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REVIEW ON VARIOUS PIEZO ELECTRIC MATERIALS AND APPLICATION OF ULTRASONIC WAVES

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ABSTRACT

This paper presents an overview of research status and development trend of piezo electric materials and their role in production of ultrasonic waves for various enormous applications in various fields. Ultrasonic production attracts more attention due to its simplicity, lower expenses, good applicability and no reservoir pollution. Through the review of the development of ultrasonic production for various application in various fields, this paper summarize the recent research progress in ultrasonic production technique i.e. piezo electric method. Finally, development trend of ultrasonic production technique by piezo electric method are given. Lower cost of ultrasonic power made possible by advances in electromechanical power conversion materials and power semiconductors has greatly contributed to the practicality of ultrasonic equipment. Yet the main reason behind the growth of power ultrasound is the ability to perform some unique jobs that save money and have become indispensable in modern manufacturing. Not all attempts to implement ultrasonic power devices have been successful, but commercial success is a function of technological state of the art and the need for the process. While stressing the more established applications, this article takes a broader look at the uses of high frequency mechanical vibratory energy, outlining the advantages and the limitations of each process.

Keywords*: piezo electric material, ultrasonic waves, simplicity, good applicability, modern manufacturing*

INTRODUCTION

The piezo electric method is more efficient method by which ultrasonic waves of frequency as high as 500 MHz can be produced. When a mechanical stress is applied to one pair of opposite faces of a piezo electric crystal, then equal and opposite electrical charges are developed on the other pair of opposite faces of the crystal. This is known as direct piezo electric effect. When an electric field is applied to one pair of opposite faces of a crystal, expansion or contraction (mechanical stress) is developed across the other pair of opposite faces of the crystal. This is called as inverse piezo electric effect. The method of producing ultrasonic waves is based on inverse piezo electric effect. When an alternating voltage is applied to one pair of opposite faces of crystal, then alternative mechanical expansions or contractions are produced on the other pair of opposite faces of crystal. Thus, the crystal is set into mechanical vibrations and it produces ultrasonic waves at resonance.

It appears that the quartz crystal is still playing a starring role in ultrasonic, nearly a century after its first role in the story of piezoelectricity. Despite numerous man-made ceramics having higher activity, sensitivity, dielectric constant, operating temperature, etc., quartz is still the choice for the sensing element in cases where the loading can be determined by the reduction in resonant frequency. In these nostalgic times one can predict that still more roles will be identified for this seasoned performer. On the other hand, numerous applications await the reliable and/or novel coupling of other transducer materials to problems of commercial interest. These applications require not only the efficient transmission of sound between the transducer and the material under investigation, but also an understanding of the interaction of ultrasound with the parameter of interest. Interactions with the undesirable variables or constraints normally present in industrial situations must also be understood. Intrusive probes are used more often than nonintrusive externally mounted, non-wetted transducers, in most types of applications. The main reason for this is that insertable probes are more easily designed to be responsive primarily to the parameter of interest, yet be relatively immune to other variables. Also, the skills required to install or use a rugged probe, are readily available in many user facilities, whereas the proper installation of externally mounted transducers sometimes requires experience and skill in the art of ultrasonic coupling. In any event, the user should understand the conditions required for satisfactory operation. When these conditions are not met, disappointing performance is to be expected. In principle, most of the industrial applications previously mentioned can be approached with a suitable combination of transducer (s) , pulsar or oscillator, receiver, a time interval meter ,phase meter or voltmeter (e.g., peak detector) , and a calculator to convert the raw c, a, or related data to the user's customary units of measure. In practice, such a general approach is confined to laboratory, experimental, or feasibility studies.

VARIOUS PIEZO ELECTRIC MATERIALS

A. Habib et al analyze mechanical characterization of sintered piezo-electric ceramic material using scanning acoustic microscope. He characterized Lead Zircon ate Titan ate (PZT) for its potential use in microelectronics. He conducted X-ray analysis (EDX) to determine the chemical composition of the PZT ceramics. He conducted scanning acoustic microscopy at 100 MHz excitation frequency for determining mechanical properties of PZT. [1]. the schematic illustration of acoustic lens is shown figure

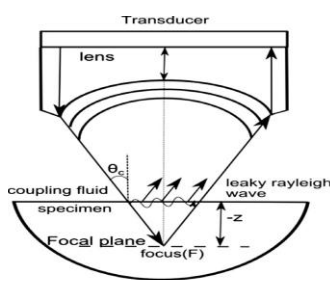

Figure 1. Schematic illustration of the acoustic lens with a focal point defocused at depth -z. Surface skimming longitudinal acoustic wave and leaky surface acoustic waves can be excited for different values of critical angle hc[1].

K. Jayakumar et al examined the effect of actuation electric potential difference on the transverse deflection of the plate. His study considers linear induced strain in the piezoelectric layer applicable to low electric fields. He applied modified Galerkin's method to the governing nonlinear partial differential equations; expression for the load–deflection relation was obtained. He carried out structural analysis of piezoelectric laminated composite plates under uniformly distributed transverse load [2].

Reagan A. Belan et al conducted examination by polarized light microscopy (PLM) reveals the formation of striation, which can be reduced by changing the growth conditions. The grown crystals exhibit a pseudo-cubic morphology and show evidence of two-dimensional growth mechanism. He investigated the domain structure and phase transition of the PMN_PT_BZT crystals are by PLM. [3]. the furnace setup is shown in figure 2.

Laxmi Prasad Suwal et al developed a disk transducer for elastic wave measurement in laboratory soil specimens. In S wave propagation he is using this equipment, it was noted that the waves in a certain frequency range (in this case approximately 10–20 kHz) were not able to be successfully transmitted. The disk transducer is a promising technique that can be further explored in the future for wave measurements in laboratory soil specimens [4].

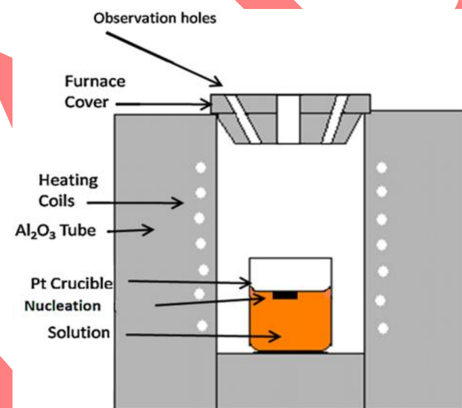

Figure 2. Furnace set-up used for high-temperature solution growth[3]

Jin-Bock Lee et al examined the relationships between the material properties of piezo-electric thin films (such as ZnO and AlN) and the frequency response characteristics of film bulk acoustic resonator (FBAR) devices based on those films. He deposited ZnO and AlN films by RF magnetron plasma reactive sputtering. [5]. Sandeep Kumar Parashar et al observed that if the piezo ceramic are excited close to their resonant frequency, they can have nonlinear vibration behavior at weak electric field. [6]. Yung Ting et al. Derive a relation for the sensitivity for the gyroscope using the Coriolis Effect, the material properties of ceramics, and the applied polarized voltage, and find that the sensitivity is proportional to the polarized electric field [7]. Roel Merry et al develop an electro-mechanical dynamic model of a walking piezo actuator. Piezoelectric actuators are often used in positioning devices that require (sub) nanometer resolution [8]. The walking piezo electric motor is shown in figure 3.

V.Yu. Topolov et al was studied the influence of the aspect ratio of ferroelectric ceramic inclusions on the piezoelectric performance and hydrostatic parameters of novel three-component 1–3-type composites based on relaxor-ferroelectric single crystals [9]. Rosa Marat-Mendes et al he described an acceleration measurement system using a piezoelectric material. He used a piezo electric material in this sensor was either a pre-polarised PVDF film or a polymer ceramic piezoelectric composite. [10].

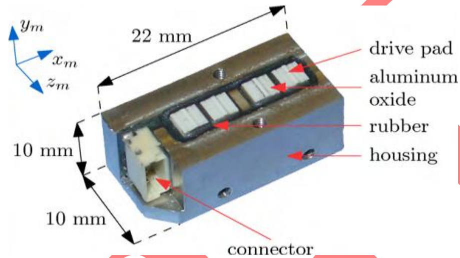

Figure 3.The walking piezo motor

Ying Chen et al. developed silicon piezo resistance encapsulated SiO_2 cantilever (Pr-Oxi-Lever) is with the electric interconnection wires insulated by a SU-8 coating layer for specifically detecting bio/chemical molecules in liquid environment. [11]. the micro cantilever is shown in figure 4.

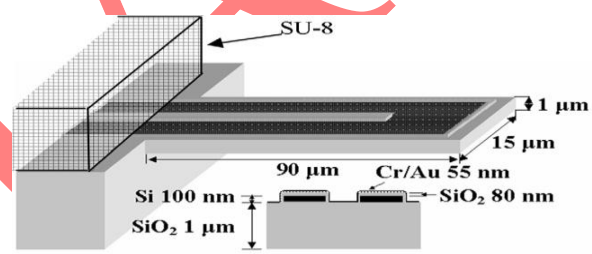

Figure 4.Schematic of the piezo-resistive SiO_2 microcantilever (abbreviated as Pr-Oxi- Lever) used for detection in liquid. The cantilever dimensions are denoted [11].

Enrico Mastropaolo et al. fabricated the Piezo-electrically actuated and sensed silicon carbide ring resonators. He conclude that The use of two separate ports for actuation and sensing purposes can facilitate the interfacing of MEMS resonators with a sustaining electronic circuit for filter, mixer and oscillator device applications [12]. Wenzhuo Wu explains that the essence of the emerging research and applications in piezotronics relies on the coupling between strain-induced polarization and semiconductor properties in piezoelectric semiconductor materials. [13].

V.Yu. Topolov demonstrates the new orientation effect in piezo-active 1-0-3-type composites. The influence of the mutual orientation of the poling direction of single-crystal and ceramic components on the properties of composites containing two ferro electric components and a piezo-passive polymer [14]. A. Eddie Setekleiv made a Comparison of piezo electric particle monitor with laser diffraction technique His results show that the piezo electric particle monitor is a good method for measuring droplet size distributions at given conditions[15]. The optical bench is shown in figure 5.

Figure 5. Optical bench Detector mounted on the left. Laser mounting on the right[15].

R. Kacprzyk et al. explains the piezo-electric properties of polypropylene laminates with a non-woven layer. He concludes that d33 values determined on the basis of the model were compared with experimental data and a good agreement was found [16]. M.R. Gajendragad et al demonstrate the development and standardization of a piezo electric immune biosensor for foot and mouth disease virus typing [17].

F. Aggogeri et al. designed a piezo-based AVC system for machine tool applications. The goal of machine tools for Ultra High Precision Machining is to guarantee high specified performances and to maintain them over life cycle time [18]. Andrzej Milecki presents an application of geometry based hysteresis modeling in compensation of hysteresis of piezo bender actuator. Firstly, a simple model for main loop modelling is proposed. Then, a geometrical description of the non-saturated hysteresis is presented and its modelling method is introduced [19]. The piezo bender is shown in figure 6.

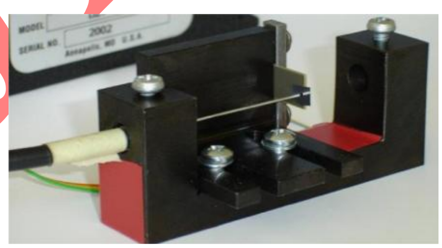

Figure 6.View of a piezo bender actuator on a test stand

K.Y. Kimet al. made a comparison of the performance of the LIPCA prototypes, it was found that the actuator with higher coefficient of unimorph actuator can generate larger actuating displacement [20]. B. Arda Gozen et al. made a method for open-loop control of dynamic motions of piezo-stack actuators. an open-loop technique to control the three-dimensional single-frequency motions of multi-axis piezo-stack actuators is presented [21]. Robert Kohler explains a phenomenological approach to temperature dependent piezo stack actuator modeling. He presents a phenomenological approach on how to model the temperature dependent behavior and the self-heating effect [22]. T. Necsoiu et al. establishes the experimental observations of the correspondence between the characteristics of piezo ceramic materials and the sensitivity of narrow-band frequency hydrophones, the hydrophones realized in the laboratory are of narrow bandwidth with high sensitivity. They can be successfully utilized in marine communication (voice communication between divers or data transmission) because they are like selective filters for the ultrasonic frequencies [23].Raghu Chandra Garimella et al. finds a new technique for generation of electrical energy using piezo sensors from unwanted ground vibrations which may affect the nearby structures or may cause sound pollution [24].

ULTRASONIC WAVES APPLICATION IN VARIOUS FIELD

ULTRASONIC WAVES IN NON-DESTRUCTIVE TESTING

Tirupan Mandal et al. studied the non-destructive testing of cementitiously stabilized materials (CSMs) using ultrasonic pulse velocity instrumentation. He conducts Flexural strength and flexural modulus tests on CSMs and their constrained modulus were recorded [25]. The PINDIT-plus equipment is shown in figure 7.

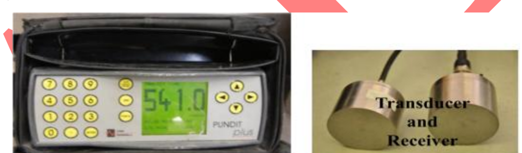

Figure 7.Ultrasonic pulse velocity test equipment (PUNDIT-PLUS) [25].

Léonard Le Jeune et al. describes a new method for Non-destructive testing, ultrasonic array imaging method which is derived from the medical Plane Wave Imaging (PWI) technique. He compared his method to Total Focusing Method (TFM) which is the reference imaging technique in NDT [26].

ULTRASONIC WAVES FOR REDUCING THE VISCOSITY OF OIL (CRUDE OIL)

Jens Strobel et al. produced a high-energy ultrasound that can induce super heavy oil to generate cavitation effect. Ultrasonic cavitation results from the effects of pressure variations on gas- and vapor-filled bubbles that serve as cavitation nuclei in the fluid [27]. The mechanical vibration caused by cavitation effect can instantly break heavy large molecules in super heavy oil into light hydrocarbon substances. The viscosity of super heavy oil will never return to the pre-treatment condition when large molecules are cracked [28]. Zheng Jiahong et.al measured the dynamic viscosity of crude oil under the action of ultrasonic field. The study found that the viscosity of crude oil is reduced by 20–25% after ultrasonic treatment for 30–60 min. Wang Ruifei et al analysed that after ultrasonic treatment, that the output of the oil well can be improve by 40–60%, oil recovery can be enhanced more than 10% [29]. Aarts et al. found that ultrasound can increases the mobility of liquids when flowing through porous medium [30].

Bjorndalen and Islam found that the relative viscosity of liquid paraffin is reduced by 10% after ultrasonic treatment for 120 s [31]. Yan Xianghong et al carried out a experiment to reduce the viscosity of crude oil using ultrasound [32]. Experimental results showed that the viscosity of 20 ml super heavy oil is reduced by 24% after 2 min ultrasonic treatment. Especially for super heavy oil mixed with ‘‘active water’’, its viscosity can be greatly reduced after ultrasonic treatment, furthermore, ultrasonic treatment can reduce the amount of active agent; in 2006, the influence of ultrasound frequency, treatment time, temperature and sound intensity on the viscosity reduction of super heavy oil respectively were studied by Dong Xianyong et al. [33] and Wu Jihui et al. [34] respectively.

ULTRASONIC WAVES FOR PLUG REMOVAL PROCESS IN OIL

Plug removal has always been technically difficulty in normal oil production. Severe vibration caused by ultrasonic wave can make paraffin crystal in waxy crude oil difficult to gather. So, as to achieve the purpose of removing paraffin plugging [35]. In contrast, the technique of removing plug using ultrasonic wave has many advantages such as strong adaptability, being simple to operate, low cost and no pollution to environment [28]. Experimental studies on removing paraffin deposition plug and polymer plug using ultrasonic wave were carried out by Roberts et al. [36]. Experimental studies carried out by the Adinathan Venkitaraman et al. on removing core pollution caused by drilling fluid and particles migration used ultrasonic wave [37].

ULTRASONIC WAVES IN WELDING PROCESS

Ultrasonic welding is a technique joining thermoplastic polymer parts without the need to dispense any additional substances. Successful integration of single sensors for one analyte in microfluidic channels had been demonstrated by T. Nieradzik et al. [38]. S. Krabbe describes that Ultrasonic welding is a suitable process for fixing chemical sensor foils both in micro fluidic systems and inside of the wells of titer plates [39]. Mantra Prasad Satpathy et al. conducted many experiments according to the full factorial design with four replications to obtain the responses like tensile shear stress, T-peel stress and weld area. As the quality is an important issue in these manufacturing industries, the optimal combinations of these process parameters are found out by using fuzzy logic approach and genetic algorithm (GA) approach. [40]

ULTRASONIC WAVES IN COAL APPLICATION

Ercan Sahinoglu et al. investigate the potential use of ultrasonic treatment in comminution of coal in water media. he used high intensity ultrasonic generator (750 W, 20 kHz) equipped with a horn transducer system and a titanium alloy horn tip (13 mm in diameter) as a source of ultrasonic treatment. [41]. S. Balakrishnan et al. studied effect of low (25 kHz) – and high-frequency (430 kHz) ultrasound waves in removing alkali elements – elements responsible for formation and growth of fouling deposits – from coals. Two methodologies (agitation and sonication) of plain water-washing and chemical-washing were employed in order to remove the water-soluble alkalis and ion-exchangeable alkalis, respectively [42]. Fig.8. shows the schematic representation of the tank-type ultrasonication system.

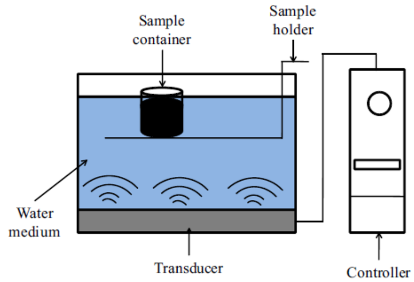

Figure 8.Schematic representation of the tank-type ultrasonication system[42]

CONCLUSION

Technological forecasting partly involves recognizing needs in industry. The energy, material quality, ecology, and economic situations in these years play vital roles to provide strong motivating factors, defining the need for new or better products, techniques, or services. This includes a need for equipments with higher accuracy involving less maintenance and rapid interpretation of data. The use of ultrasonic waves found numerous applications like reducing the viscosity of oil, in the process of plug removal in oil, non-destructive testing, and welding processes and even in coal application. Ultrasonic plastic welding has become now-a- days a large-scale industrial process while the considerably researched metallurgical and metal working areas have resulted in relatively high. The attention paid to a given ultrasonic area is largely influenced by the topic of the day, as evidenced by current interest in ultrasonic fuel treatment , waste treatment , oil well rejuvenation, etc., and is not always related to the true worth of the process. The cost of an acoustic watt has been declining and following the general technological trend will continue to do so in the future. This will make ultrasonic power more competitive with conventional processes. The second factor is that more ultrasonic equipment is now in use and more people are working with it. This increased exposure will undoubtedly lead to new uses.

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