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Research Paper

A Review on Vibration Based Piezoelectric Energy Harvesters

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Abstract

This article reviews the mechanics of energy harvesting from various mechanical vibrations. Contemporary approach in hand-held electronic gadgets and low power sensors for wireless networks require a continuous or long battery life for uninturupted performance. Hence, there is a need for permanent and compact power supplies for advanced electronic devices. The most important part of the transducer is energy harvester which converts mechanical vibrations into electrical energy. Piezoelectric materials are important for energy conversion from mechanical vibrations. There has been a lot of research work to establish simple, clean and energy-efficient vibration-harvesting devices using piezoelectric materials. These piezoelectric substances are generally classified into piezoelectric ceramics and piezoelectric polymers. This review article discusses various piezoelectric materials and reviews some important device configurations for piezo-electric energy harvesters.

Keywords:piezo electrics, energy harvesters, piezo-electric polymers, cantilevers.

1 Introduction

Energy harvesting is a technique of extracting energy from various environmental energy sources such as ambient vibrations and motion of biological systems. The various environmental energy sources which are usable for harvesting small amount of energy for portable devices are ambient radio frequency, ambient light (artificial and natural light for photovoltaics), mechanical sources and thermal sources. Energy harvesting is also called as power harvesting or energy scavenging. With current advances in smart systems such as wireless sensors etc, the need for portable devices and wireless sensors is growing rapidly. Since these devices are portable, it is desirable that they are self-powered. Currently, in most cases the portable smart systems are powered by batteries. Batteries are generally undesirable because of the need for recharging or replacement. Therefore, considerable research effort has been directed for technology in energy harvesting for the evolution of self-powered sources for portable devices and wireless sensor system.

Microscale energy harvesting technology is targeted as the substitute for the conventional battery, and is based primarily on mechanical vibrations. In addition, most of these devices lack the energy source to be able to operate both indoors and outdoors, largely unaffected by ambient conditions of temperature and humidity. In this regard, vibrations associated with the body motions become attractive energy options for self-powering small electronic devices.

There are diverse mechanisms to convert mechanical energy from vibrating or moving objects into electricity needed by electronic devices, which include electromagnetic induction, electrostatic storage, and piezoelectric generation. Compared to electrostatic and electromagnetic methods, energy collection with piezoelectric materials provides relatively higher energy efficiency, and most importantly, better flexibility in portable electronic systems. Since piezoelectric material can change mechanical vibrations into electricity with very elementary structures, piezoelectric power conversions for portable systems such as wireless sensor networks are significant [1,2]. Further, while electromagnetic (EM) generators are suitable for generating energy at high frequencies, piezoelectric harvesters can give better performance than electromagnetic generators at relatively low frequencies. In addition, the volume occupied by the piezoelectric harvester is smaller than that of the EM generators for a given power density. Hence, piezoelectric transformation is a superior choice to yield energy at frequencies in the range 100-1000 Hz.

Piezoelectricity represents generation of charge or voltage in a piezoelectric material with the application of pressure. When a time alternating pressure is applied, then a time varying voltage will be generated at the two opposite surfaces of the piezoelectric material. Certain crystalline materials like tourmaline, quartz, Rochelle salt, and barium

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Research Paper

An Ethanol Sensor Review: Materials, Techniques and Performance

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Abstract

Sensing and detection of ethanol is essential for a various applications which include production of ethanol, fuel processing, chemical processing in industry, traffic management and societal applications. The advancement of nanotechnology has created huge potential to develop highly sensitive, portable, low cost sensors with low power consumption. A large number of materials and processes have been studied for the development of ethanol sensors. The large surface-to-volume ratio of nanostructures and nanomaterials is ideal for the adsorption of ethanol molecules. The advent of carbon nanotubes (CNTs) in particular, has advanced the development of gas sensors that exploit unique morphology, geometry, and material properties of CNTs. This review article focuses on the various methods and techniques used and various fabrication technologies involved in the development of ethanol sensors, and also reviews various performance characteristics of the sensors.

Keywords:- Ethanol sensors, selectivity, sensitivity, bismuth ferrite, redox reaction, thin films, nanostructures.

1 Introduction

Harmful gases are generated by industries and numerous other sources, rapidly deteriorates the environment; this leads not only to various health issues of humans, but also causes unnatural weather changes, environmental changes and ozone depletion[1].Hence, there is an urgent need for the detection of toxic and harmful gases. During the last few years, the demand for portable gas sensors has increased tremendously to detect the gases generated by industries, automobiles and environmental pollutants, etc. Therefore, there is a requirement for the development of efficient sensors having better sensitivity, selectivity, stability and a lower operating temperature.

Among the R & D efforts in the area of vapour sensors during the last few years, the work in the area of ethanol sensors has become extremely important. Ethanol vapour sensors with high selectivity and sensitivity have important applications as a device in traffic management, controlling the process of fermentation, food package testing for safety, wine making and medical applications. Ethanol is extensively used in liquors, scientific and industrial sectors.

The oxides of semiconductors such as ZnO, SnO_2[2 − 4], Fe_2O_3[5], $CuO - SnO_2$ [5], and others have been generally utilized as an economical sensor for hazardous, toxic and flammable vapours and gases in security and automotive applications.

The interesting physical properties of perovskite materials with the formula ABO_3 have generated enormous attention, and have found applications in several technological areas [6-8]. Among the perovskites, $BiFeO_3$ (BFO) is gaining prominence since it shows multiferroic properties simultaneously exhibits ferroelectric and ferromagnetic ordering [9-10].The sensor which is operating at room temperature is reported by Palkar et al.[11],who have demonstrated the performance of high resistivity thin films of $BiFeO_3$ as an ethanol sensor at room temperature. This paper reviews materials, methods and detection techniques for ethanol sensing, fabrication techniques such as growth of thin films, sensor development and evaluation of their performance measures such as sensitivity, selectivity, response and recovery time.

2 Materials for Ethanol Sensor

There are varieties of materials used for detection of ethanol in the last few years. Most important materials used are: ZnO, Al_2O_3, Multiwalled Carbon Nano Tube (MWCNT)-doped ZnO, Indium Zinc Oxide, polyaniline (PANi) with MWCNT, magnesium ferrite, $CdIn_2O_4$ nanoparticles, vanadium pentoxide, SnO_2, Sb doped SnO_2,TiO_2-doped SnO_2, mesoporous $ZnO - SnO_2$, titanium oxide, $LaFeO_3$, bismuth ferrite and barium substituted bismuth ferrite.

The ethanol gas detecting properties for thick flims of doped and pure zinc oxides were investigated by Patil et al. [5]. Screen printing techniques was utilized to prepare the thick films of pure ZnO. The effect of doping and microstructure of the film on the gas response, selectivity, response time and recovery time when exposed to ethanol vapours were studied and discussed. Pure ZnO

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Electrocatalytic reduction of CO_2 into useful chemicals-A Brief Review

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Abstract

Electro reduction of CO_2 has become a subject of great importance over the last few decades. This is fundamentally because CO_2 is a notorious green house gas released both by artificial and natural processes. This review highlights current status and future directions in the electroreduction of CO_2 into sustainable production of useful fuels. The current trends in understanding of CO_2 reduction process and the pathways through which various products are formed are discussed. Electro Catalysts play a very important role in the CO_2 reduction process to generate low-carbon fuels, including CO, $HCOOH/HCOO^-$, CH_2O, $H_2C_2O_4/HC_2O_{4^-}$, C_2H_4, CH_{4^-}, CH_3OH, CH_3CH_2OH and others. The electro-catalysts can be classified into several types, which include metals, metal oxides, metal alloys, metal complexes, polymers/organic molecules, and others. The vital characteristics of electro-catalysts which include product selectivity, activity, Faradaic efficiency and catalytic stability have been discussed in detail. The experimental evidence available so far indicates copper is the best catalyst for electroreduction of CO_2 into hydrocarbons. In particular, recent developments showing high selectivity and faradaic efficiency for generation of ethanol in oxygen derived copper nanoparticles as well as copper nanoparticles supported on carbon nano-spikes are extremely interesting. The review also presents basic aspects of electrochemical cell for the electroreduction of CO_2. Finally, the demonstration of feasibility of a two step CO_2 conversion into liquid fuels and the challenges in developing highly active and stable electro-catalysts for reduction of CO_2 are discussed, indicating directions for future research and development in this very important area.

Keywords: CO_2 conversion, CO_2 reduction, Copper, Ethanol, electro-catalysis, Reaction mechanism.

1 Introduction

The electrocatalytic conversion of carbon dioxide (CO_2) into useful chemicals has attracted many researchers worldwide for decades as it can enable a sustainable low temperature redox cycle for energy conversion and storage [1, 2]. While CO_2 is an essential substance for the growth of all plants and for numerous industrial processes, it has now become a significant greenhouse gas due to both natural and manmade processes [3-6]. In an ideal situation, CO_2 consumed should be balanced with what is produced on Earth, so that the level of CO_2 remains constant to maintain environmental stability. However, increased human industrial activities and consumption of fossil fuels has caused imbalance in CO_2 concentration in the environment and has made global warming an urgent issue. Hence, reduction of CO_2 production and conversion of excess CO_2 into useful chemicals is critical, for environmental protection. Therefore, various governments all over the world have shown concern by increasing their funding for research to address the CO_2 issue. Hence, electrochemical reduction of CO_2 into useful products and chemicals is urgently needed [7,8]. However, Carbon dioxide (CO_2) produced by most hydrocarbon feedstock combustion processes is a thermodynamically stable product [9] and hence, reduction of CO_2 is challenging.

During the last 30 years a great deal of research effort has been directed in the electrochemical reduction of CO_2. Electrochemical conversion of CO_2 into hydrocarbons was reported in 1985 by Hori et al. using cathode materials such as Cd, In, Sn and Pb which predominantly gave formate and small amount of CO, CH_4 and H_2. More importantly, they reported the production of CH_4 on pure copper as a cathode for the first time [10]. In 1986, the same authors reported the production of CH_4 and C_2H_4 by electrochemical

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Research Paper

Design and simulation of MEMS P(VDF-TrFE) cantilevers

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Abstract

This paper presents design and simulation of micro-electromechanical systems (MEMS) based piezoelectric cantilevers and beams. Poly (vinylidine fluoride-trifluoroethylene) (P (VDF-TrFE)) co-polymer was chosen as the piezoelectric material which has better piezoelectric properties than other polymers. These piezoelectric co-polymer cantilevers form the main elements as low level and low frequency energy harvesters or vibration sensors. P (VDF-TrFE) cantilevers and beams were designed to take advantage of unimorph d_{33} mode. The design has an active P(VDF-TrFE) layer, Cr/Au electrode of interdigitated pattern for power/signal output. The design is to be implemented on 2 inch diameter, <110> silicon base, bulk micro-machined using TMAH etchant. P(VDF-TrFE) cantilevers and beams were simulated using Comsol Multiphysics simulation software with dimensions in the range 100-400μm width, Length 200-2000μm and all having thickness of 2.5μm. The mechanical and electrical properties of cantilevers were analyzed during the simulation. The results show that the fundamental resonance frequency varied from 6.483 kHz for 100 (W) x 200 (L) μm^2 to 63.328 Hz for 400 (W) x 2000 (L) μm^2 cantilevers. Similarly, the fundamental resonance frequency varied from 41.98 kHz for 100 (W) x 2000 (L) μm^2 to 410.76 Hz for 400 (W) x 2000 (L) μm^2 for beams. Hence, it is clear from the simulation results that, as the length of cantilever/beams increases fundamental resonance frequency decreases.

Keywords: Microelectromechanical systems, P(VDF-TrFE) cantilevers, beams, energy harvesters, vibration.

1 Introduction

With the advancement of technology in electronic systems such as wireless sensors, mobile phones, external wearable medical devices etc, researchers have focused on advancement of smaller volume and durable power sources. Batteries as a conventional power sources have some limitations due to its higher volume and a limited lifetime [1, 2]. To reduce the energy sources issue, energy harvesting is an attractive way to extract energy from environmental renewable energy sources such as solar, wind, tidal and geothermal [3]. Furthermore, ambient mechanical vibration can be recycled to generate electrical energy for wireless sensor networks, chemical sensors [4] and health monitoring [5]. Vibration based energy harvesters efficiently convert vibration energy into electrical energy using three electromechanical transduction processes: electrostatic, electromagnetic, and piezoelectric [6-8]. Among those transduction methods, piezoelectric transducers have attained much attention due to the simplicity in configuration and higher conversion efficiency [9, 10].

In piezoelectric transduction there are some piezoelectric materials namely, Lead Zirconate Titanate (PZT), Polyvinylidene Fluoride (PVDF) and their co-polymers [11], and Aluminium nitride (AlN) [6]. When those piezoelectric materials are configured for mechanical energy, then electrical energy will be generated and vice versa as shown in Figure 1 [12].

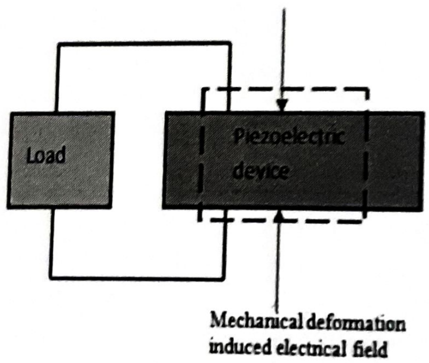

Figure 1: Piezoelectric effect of piezoelectric materials.

Ambient mechanical vibration sources generally provide lower frequencies (< 1000 Hz); in order to utilize ambient vibration properly, resonant frequency of piezoelectric energy harvester should be in the range of vibration. Moreover, maximum energy can be harvested efficiently when energy harvester is driven at the resonant frequency [13]. However, there is a limited choice