metal-metal and metal-semi-metal bond is partially metallic and partially ionic or covalent (EuMaT, 2012). Strong interatomic bonding leads to high values of the Young's modulus. The ordered superlattice structure means that larger shear forces are required to cause plastic deformation of the lattice leading to generally stronger and less ductile materials. The modern interest in intermetallic materials derives from a variety of attractive properties which they display. From a mechanical point of view, they can offer a compromise between metallic and ceramic properties when, for example, retention of high temperature strength is important enough to sacrifice some toughness and ease of processing. They can also exhibit desirable magnetic and chemical properties owing to crystalline order and mixed (metallic, ionic and covalent) bonding. Aluminides and silicides are the most notable group of intermetallic materials and have several engineering applications or are promising candidates for future applications (EuMaT, 2012) .

Metal - Ceramic Composites: The possibilities of combining reinforcing phases with metallic and/or ceramic matrices are huge. A new family of complex materials, metal-ceramic composites was thus formed offering a large range of properties beyond those provided by the unreinforced matrix. The metal-ceramic composites have attracted the interest of the industry and research organisations due to excellent mechanical properties combined with high and tailorable thermal and electrical conductivity, low to moderate thermal expansion, good wear resistance and good behaviour at high temperatures. Depending on the base material one distinguishes ceramic-matrix composites (CMC) and metal-matrix composites (MMC). The ceramic-matrix composites can be reinforced with ceramic and/or metal inclusions in the form of particles, discontinuous fibres (e.g. whiskers) endless fibers, or layered ceramic coatings or multilayers. Also, there is a new class of metal-ceramic composites with interpenetrating network microstructure like Al_2O_3/Al or Cu (alloys), TiO_2/Al (alloys), Al_2O_3/MexAly (intermetallic compounds) and see Figure 12 (EuMaT, 2012).

Functionally Graded Materials for Biomedical and Transport Applications: The mechanical and thermal response of materials with spatial gradients in composition and microstructure is of considerable interest in numerous technological areas. The graded transition in composition across an interface of two materials (for instance, metal and ceramics or polymer) can essentially reduce the thermal stresses and stress concentration at intersection with free surfaces. Similarly, the stress intensity factor at the crack tip can be altered by varying the gradient properties across the interface. The ceramic-metal FGMs exhibit higher fracture resistance parameters resulting in higher toughness due to crack bridging in a grade volume fraction. Varying thermal expansion in graded layers induces residual stress and affects the crack growth mode. In fact, the interface bonding is much improved by providing smooth composition variation when traversing the interface. The interest in graded materials focused primarily on the control of thermal stresses in elements exposed to high temperatures (to1600^{o}C), for instance in gas turbine blades, aerospace structures, solid-oxide fuel cells, energy conversion systems using thermoelectric or thermionic materials (thermal barrier coatings, TBC).

Subsequent applications of wide variety include fusion and fast-breeder reactors as a first-wall composite materials, piezoelectric and thermoelectric devices, high density magnetic recording media, in optical applications as graded refractive index materials in audio-video disks, in bioengineering as orthopaedic and dental implants, in structures as fire retardant doors and penetration resistant materials for armor plates and bullet-proof vests This section is of the SRA is focused on two representative "subgroups" of FGMs: (i) high-performance graded coatings for the aeronautic, automotive, machinery, and energy industry and (ii) functionally graded biomedical materials (such as implants for large defect repair and regeneration or biodegradable scaffolds for tissue engineering) , Figure 13.(EuMaT, 2012). The graded protective coatings deliver high temperature oxidation resistance, good mechanical/tribological properties, and/or oxidation and hot corrosion resistance as well as thermal insulation. In such materials, typically two components (TiAl-X, glass-ceramic, etc.) are mixed, and their volume fractions are varied along spatial directions, at one specific observation scale. Biological materials are, as a rule, characterized by microstructural and compositional gradients, well adapted to maximize the probability of survival.

These gradients are existing on several length scales - biological materials are hierarchically organized. Such highly complex organizations have been at the focus of basic science for decades, but they have also inspired the technological field. Composition and microstructures of many biological materials have been elucidated and understood, while the implications of this hierarchy on the materials' properties have been generally less understood (with notable exception of the elasticity of bone).Recent highlights in the biomedical FGMs comprise pore-graded 3-D scaffolds, produced by using a bioactive glass. Two types of porous structures were produced: (i) wholly porous scaffolds with pore gradient able to mimic the trabecular texture of cancellous bone, and (ii) double-structure scaffolds able to mimic the cancellous-cortical bone system by coupling a porous region with a compact layer. Most remarkably such structures exhibited mechanical properties comparable to those of natural bone tissue and therefore have the potential of replacing of load-bearing bone portions.

VAMs Applications: Africa is the world's top producer of numerous mineral commodities and has the world's greatest resources of many more, but most of Africa still lacks systematic geological mapping which could bring to light a much greater resource base. Unfortunately, most of Africa's minerals are exported as ores, concentrates or metals, without significant value-addition.Africa's dire need to industrialise is universally acknowledged. The structural transformation of our economies must be an essential component of any long-term strategy to ensure the achievement of the Millennium Development Goals (MDGs) in Africa, eradicate poverty and underpin sustainable growth and development across our continent. The key issue, however, is in the formulation and implementation of workable industrialisation strategies based on the continent's unique strengths, rather than the emulation of strategies that may have been effective in other contexts.Africa continent is believed to contain roughly 30% of the world's mineral reserves, much of it unexplored (Prichard, 2009).

Rio Tinto Plc and ArcelorMittal to announce intended investments of over $US25 billion on over 3000 miles of railway construction and 11 new ports across iron ore-rich West Africa (De Backer, 2012). sub-Saharan Africa accounted for 21 percent of the world's land mass, yet received only 4 percent of global expenditures on mineral exploration[7]
Continued innovation and human resources development are key to reducing the dependence on the initial factor endowment (natural resources) and to building and sustaining a locally embedded, competitive and diversified economy. Conversely, where there is underdeveloped human, knowledge, physical and institutional capital, as well as governance deficiencies, insufficient innovation systems, low rates of technology awareness and progress, and inefficient economic and business organization, it is impossible to turn the initial factor endowment into a platform to build successful clusters and diversified economies.In spite of the abundant and diverse solid mineral deposits in Nigeria[8] (about 44 different types of non-oil mineral resources including gold, copper, iron-ore, limestone, bitumen, lignite, coal, lead/zinc, gypsum, kaolin, sapphire, granite, laterite, sand, and clay) abound across the 36 States of the country and the Federal Capital Territory, Abuja, contribution of the solid mineral sector to overall GDP remains abysmally low and lags behind the figures for major African peers such as Guinea, Botswana, Democratic Republic of Congo (DRC), Ghana, Cote D'Ivoire and South Africa. Currently, solid minerals sector contributes averagely about 0.5 percent to GDP, accounts for about 0.3 percent of national employment and 0.02 percent of exports.

This contribution is a reversal of historically higher percentages of up to 5 percent in the 1960s–70s, when the economy was largely sustained by agriculture and exploration of solid minerals.

Climate: Short-term milestones in the environment and climate societal challenge concern building materials, namely those which are energy efficient (e.g., dye- sensitised polymer solar cells) and those obtained through recycling (e.g., ashes and again polymers). In parallel, there are needs for membranes for clean environment and polymers, ceramics and/or carbon-based materials for CO_2 removal. Materials for sensors are another group of interest in the short term, with particular requirements for multi-functionality in the context of environmental monitoring. Underlying requirements for all these materials families are ad hoc processing science. Reliable and inexpensive water treatment and storage is a mid-term challenge together with autonomous water treatment units for remote locations. In a longer perspective, bio-based and self-assembled new materials will present potential interest to face needs in the environment and climate challenges.

Health: Ageing and sedentarisation of the population are the driving forces for research in materials for health. Short-term milestones in this area are autonomous bio-sensors, non-invasive therapy and drug delivery, and polymeric coatings, biomedical and also architectured, for digital lenses. Additional needs concern simple biodegradable implants, scaffolds with angiogenic potential and sensors. For the latter, advanced polymers and other organic materials are needed for mobile patient monitoring. Mid- term milestones are lab-on-chip for fast, portable, multiplex diagnostics, implants with added biological factors, bioactive glasses with therapeutic ion release ability, with additional pronounced needs on surface chemistry functionalisation for cell expression.

Longer-term milestones are artificial muscles, superconductors and materials for nano-biomedicine, namely magnetic nanoparticles for cancer treatment. Also, dual-function (theranostic) optical fibres, resorbable bio-compatible Mg-based devices (for stents and orthopedic applications),patches for cardiac regeneration, biodegradable stents, artificial cellular factories for drugs, materials with tunable stiffness for implants and lab-on-chip for module organs (all/tissue dips). Milestones in a more visionary perspective are nanoparticles for combating infections and cell printing scaffolds(EuMaT, 2012).

Information and Communication: New (ceramic) materials for lasers, including high power ones, new optical fibers, and polymer composite (light) materials for telecommunications satellites are short-term milestones in the information and communication domain. There are significant, short-term needs for inexpensive electronics such as plastic ones for smart labels or low cost printed ones made from organic conductors and semiconductors with corresponding milestones concerning the production of throw away and flexible devices with acceptable lifetimes(EuMaT, 2012).

Food security and the bio-based economy: By 2025 this number likely will increase vastly (especially in Africa and South Asia), as food demand in emerging countries increases. Moreover, supply is likely to be reduced and food prices may prove prohibitive for the poorest groups because of the reduction of agricultural land, irrigation problems and the general effects of climate change[9].Value Added Materials in the chemical sector that support agriculture production may be an important factor in future solutions. In general the VAMs may not directly influence the food production sector apart from such applications as: advanced chemicals and biochemicals supporting agricultural production; and new packaging materials for food.

Water: Half of the world's population will face water shortages by 2035, according to the UN. Rising demands from population growth, greater consumption, and agricultural production will outstrip water supplies, which will become less reliable in some regions from groundwater depletion and changing precipitation patterns[10].Water suppliers are already using new technologies based on 'VAMs' influence can be expected to grow in the future. Applications for water supply systems include:

- Materials for advanced technologies to permit the re-use of waste water;
- Materials for treatment systems for rainwater harvesting;
- Materials that remove microbial pollution (including viruses) and emerging contaminants;
- Materials for seawater desalination by innovative solar-powered membrane distillation systems; Integrated long-term materials and components, based on innovative, cost-efficient technologies, for new and existing infrastructures;
- Materials for manufacturing nanoporous membranes (filtration, packaging, electrolytic devices, large surface electrodes);
- Materials that reduce energy and chemical use in water and wastewater treatment systems.
- Materials developments are often invisible to users of technology, but they are at the heart of so many important advances. The connection is clear between materials research and the energy technologies that we rely on today and those we need for our future.

Materials research and development is a global pursuit. It covers a broad set of science and engineering disciplines and engages researchers across academia, industry and government laboratories.

Materials research seeks to understand fundamental physical and chemical properties, and then use that understanding to improve the technology base that we count on to meet our needs for energy, national security and defense, information technology and telecommunications, consumer products, health care, and more will take the same long-term approach. This means investing in the leading-edge research and educating the next generations of scientists and engineers needed to secure our country's technological leadership. Despite these technological triumphs, a large part of the world lives without adequate energy. 1.5 billion people have no access to electricity, and the electricity grid is woefully inadequate in many other areas of the world. Tremendous opportunities currently exist for transitioning from carbon-based energy sources such as gasoline for engines to electric motors for transportation, as well as from coal-fired electric power generation to renewable, clean solar, nuclear and wind energy sources for electricity, and thereby dramatically

[7.] World Bank (1992) 'Strategy for African Mining' World Bank Technical Paper no. 181, Africa Technical Development Series, Mining Unit, Industry and Energy Division (Washington, DC: World Bank.

[8.]Nigeria's Mining and Metal Sector Investment Promotion Brochur August, 2016 increasing the capacity and reliability of urban grids in high density population countries like Nigeria, China, Brazil and India. These advances will require a new generation of advanced materials, including:

- Battery materials for massive electrical energy storage
- High-efficiency andlow cost solar cells
- Corrosion-resistant alloys for high-temperature power conversion
- Strong lightweight composites for turbine blades
- Superconducting power distribution cables
- Advanced power handling electronics, and more.

Materials developments are often invisible to users of technology, but they are at the heart of so many important advances. Materials research and development is a global pursuit. It covers a broad set of science and engineering disciplines and engages researchers across academia, industry and government laboratories. Materials research seeks to understand fundamental physical and chemical properties, and then use that understanding to improve the technology base that we count on to meet our needs for energy, national security and defense, information technology and telecommunications, consumer products, health care, and more will take the same long-term approach.This means investing in the leading-edge research and educating the next generations of scientists and engineers.

Smart, green and integrated transport: Transport is rightly considered as a key societal challenge. It should be also kept in mind that transport is a key condition for competitiveness. Value added materials will play a central role in one of the key grand challenges - green transport.

- Innovative solutions for transport address materials and manufacturing processes for lower fuel consumption and development of alternative fuel sources. Materials science is engaged in developing new construction materials for roads and rail roads, as well as materials for transport security.
- It must be noted that advanced materials are used now in the transport industry to a very large extent. This may be seen in the advanced cars produced today.

Advanced cars begin with a chassis of complex aluminium composite (machine materials optimization) . In many cases they are covered with nano enhanced, self-healing coatings, with anti- reflex windows produced of advanced glass. The interiors are filled-in with advanced electronics and sensors. Finally, energy supply in combustion vehicles uses a number of composites based on polymers and ceramic materials. The future holds more environmentally-friendly solutions, with advanced materials used for efficient energy storage as well as materials for alternative energy production (hydrogen fuel cells, photovoltaics, and so on). The 'green' aspect of transport is very much aligned with two other Grand challenges described here– 'resource efficiency and climate action' and 'secure, clean and efficient energy'. Further examples of applications of VAMs for transport will be developed in other sections.Transport is rightly considered as a key societal challenge. It should be also kept in mind that transport is a key condition for competitiveness.'[12]

[9]"How to Feed the World in 2050", at FAO Headquarters in Rome on 12-13 October, 2009.

[10]. Global Trends : Paradox of Progress. A publication of the National Intelligence Council, 2017. NIC 2017-001 ISBN 978-0-16-093614-2 www.dni.gov/nic/globaltrends.

Analytical Tools: Characterisation of advanced materials, and par- ticularly of materials with necessarily complex structures such as bio and functional ones, requires analytical tools for observation and monitoring all relevant length scales (nano, micro, meso and macro). Moreover, detailed insight in the matter through analytical tools beyond the state of the art will be an invaluable contribution to the modelling of the structure-properties relationship and there- fore to understanding, controlling and monitoring properties and performance of materials, devices and systems (Figure 12). Such tools should demon- strate high spatial resolution and ability to follow the behaviour of the material systems in time. In this perspective, recent progress has been made on synchrotron-based methods with respect to in situ capabilities as well as nanofocusing, pushing the spatial resolution further into the nm range. Analytical tools should be able to operate in situ, in an operating environment involving, for exam- ple, high pressure or living organisms. Surface analysis is a particular field requiring appropriate analytical tools using ultrahigh vacuum electron microscopy and also very low energy modes of the electron microscopy and spectromicroscopy and see Figure 14.

Free Electron Laser (FEL) facilities have emerged as a novel scientific tool and should be developed for detailed structural analysis at timescales down to femtoseconds. Furthermore, materials processing requires in situ analytical tools, which contributes to the optimisation of the process itself (by providing process modelling with reliable data) and also to the processing-structure relationship. There is a crucial need for the combination of local tools, facilities and infrastructures as well as large facilities. It is worth recalling here the pan-European effort to produce a comprehensive inventor y of research infra- structures of major relevance in Europe across all scientific domains. This project, entitled Mapping of the European Research Infrastructure Landscape (MERIL), is accessible to the public through an interactive online portal.[13]
Figure 14. Analysis in 3D and at the atomic scale of a MOS transistor by atom probe tomography [14](APT): A transistor has been extracted from SRAM memories (a) using focused ion beam and shaped into a tip (b) to be analysed by APT (c). In (c), the atoms drawn as points define the transistor parts: contact (NiSi), gate (poly-Si) and spacers (SiO2). The arsenic atoms (dopants) have been enlarged to show the segregation at the NiSi/Si interface that changes the electrical properties.

Characterisation of advanced materials, and particularly of materials with necessarily complex structures such as bio and functional ones, requires analytical tools for observation and monitoring all relevant length scales (nano, micro, meso and macro). Moreover, detailed insight in the matter through analytical tools beyond the state-of -the -art will be an invaluable contribution to the modelling of the structure-properties relationship and therefore to understanding, controlling and monitoring properties and performance of materials, devices and systems . Such tools should demonstrate high spatial resolution and ability to follow the behaviour of the material systems in time. In this perspective, recent progress has been made on synchrotron-based methods with respect to in situ capabilities as well as nanofocusing, pushing the spatial resolution further into the nm range. Analytical tools should be able to operate in situ, in an operating environment involving, for example, high pressure or living organisms. Surface analysis is a particular field requiring appropriate analytical tools using ultrahigh vacuum electron microscopy and also very low energy modes of the electron microscopy and spectromicroscopy. Free Electron Laser (FEL) facilities have emerged as a novel scientific tool and should be developed for detailed structural analysis at timescales down to femtoseconds.

- Cell and Tissue Engineering Laboratories; five dedicated cell culture laboratories, a molecular biology facility and general purpose laboratories
- Confocal microscopy unit incorporating two confocal microscopes, enabling advanced 3D imaging of living cells
- Mechanical Testing Facilities
- NanoVision Centre; our state-of-the-art microscopy unit bringing together the latest microscope techniques for structural, chemical and mechanical analysis at the nanometer scale
- Spectroscopy Laboratory.
- Thermal Analysis Laboratory.

Research Industrial/Sectorial Partnerships: Research paradox in Africa is particularly evident further downstream, at the later stages (after proof-of-concept) of what is often called the 'valley of death ' in the innovation chain or the ' market evolution of start-ups'. The lack of sufficient public–private funds for prototyping after technology validation has demonstrated the innovative potentialis a clear example of the existing shortcomings for converting scientific results into products. This gap is an intrinsic feature of a market economy. To negotiate the valley and to become more competitive, Africa needs its own tailored funding models for pilot lines and prototype production facilities. The so-called 'knowledge society' is necessary for but not alone sufficient to sustain a modern economy. Knowledge must be exploited through innovative manufacturing facilities. New materials, new processes and life cycles underpin manufacturing innovation.

Partnership With Academic Institutions: VAMs R&D activities on potentially disruptive processes / products. This carries the risk that some breakthrough from research laboratories may not find timely implementation in the market through the involvement of Nigeria /Africa companies. To facilitate industry's participation in high-risk research that has medium-term application potential, new and flexible public-private-partnership (PPP) initiatives need to be explored and tested in VAMs. These new PPP experiments should include SMEs, industrial consortia, academia, Research and Technology Organisations (RTOs) and governmental research organisations. Whilst they should minimise the risk to SMEs for participation, these PPPs should target medium- to long-term technology validation even where a practical return on investment in the form of new products is not predictable .PDF. VAMs is profiling of 11 classes of materials:

- Multi-functional materials
- Multi-structural materials
- Metamaterials and artificially structured
- functional materials
- Nano-enabled materials in metallurgy, forestry,
- energy efficiency, etc.

- [13]. http://portal.meril.eu/converis-esf/publicweb/research_infrastructure/3395 Informal discussion with stakeholders on the transport component of the next common strategic framework for research and innovation, Brussels, 16 June, 2011.
[14]. Panciera F, Hoummada K, Gregoire M, Juhel M, Bicais N, and Mangelinck D (2011). Three dimensional distributions of arsenic and platinum within NiSi contact and gate of an n-type transistor Applied Physics Letters 99, 051911 (2011)

- Bio and bio-based materials
- Bio-inspired materials
- Materials for targeted surface properties
- Metals
- Ceramics, including cement and glass, and composites including natural fibres
- reinforcement
- Polymers
- Soft materials.

Knowledge Diffusion: VAMS will "link" industry/academia clearly indicates that values underpin all engagement activity, be that in the form of 'Engagement Practices or Engaged Scholarship activity'. Engagement is not a passing phase or for the faint of heart. Creating engagement will not be easy for it faces considerable resistance by institutional inertia, traditional definitions of scholarship and pressures from a market-based economy. The promise of engagement however lies in its potential to rejuvenate the academy, redefine scholarship and involve society in a productive conversation about the role of education in the new century. Engagement is higher education's larger purpose (Brukardt et al. 2004). In soild mineral sector in Africa, this wave of mining code liberalization would continue to be adopted across a large number of African states. In sum, the pressures introduced by international donors and financial institutions, along with the post-independence history of underperformance by state-run enterprises in the mining sector, led to the widespread adoption of liberalized mining codes across the. African continent but no impacts of academia in development of raw materials or value additions. These reforms most often restricted the role of the state from one of owner-operator to a benign "facilitator" of private sector investment. To the extent that natural resource management strategies directed at environmental or social protections informed these legislative shifts, they remained heavily reliant on "self-regulation" by private sector operators.Natural resource dependency also insulates national leaders from public pressure since they do not rely on taxation of their populations for revenue, with an established correlation between resource abundance and political corruption (Ross, 2012).

Africa Raw material development: One of the most noteworthy recent initiatives has originated from African nations themselves, through the adoption of the Africa Mining Vision (AMV) by Heads of State at the 2009 African Union (AU) summit. The AMV advances a holistic framework for improving Africa's mining regimes, focused on balancing the requirements of transparency and accountability with the need to integrate mining into Africa's long-term development at the local, national and regional level. Above all, this means transforming natural resource capital and "transient" wealth into lasting forms of capital and industrial growth, with the ultimate objective of reducing African states economic dependence on primary resource exports. The AMV demands a "knowledge-driven African mining sector that catalyses and contributes to the broad-based growth and development of, and is fully integrated into, an African market" .VAMs will use this as a platform for value addition of raw materials. In African Union-speak, this is a call for a continent-wide commitment to beneficiation. Beneficiation is the grafting of a macroeconomic vision onto mining policy. It is easier conceptualised than realised. VAMs will focus on industrial minerals across Africa, which are commodities, single or group, whose ‘physical or chemical properties, and not their metallic, energetic or gem properties are the main basis for industrial purposes’ (Karlsen and Sturt, 2000). Examples include calcium, potash, pumice, calbonate, feldspar, quartz/quartzite, talc, graphite, dolomite and mica. The main consuming markets for these products are indicates, abrasives, absorbents, agriculture, cement, ceramics, chemicals, construction, oil well drilling, electronics, filtration, foundry, glass, metallurgy, paint, pigments, paper, plastics, refractories, flame retardants and welding (Driscoll, 2004). But as ‘manufacturing in using VAMs in Africa countries is an infant industry’ (Hoestenberghe and Roelfsema, 2006), detailed market analysis is necessary to determine those industrial minerals that can contribute to the growth of local industries. Demand from emerging technologies (including demand for rare earths) is expected to increase significantly by 2030, according to EU estimates.[15]

VAMs Infrastructure for Development: Engaged teaching and learning links student academic activity to the “real world” by integrating disciplinary knowledge into communities local, regional, business/industry or special interest. The development of new knowledge requires a move from highly abstract and philosophical statements [to] a real world of budgets, deadlines, office politics (Davenport and Prusak, 2000). Engaged teaching and learning also strengthens the relationships between higher education and communities. The need to provide connection between the real world and curriculum (Bradley et al., 2007); to encourage curriculum development that would include contribution from the community, including students, in activities that are 'collaborative problem-based, interdisciplinary, intentional and respectful' (Brukardt et al.,2004); to improve the quality of curriculum and teaching and learning delivery (Buys and Bursnall,2007); and to provide curriculum context (Favish and McMillan, 2009).

Combinatorial Chemistry and High Throughput Materials Science and Engineering: There is a lack of available extended materials libraries with well identified processing-structure- properties (and performance) relationships with regard to the huge number of the available pos-sibilities.[10]This situation is strongly antinomic with today’s societal needs, requiring beyond the state of the art technologies and materials solu- tions. Meeting such pronounced societal needs involves either incorporation of new function- alities into ‘classical’ materials (ceramics, metals, textiles, paper, building and construction, etc.) to give them a higher added value, and/or identifica- tion of new materials with original properties or multifunctionality. Taking into account that (i) variety is high, (ii) opportunity is high, (iii) prob- ability of finding the best solution is low, and (iv) sampling and screening process is time consuming, such requirements are incompatible with the ‘one at a time’ methods that are mainly used nowadays. Although well established, a further application of these methods is expected to lead to slow innovation rates, and to expensive, time- and resources-con-suming processes. Hence, a solution must be found to overcome the problems related to the number of possible combinations of ternary and higher order systems and to the subsequent extended fields of properties to be explored, managed, mined and modelled. Alternative routes to meet the need for high throughput screening of complex systems has been provided by the pharmaceutical and biotech- nology industries. In these fields, automation of the fabrication of specimen arrays, screening techniques and informatics have hastened the development of important new drugs and genetic therapies, which accounts in part for the biotechnical revolution now in progress. Combinatorial, high throughput processing of materials of variable composition, screening of their (micro-)structure and properties, and efficient solutions for the storage, the manage- ment and the mining of data libraries are requested (Figure 13). The need for detailed data libraries iscoherent with the increasing performance of modelling tools which requires stronger and faster experimental validation. modelling and more precisely of computational materials science to future materials and challenges is provided in the ad hoc science position paper elaborated by MatSEEC.[11]

Soft Exoskeletons: Ambitious Defense Advanced Research Projects Agency (DARPA) projects that could revolutionize the armed forces is the wing of the U.S. Department of Defense that’s responsible for developing emerging technologies for military use. With everything from brain implants to robo-suits, the agency trying is hardest to make future tech a 2018 reality and to do it sooner than those who would seek to use that technology against the United States. Soft exoskeletons is a cutting edge technologies can also be used to “supercharge” troops by giving humans enhanced abilities, including faster speeds and greater strength. Working with researchers from Harvard’s Wyss Institute for Biologically Inspired Engineering, DARPA’s Soft Exosuit is a lightweight skeleton frame for soldiers which can augment its wearer’s strength and endurance; using in-built sensors and a micro-computer to intelligently match the requirements of its user. Human body offers you all kinds of feedback about how you are faring when it comes to health. However, a DARPA project created in association with the U.S. Army Research Office promises to take this to the next level - courtesy of tissue-integrated biosensor technology. The idea is to implant tiny soft hydrogel-based sensors under the skin, and use them to measure biomarkers related to oxygen, glucose, lactate, urea, and ion levels. These sensors could stay in the body for up to two years, and read out information direct to connected devices like smartphones. A consumer-facing version of the same technology could one day help individuals manage chronic diseases such as diabetes.

Self-guiding bullet: A sniper bullet that changes trajectory after its been fired sounds totally like the stuff of science fiction. However, it describes a real life project being carried out by DARPA which could soon nullify misfiring problems related to weather conditions, wind or plain old shooter errors. EXACTO ammunition uses an in-built guidance system to keep it on target. Sadly, the whole “secret government project” thing means that specifics about how the guidance system works are classified.

The Impacts of VAMS- The Fourth Industrial Revolution: The proposed impacts of VAMS in the regional engagement (Figure 16). The future project Industry 4.0 relates to an approach to industrial history, proposing four industrial revolutions. The first of these revolutions was based on the introduction of water and steam power. The second one focused on electrical energy and industrial forms of organisation, emphasising the division of labour.

[15] Report of the Ad hoc group on defining critical raw materials, June 2010, Brussels. http://ec.europa.eu/enterprise/policies/raw- materials/ files/ docs/report-b_en.pdf

In a way, these two early revolutions depend crucially on innovative form of power supply. In contrast, the third and fourth revolutions relate primarily to information and communication technologies (ICT). In this context, the third industrial revolution used ICT for automatic control of production machinery. The upcoming fourth industrial revolution takes this to a qualitatively new level characterised by the employment of Cyber-Physical Systems (CPS). CPS are distributed smart systems – microsystems or MEMS (Micro Electro Mechanical Systems) – including electronic, mechanical and possibly also optical or fluidic components. Usually, they also include sensing, information processing and (rather en) actuating functions and are embedded in communication networks; this is also how CPS relates to the Internet of Things (IoT) paradigm and see Figure 15 above. VAMs powers the IoTs globally.

Figure 15. Thin film combinatorial materials science is based on fabrication of materials libraries by special (sputter) deposition processes. Binary, ternary as well as large fractions of quaternar y materials systems are fabricated in a single experiment. Libraries are characterised by high throughput methods in order to determine ef ficiently compositional, structural and functional properties. The resulting data is visualised, e.g., in a ternar y composition triangle. Colour coding helps identif y regions of interest, which can be investigated in more detail in a 2nd combinatorial cycle[12]. They are able to perform processes in perception, cognition, and action which are said to become increasingly closer to human performance. The 'intelligent' capacities of CPS usually emerge from more or less flexible- cooperation of distributed systems. In this regard, CPS is also related to the concepts of Pervasive Computing and Ambient Intelligence. Beyond CPS themselves, aspects of Human Machine-Interaction (or, eventually, even Human-Machine-Cooperation) as new forms of industrial organisation and rather socio-economic phenomena need also to be taken into consideration for successful implementation of Industry 4.0

The Internet of Everything @VAMS: The internet is the physical layer or network made up of switches, routers, and other equipment. Its primary function is to transport information from one point to another quickly, reliably, and securely. The web, on the other hand, is an application layer that operates on top of the Internet. Its primary role is to provide an interface that makes the information flowing across the Internet usable The Internet of Everything (IoE) of Internet of Things (IoT) is about building up a new infrastructure that combines ubiquitous sensors and wireless connectivity in order to greatly expand the data collected about physical and economic activities; expanding 'big data' processing capabilities to make sense of all that new data; providing better ways for people to access that data in real-time; and creating new frameworks for real-time collaboration both within and across organizations. The result: individuals, companies, military and governmental organizations will be able to near- instantaneously adjust decisions to a continually changing complex environment. We are already seeing the start of this, as drivers have become accustomed to using the traffic data from Google Maps-garnered from smartphones in cars-to change their routes on the fly.

While pervasiveness increases through new applications and wider adoption, the scalability requirements of the Internet of Things have to be met and see Figure 16. A full understanding of the system-level complexity, cost reduction of key components driven by economy of scale, interoperability, standards and clear business propositions will drive wide-scale deployment and adoption of (IoE) applications and services. Investment in sensors, data and communications infrastructure will support this expansion. International governance frameworks will be in place and there will be a high level of choice and control in how people interact with and use a range of robust and reliable (IoE) services. IoE devices can sense and communicate via the Internet, they can go beyond local embedded processing to access and take advantage of remote super-computing nodes. This allows a device to run more sophisticated analyses make complex decisions and respond to local needs quickly, often with no human intervention required. Connecting those smart devices (nodes) to the web has also started happening, although at a slower rate. The pieces of the technology puzzle are coming together to accommodate the Internet of Things sooner than most people expect. Just as the Internet phenomenon happened not so long ago and caught like a wildfire, the Internet of Things will touch every aspect of our lives in less than a decade. Are you ready for it?

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[10] An illustration of the huge number of possibilities which remains unexplored is that with approximately 80 metallic elements available, one expects more than 6,000 binary systems, and at least 500,000 ternary and 40,000,000 quaternary ones. Up to now, not all binary systems and less than 8,000 ternary ones (not to mention quaternaries) have been looked at crystallographically but, with the exception of a few cases, there is no information on their physical and chemical properties. Corollary to this context, ternary or quaternary alloys in which three or four components, at comparable quantities, determine the basic properties (e.g., the precipitate-hardened nickel alloys) are only scarcely used in metal- based industries.

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