Impact of Ceramics in Alternative and Renewable Energy – A Review

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Abstract

Global energy consumption is forecast to increase 44% from 2006 levels by 2030. While the use of natural gas and coal will grow the fastest growing source of energy will be renewable. Ceramic materials are at the beacon of this fast energy trend. This paper examines synthesis, characterization and the impact of ceramic materials in renewable and alternative applications such as solar power and concentrate/solar fuel, batteries, nuclear power, energy harvesting and wind energy. The paper also explores the competitive edge renewable and alternative energy ceramic materials are gaining over conventional materials and fossil. In the end, conclusion and recommendation were advanced.

Keyword: Ceramic materials, renewable and alternative energy.

Introduction

Mankind has found applications for ceramic for the past 30 millennia, every day new and different applications are being discovered. This truly makes ceramics a Stone Age material, with space age qualities. The numerous branches of ceramic technology are frequently classified as either traditional or advanced .traditional ceramics. These include the older technologies, such as clay products, silicate glass and cement, while advance ceramics consist of carbides, pure oxides, nitride, non-silicate glasses and many others (Saito, 1988)

Schartz (1992), classified ceramic materials to include minerals, vitreous ceramic, refractory groups, cement and concrete, glasses and diamond. Ceramic materials offer many advantages compared to other materials they are harder and stiffer than steel, more heat and corrosion resistant than metals or polymers, and their raw materials are both plentiful and inexpensive. Ceramic material displays a wide range of proportion which facilitates their use in many different areas. Alternative and renewable energy are recent research and development field where ceramic materials are helping to keep our planet cleaner while meeting enormous energy consumption of increasing human population.

This paper reviews recent contribution on the impact of ceramic materials in alternative and renewable energy as a panacea to global warming and future substitute to fossil fuel.

Synthesis of Energy Ceramics

Various methods are employed in synthesizing ceramic materials for energy applications.

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Table 1: Shows mechanochemical, solid state reaction and wet methods of synthesizing

S/N	METHODS	DESCRIPTION	REFERENCES
1	Mechanochemical	Mechanochemical alloying, high-energy, milling, or high energy activation	Suryanarayana.C., et al 2001. Weeber .A.W., et al 1998. Zhang. D.L., et al 2004 Harris J.R, et al 2001 Fores. F.H., et al 2001 Hong H., et al 1996. Koch C., 1998
2	Solid state reaction	Sintered oxide based ceramic	Zonghai C., et al 2011
3	Wet-chemical	Sol-gel, Solvent Precipitation, Hydro/Solvent	Elenal A.T., et al 2012

CHARACTERIZATION OF ENERGY CERAMICS
Analyse the numerous techniques employed in characterizing energy ceramic microstructure, thermal analysis, spectra analysis and electric/ferroelectric measurement are the often used.

Table 2: Shows characterization techniques employed in energy ceramics

S/N	CHARACTERIZATION	DESCRIPTION	REFERENCES
1	- Atomic Force Microscopy - Transmission Microscopy and Spectroscopy - Scanning Electroscopy - X-ray Diffraction	Microstructure	Kong,L.B., et al 2008.
2	- Differentiate Thermal Analysis (DTA) - Differentiate scanning Calorimetail (DSC) - Thermogravimetery (TG) - Thermomechanical Analysis (TMA)	Thermal Analysis	Kong, L.B., et al 2000 Brankovic, Z., et al 2003 Kong, L.B., et al 2001 Xue, J.M., 2000 Vaidhyanathan, B. et al 2001 Kong, L.B., et al 2002 Wang, J., et al 1999 Xue, J.M., 1999 Wang, J., et al 2000
3	Raman Scattering and Infrared (IR) Reflection Transmission	Spectra Analysis	Tan, Y.L., et al 2000 Dias, A. and Moreira, R.L, (2003)
4	- Related Dielectric constant - Hysteresis loops - Piezoelectric coefficients - Pyroelectric	Electrical and Ferroelectric measurement	Gao, X.S., et al 2002 Kong, L.B., et al 2001

Renewable and Alternative Energy

Renewable energy is energy generated from natural resources such as sunlight, wind, rain and geothermal heat, which are renewable (Naturally replenished). Renewable energy technologies range from solar power, and power hydroelectric/microhydro, biomass and biofuels for transportation. This energy cannot be exhausted and is constantly renewed.

Alternative energy is a term used for an energy source that is an alternative to using fuels generally, it indicated energies that are non-traditional and have low environment impact. The term alternative is used to contrast with fossil fuels according to some sources. By most definitions, alternative energy does not harm the environment, a distinction which may or may not have significant environment impact. (Fetherly, 1957).

Ceramic Materials in Batteries and Energy Storage

Batteries are devices that convert chemical energy into electrical energy. There many types of batteries available, representing a multi-billion dollar industry. The state –of-the-art electrical energy storage systems are not able to meet the requirements for energy-efficient use in transportation, grid and commercial technologies. Battery technology seeks news concepts in materials design to overcome the cement limitations of performance and life time. More critical insight is required to both in terms of material structures as well as interfacial reaction. To produce next generation electrode materials and battery cells enabling higher energy densities and longer cycling abilities.

The nano ceramic material known as Cobaltite (Calcium Cobalt Oxide, $CaCo_4O_9$) is employed as a recent breakthrough renewable and alternative energy material in battery anode and cathode component. With this ceramic material for a capacitance value can be achieve upward of 700mm Ah/g (Edwards, 2013). This ground breaking effort is helping to improve battery in telecommunication site backup power, hybrid locomotive, and more.

Ceramic Materials in Nuclear Power

Nuclear power extracts energy from controlled nuclear reactions. Ceramics are helping to improve performances previously limited by available materials and in the development of advanced materials that withstand harsh operating environment.

Silicon carbide ceramic composite became the choice nuclear fuel rod container material after the 2011 Fukushina Daiichi nuclear power plant disaster in Japan. EWI materials group in 2013 tested sic ceramic-matrix composite as replacement for the previously used zirconium alloy fuel cladding in light water reactors. Although the silicon carbide cladding or container would not have prevented the Japanese disaster, it might have prevented some of the cascading problems that occurs including the deteriorative of the zirconium alloy cladding, an event that eventually contribute to chemical reaction that resulted in the explosion at the Fukushnia reactor (Herderick 2013).

Ceramic Materials in Solar

Power contractors and solar fuels concentrated solar power (CSP) is becoming a technology for large scale, and power generation using solar energy. There is significant ongoing effort worldwide to bring down the cost of producing electricity from CSP. This requires development of new materials. CSP is a small but growing source of clean energy which comprises about 2 percent of global energy production and is expected to grow significantly over coming decades (Levinson 1996).

Two types of generators are being developed, a field of parabolic reflectors and a solar tower. Ceramics are used in both to provide the crucial high temperature materials which liven the chamber where the sun rays are focused. Porous silicon carbide foam is use as the best absorber material which transfer and distribute heat flux focused by heliostats (Erik, 2012).

Solar Fuels

Direct production of fuels from solar energy represents the most prominent and promising avenue for sustainable energy solutions derived from regenerative, primary energy sources. The utilization of solar energy not only calls for efficient photovoltaic and photoelectron chemical devices, but also for identification of abundant, inexpensive and stable photoactives. Piezoceramics are ceramics that accumulate electrical charge, when mechanical stress such as bending, or any pressure is applied to it. Ceramic materials such as zirconium titanate, lead-titanate are employed as piezomaterials in energy harvesting (Charles, 2001).

Ceramic Materials in Wind-Energy

Many of earlier wind energy failed to deliver efficient energy and were only financially viable as tax shelters. More recently nano ceramics such as Yttria stabilized zirconia (YSZ) and composite have played a part in the development of higher and more efficient wind turbines. This has helped to more than double the energy outcome from a single wind energy turbine previously achieved (Edward, 2013). Also researchers at Kensselaer Polytechnic Institute in New York have developed new nano-engineered ceramic materials to store energy from wind turbines and solar arrays.

The feat cracked open the energy "bottleneck" inherent in wind arid solar power, which arises from the variable nature of wind and sunlight. The result of this is the emergence of materials enabling efficient light harvesting, charge separation and collection, and chemical transformation (Levinson, 1996). The ceramic materials copper indium selenide $CuInSe_2$ in its nano scale has been developed to address the silicon – based photovoltaic solar energy collector's challenge of being able to absorb energy only from relatively narrow range of sun's light wave emission. The mechanism for this special ceramic is that it can expand either on traditional band gaps or create multiple band gap, which create an absorption layers that allows it capture energy from portions of the light's spectrum not collected by silicon-based DV cells (Wessels et. al., 1984).

Ceramic Material in Energy Harvesting

A new area of renewable energy is the capture of energy readily available from the environment and its conversion into useable electrical energy. Prototypes have been developed by Morgan Technical Ceramics of this alternative energy source which matches electronics and piezoceramics to develop more efficient energy harvesters. The Kennselaer efforts are tiny layers of a new composite made of glass and ferroelectric nanopower. The glass is alkali-free and low melting, which enables the capacitor to handle high electric fields. The result is a smaller, lighter, long lasting (basically forever) and more efficient device that is used in conventional energy storage as well as intermittent sources such as wind. (Saito, 1988).

Conclusion

Ceramic materials have contributed enormously in the multibillion energy industry. The moral commitment to pass a cleaner planet to the next generation is making ceramics more relevant in the areas of alternative and renewable energy. Cars with minimal or no emission are now possible via ceramic battery and solid oxide fuel. Solar energy and solar fuel technology are attaining unprecedented efficiencies and performances through new nano ceramic materials in solar towers and parabolic reflector components. The safety of nuclear reactors and facilities as alternative energy is attaining standards that would avoid explosions. This is attained through ceramic composite nuclear fuel cladding material. Today it is possible to harvest energy from football, shoes and clothing via piezo-ceramic energy harvesting materials to power our phones and power packs. Thanks to the contribution of nanopower ferroelectric ceramics employed in the development of capacitors for wind energy (turbines) system. The intermittent and variable nature of wind is no longer a problem as the new capacitor can handle electric field for long lasting efficiency.

Some recommendations are therefore made.

1. Nigeria alternative energy exposition (NAE) should be empowered by government and private, stake holders to hold more conferences and expositions geared towards the development of indigenous researchers, materials and products in renewable and alternative energy.
2. Federal government should beyond putting in place robust Renewable Energy Policy (REP), establish implementation regime that will really grow this sector.
3. More effort needs to be put in place by researchers and relevant agencies to scale down the cost of producing efficient energy en masse. This will be the game changer to complete replacement of fossil fuel.
4. The Ceramic Researchers Association of Nigeria (CeRAN) should collaborated with international agencies on renewable and alternative energy to host conference on this theme, as this will bolster research exchange, develop ceramic technology programs and provide off-grid/mini-grid renewable energy solutions in Nigeria.

References

Charles AA (2001). Hand Book of Ceramics, Glass and Diamond. McGraw Hill; New York.

Edward D. (2013). Alfred to Lend Ceramic Electrolytes and Glass to GE Global Research Battery Project American Ceramic Society Bulletin. Vol, 91, No: 5

Fetterly G.H (1957). Electrical Condition in SiC Electrochem. Soc., Vol., 104

Herderick E. (2013).New Nuclear Fuel Rod Jachet Acers Butteting, Vol.91. No9.

Levinson, I.M. (1996) Electronic Ceramic: Properties, Devices and Applications. Marcel Decker, New York.

Saito, S. 91988). True Ceramics. Elsevier Science, New York.

Wessel, B.W., Chin, G.Y. (1984). Advances in Electronic Materials. American Society of Materials, Metal Park, Ohio.