Connect Webinar

Hidden Heroes in Energy Technologies: Advanced Ceramics

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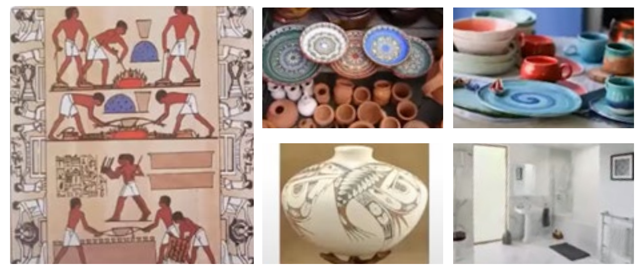
Ceramic Materials

Ceramics are inorganic and non-metallic materials obtained through heat treatment at high temperatures. They can be crystalline, partially crystalline or amorphous. They are divided into two main groups: traditional ceramics and advanced ceramics.



Daily use of ceramics

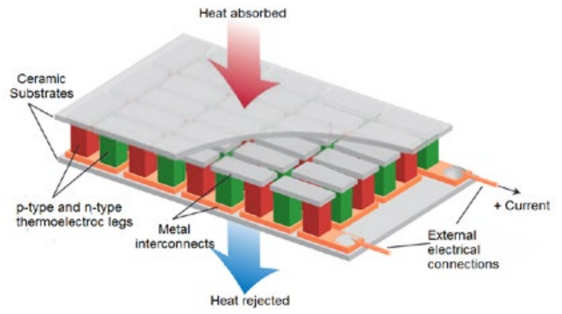
What is the Difference of Advanced Ceramics?

Advanced ceramics display different niche properties, compared to the traditional ceramics. They are such materials capable of increasing the productivity as there can be applicable to the industry and integrated into different systems. Apart from these, they also differ in terms of raw materials, production methods and structurally. They have a high resistance to heat, high corrosion resistance and they can also be biocompatible. Besides, they have a very good electrical, thermal and mechanical properties, which in turn enable the use of advanced technology ceramics in technological applications, differently from the traditional ceramics.

1) Nitrides
2) Silicates
3) Carbides
4) Oxides

Thermoelectric Devices and Applications

Thermoelectric devices are the units that convert heat energy into electrical energy. This transformation takes place due to Seebeck effect which occurs when a temperature gradient is applied to a material. The carriers tend to diffuse from hot side to cold side of the material and as a consequence of this flow a net charge occurs at the cold side. As a result, an electrostatic potential is created which is used to define the Seebeck coefficient.

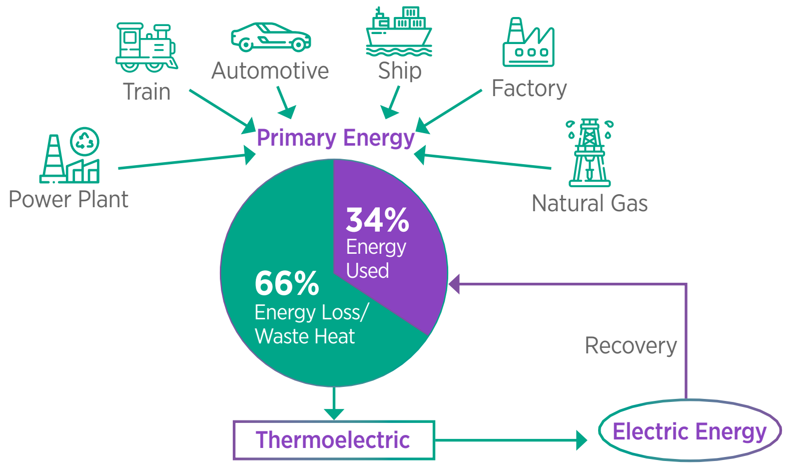


Structure of thermoelectric modules[1]

Thermoelectric devices contain many thermoelectric couples consisting of n-type (containing free electrons) and p-type (containing free holes) thermoelectric elements wired electrically in series and thermally in parallel. So, thermoelectric module is formed one of those pairs that are combined in between two ceramic substrate.

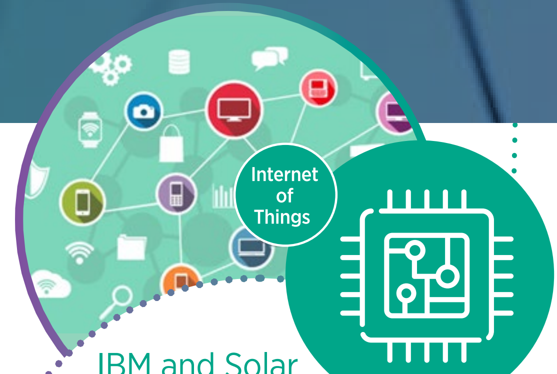
Use of thermoelectric devices for different purposes[2]

Thermoelectric materials can be used in many areas from the automotive industry to aerospace applications to solar towers and sensors. For example, the heat generated by the automobile while it is running can be converted into electricity and reused, thanks to thermoelectric modules. NASA's spacecraft Voyager uses a generator consisting of thermoelectric modules.

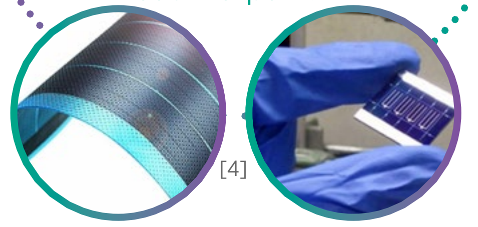


Internet of Things and Thermoelectric Devices[3]

Internet of things is the communication network that enables the physical systems through which you connect to the internet and the information systems to operate by communicating with each other. This communication network is currently in use and it appears as a system that we will definitely use more widely in the future. We will witness that both the batteries supplying power to the micro sensors, and the thermoelectric modules used in these systems will reduce in size in the future. This will happen with the thin-film technology, which enables us to produce materials in smaller sizes and to achieve higher performances.



IBM and Solar Frontier will carry out joint studies for thin-film solar cell technology that can be produced using less costly and naturally-abundant materials. Thin film solar cell formed with a combination of copper, zinc, tin, sulphur and selenium elements have advantages over their counterparts.[5]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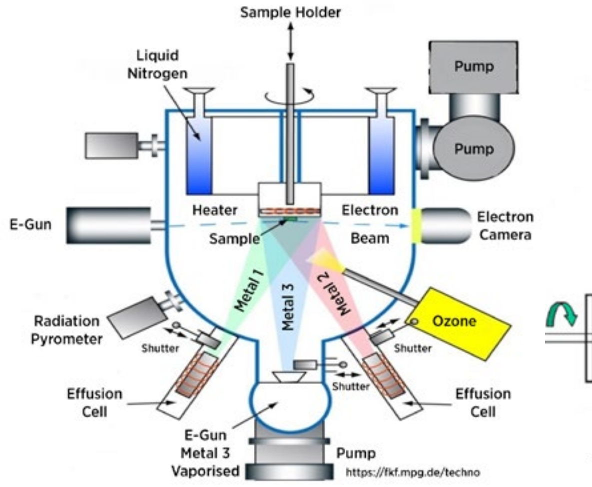
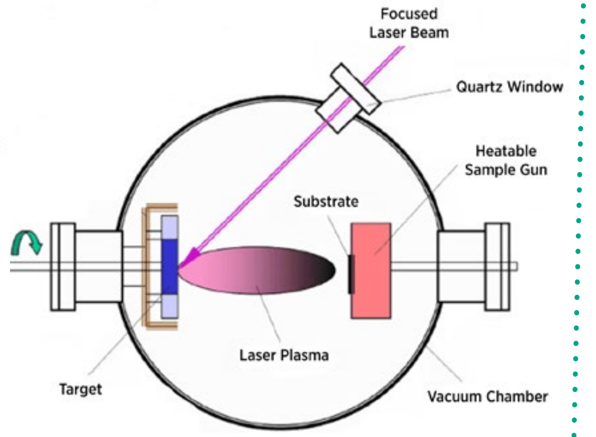
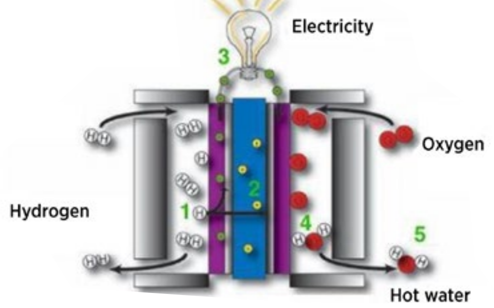




One of the thin film synthesis methods, oxide molecular beam epitaxy (MBE) method can be considered atomic spray painting. By controlling the shutters of the effusion cells and the temperature in the system, required structure is synthesized on the heated substrate. Another thin film synthesis method is the pulsed laser deposition. In this method, the surface layer of a multi-component target is vaporized with a UV laser, which is then condensed on a substrate in a low-vacuum environment, and thus a thin film is obtained. The target material here consists of the sintered composite of the ceramic film we want to enlarge [7]. Using both techniques, ultra-thin thermoelectric ceramic films can be synthesized by controlling at the atomic level that can be used for instance, in sensors for IoT applications. [8,9].

Fuel Cells, Battery Technologies and Advanced Ceramics

Ceramic materials are used in the cathode material, electrolyte material and anode materials in a solid oxide fuel cell. For example, yttrium doped zirconium oxide appears as the anode material for high-tech ceramic. Likewise, silicon manganese oxide is one of the ceramics that can be used in this application owing to their ionic conductivity. Since these devices operate at high temperatures, the materials which are chemically and mechanically stable are needed. Therefore, silicates, for example, are used as cathode support to them. Today, in addition to oxide-based ion-conducting ceramic electrolytes, ceramic electrolytes that provide proton conduction have also started to be used.

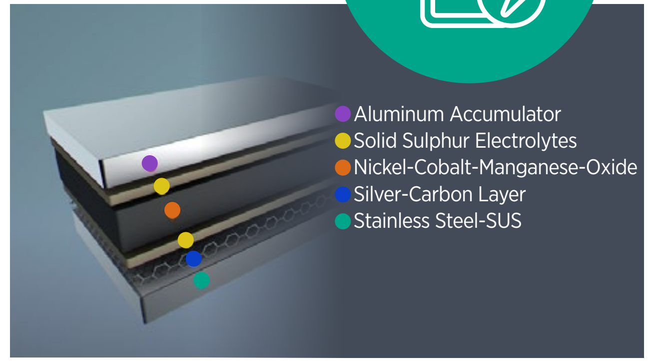


One of the areas where advanced ceramics are used is the battery technologies. Batteries are used for a wide range of purposes in daily life. The performance of battery defines on the performance of mobile phones, one of the mostly used devices, and how long we can use it.

Today, lithium ion technology is the mostly used one in battery technology. In the near future, we will see solid-state batteries, especially in e-mobility applications. Solid-state batteries are the batteries that have higher energy density by allowing for the use of lithium as an anode, in which we can use solid electrolytes instead of liquid electrolytes, therefore they are safer batteries. However, they are more costly. [10] The solid electrolyte material used in these batteries (e.g. oxides, sulphides, phosphates) is ceramic-based. Moreover, it is thought that these batteries will find usage in the pacemakers, RFID and wearable devices.

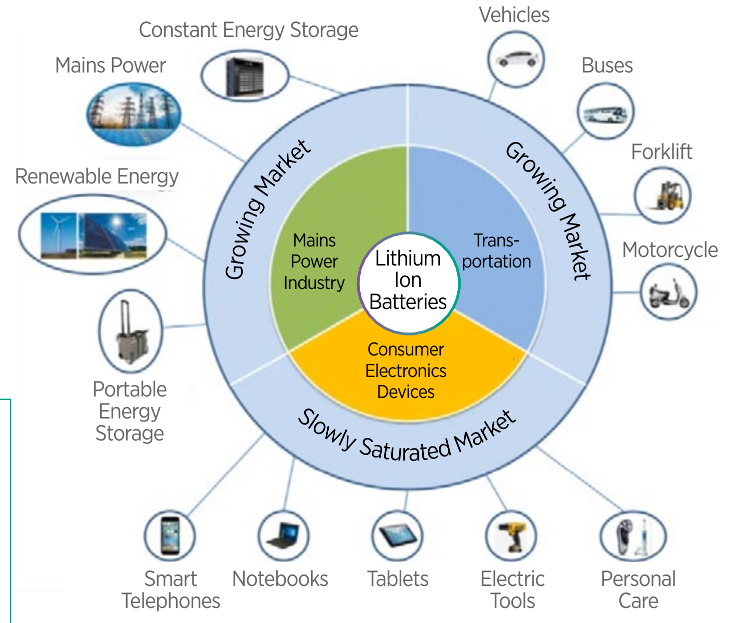
Comparison of traditional LIB structure and energy output to that of next-generation SSBs. [10]
LIB: Lithium Ion Battery

2019 Nobel Prize in Chemistry was awarded to John B. Goodenough, M. Stanley Whittingham and Akira Yoshino. Scientists have carried out a study on the "development of lithium-ion batteries".



Leading Edge Solid State Battery - 900 Wh/L Samsung 2020 [16]

Solid state batteries, which will be able to provide lower risk and higher energy density in comparison with the weight, concern all sectors, especially the automotive sector. The disadvantages of lithium-ion batteries can be solved with this advanced technology. Furthermore, solid state batteries are expected to be cheaper, smaller and to last longer than the lithium batteries we use today. Advanced ceramics are also the key materials in solid-state battery technology, as in many other areas. These 'hidden champions' often go unnoticed by the user and the consumer, but they play a critical role for generating sustainable and secure energy in the future[11].

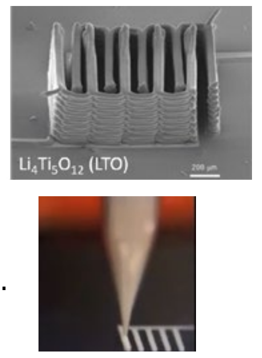


Applications of Lithium Ion Batteries in three main areas, including consumer electronics and devices, transportation, mains power and industry [12]

Advanced Technology Production Methods New Techniques

1. Additive Manufacturing

A) Printing with 3D Printers
The production and printing of a ceramic-based ink with 3D Printers. The example above shows Lithium Titanium Oxide-based anode material produced in small size, with a 3D printer[13].



B) Laser Based Systems
With this technique, it is possible to significantly improve the rate capability of cathodes within the range of porosities and active mass loading investigated here by an appropriate laser treatment after calendering.[14]

2. Cold Sintering

A technique that allows much shorter sintering times at lower temperatures, and especially its use in future battery technologies foresees the introduction of innovative products. [15]

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