Piezoelectric materials “Potentials and Constrains”
Upgrading Designs and Techniques

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Abstract:

Architecture everywhere is now witnessing a polemical diversity where existing evidence of mega projects present variety of approaches. These approaches vary according to the different problems that face the architect starting from climate conditions to reaching new records in architectural technology. High technology has to be understood as the tool to achieving our goals in all fields including architecture. One of the global goals nowadays is preserving our non-renewable energy resources as well as finding new renewable resources of energy. Piezoelectric materials are one of the means now to generating energy out of pressure, and this can be obtained in our daily life with no additional effort but using these materials from the beginning.

Research Problem:

The world is running out of energy in some decades and this is due to the rely on non-renewable sources of energy.

Electricity is one of the main forms of energy needed everywhere to run different kinds of machines, buildings and cities.

Research Objectives:

It is intended to examine what could be the role of piezoelectric materials in generating energy without pollution. Also it is important to know the barriers to using piezoelectric materials or the disadvantages of using them and how they could be reduced, recommending further research in such a point.

The paper thus aims to identify new architectural techniques of using renewable sources of energy in buildings with least harm and most efficiency.

Hypothesis;

New technology can help solve major environmental problems; like that of lack of energy resources and one of its applications is piezoelectric materials usage in generating energy through pressure force.

Research Questions:

What are the new technologies that would provide us with environmentally friendly materials suitable for energy production?

What are the advantages and disadvantages of using piezoelectric materials?

What are the applications where piezoelectric materials are already used in?

Methodology:

The research is planned to answer the previously mentioned questions through different phases or stages. Some of these stages may be theoretical and others are practical.

Firstly, studying the historical background of piezoelectric effect and its discovery.

Secondly, defining the roles of piezoelectric effect application on some materials.

Analyzing some international examples of piezoelectric materials and their advantages and disadvantages.

1 Introduction

The piezoelectric effect describes the relation between a mechanical stress and an electrical voltage in solids.

It is reversible: an applied mechanical stress will generate a voltage and an applied voltage will change the shape of the solid by a small amount (up to a 4% change in volume).

In physics, the piezoelectric effect can be described as the link between electrostatics and mechanics.

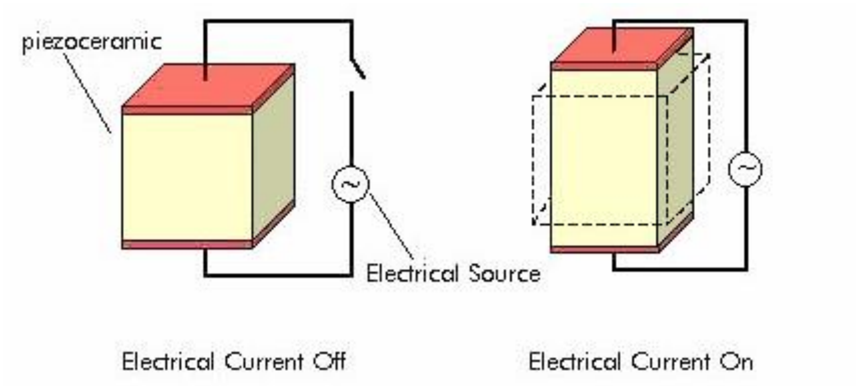


Figure**1** showing voltage changing the shape of the solid (up to 4% in volume)

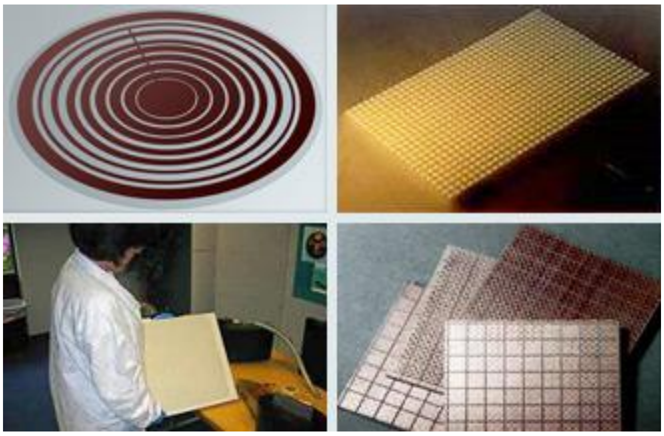
1.1 Historical background

The piezoelectric effect was discovered in 1880 by the Jacques and Pierre Curie brothers. They found out that when a mechanical stress was applied on crystals such as tourmaline, tourmaline, topaz, quartz, Rochelle salt and cane sugar, electrical charges appeared, and this voltage was proportional to the stress.

First applications were piezoelectric ultrasonic transducers and soon swinging quartz for standards of frequency (quartz clocks).

An everyday life application example is your car's airbag sensor. The material detects the intensity of the shock and sends an electrical signal which triggers the airbag.

1.2 Piezoelectric materials



The piezoelectric effect occurs only in non conductive materials. Piezoelectric materials can be divided in 2 main groups: crystals and ceramics. The most well-known piezoelectric material is quartz (SiO_2).

1.3 Piezoelectric Exercise

The dipoles in macroscopic sample of material can have random orientations in which case the material has no net moment. This situation is pictured in Fig.3 below.

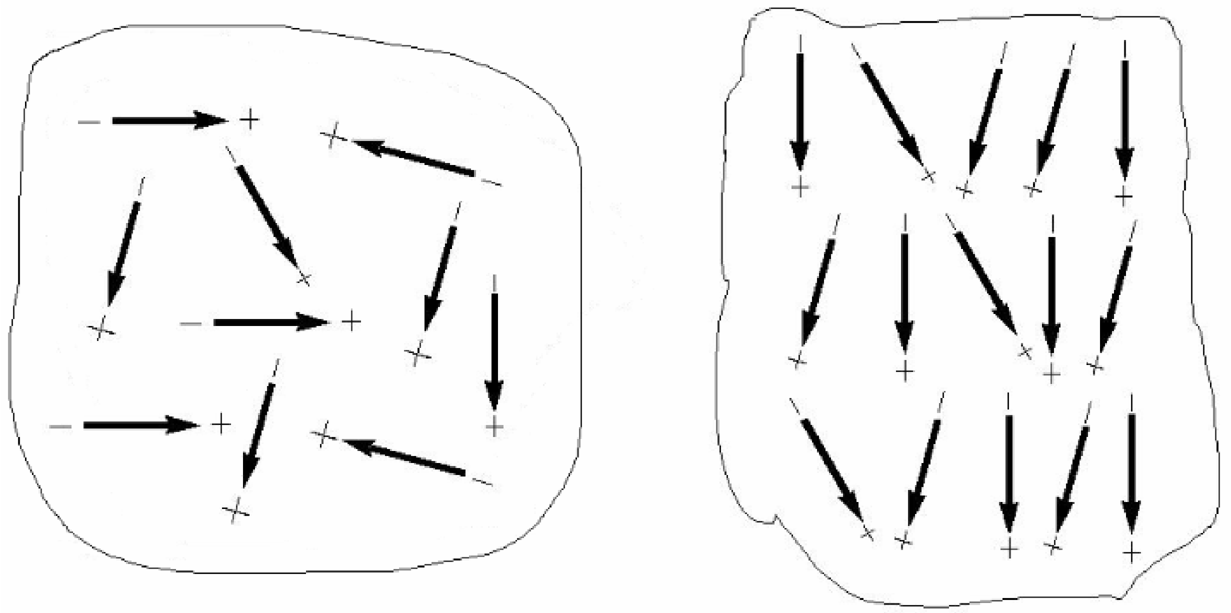


Figure**2**: Different align domains

Applying a strong electric field under the appropriate conditions (temperature, pressure, etc) can produce alignment of the dipoles as schematically pictured in (2) and (3) above. The oriented dipolar domains pictured above can loose their structure at high temperature, with wear etc. Poled ferroelectric materials form materials which are piezoelectric; that is they produce a voltage when stressed. Conversely, when a voltage is applied to a sample of piezoelectric material that sample changes shape. The voltage which develops in a piezoelectric are due to the formation of net positive and negative charges on the surface of the material when it a sample of it is stressed.

Piezoelectric materials create a voltage when their temperature is changed, Piezoelectric materials are piezoelectric but the converse is not always true. PVDF is both piezoelectric and piezoelectric with both effects arising out of the ferroelectric properties of the poled polymer. Note that the voltage effect observed with piezoelectric materials is transient and is absent if there is no stress on the material.

2 Applications of Piezoelectric effect

Piezoelectric flooring is a technology with a wide range of applications that is slowly being adopted in the race to develop alternative energy sources. After all, human power is readily available in pretty much any area with heavy foot traffic, such as a dancing floors, or touristic attraction places.

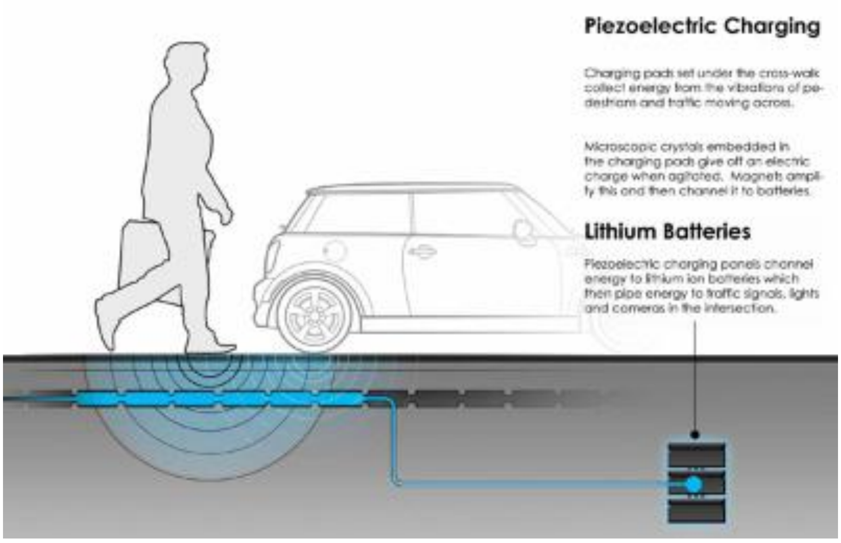
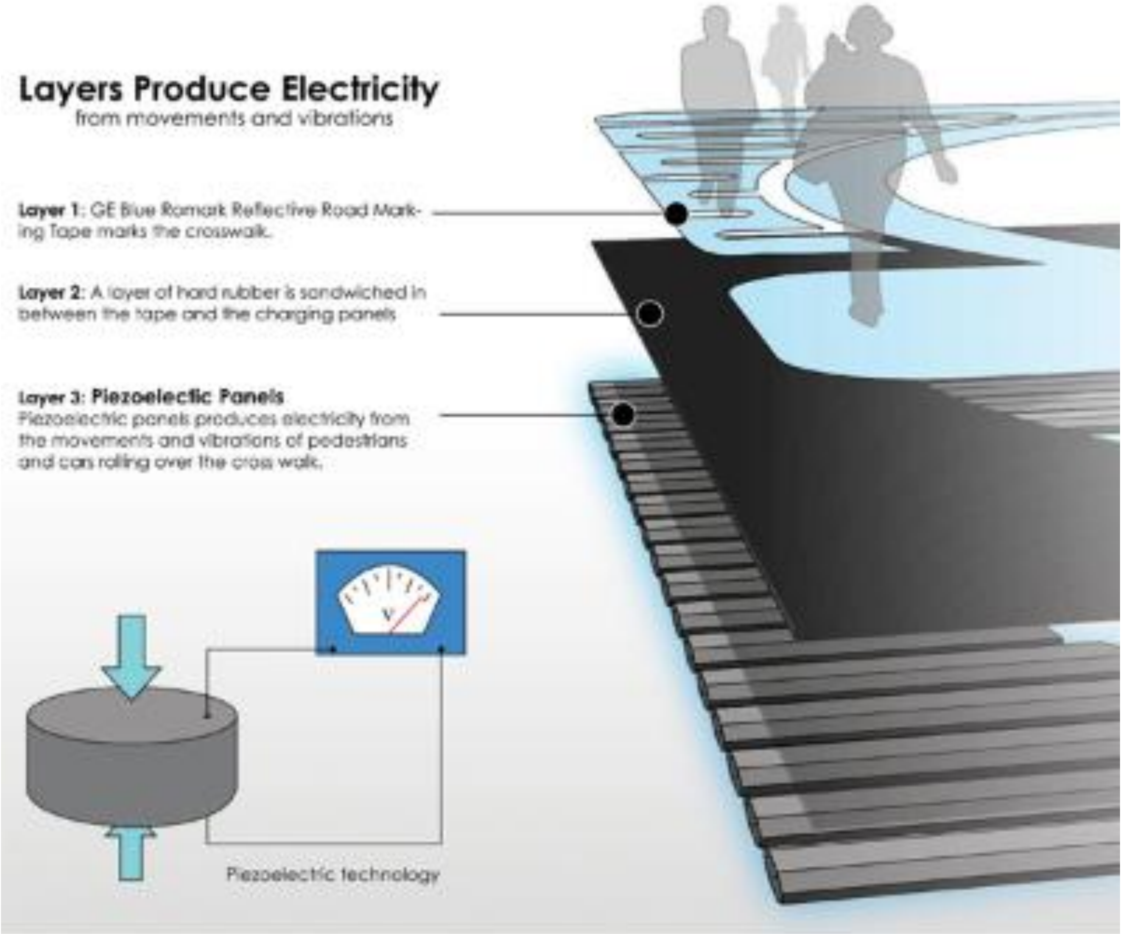


Figure**3** Piezoelectric flooring.

Piezoelectric are already commonly used in a number of applications. Quartz clocks, for example, rely on piezoelectricity for power, as do many sensors, lighters, and actuators. But these are the old uses for piezoelectricity. Scientists today have much more interesting piezoelectric plans in mind. One of the most popular uses for piezoelectricity in the past few years relies on roads and sidewalks. It all started in 2008 with **Club Watt**, a dance spot in the Netherlands dubbed the world's first sustainable dance club. The club installed piezoelectric materials in its dance floor to turn patrons' moves into electricity that is used to change the color of the floor's surface.

After Club Watt, the piezoelectric floors kept coming. A **Tokyo railway station** installed a piezoelectric floor that uses kinetic energy to generate 1,400 kW of energy per day—enough to power ticket gates and displays. Toulouse, France, recently became the first city to put pressure-sensitive piezoelectric modules on the sidewalk, generating enough energy to power streetlamps. And the United Kingdom plans to install power-generating tiles on London streets to light up bus stops and pedestrian crossings.

Piezoelectric are also increasingly becoming common on **roads**. In 2009, a British supermarket installed kinetic road plates that collect energy from customers driving over road bumps in the store parking lot. The road plates are pushed down by vehicle weight, which creates a rocking motion that turns generators. The system is used to power the supermarket's checkout lines.

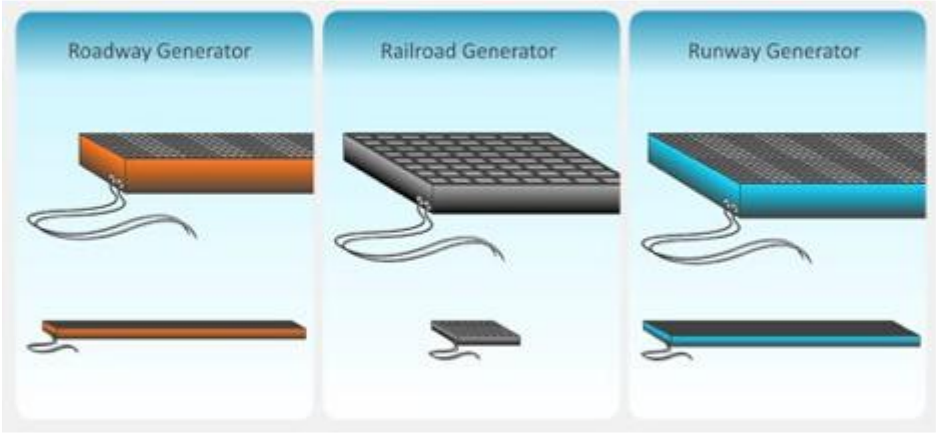


In Israel, a company called Innowattech is installing **strips of asphalt** embedded with piezoelectric materials. According to the company, the generators could produce 1 MWh of electricity from a four lane highway, or enough to power 2,500 homes.

The technology just keeps getting better, too. Last year, Princeton University researchers combined silicone and nano-ribbons of lead zirconate titanate to create **PZT**, an ultra-efficient piezoelectric material that can convert up to 80 percent of mechanical energy into electricity. PZT is 100 times more efficient than quartz. It's so efficient, in fact, that the material could be used to harness energy from the minute vibrations found in items like shoes and clothing. That means a piezoelectric-equipped shirt could potentially charge up your cell phone after a day of activity.

Piezoelectric sidewalks, roads, and clothing items haven't taken off in a big way quite yet, but they probably will soon. As we become more reliant on having fully-charged gadgets with us at all times, a shirt or pair of shoes that can prevent a device from dying will be incredibly valuable.

3 The Tokyo station



In Japan they have been trialing these systems for the past year. They have recently improved and expanded the system by changing the floor covering from rubber to stone tiles, and have improved the layout of the mechanisms to improve energy generation. The total amount of floor-space will add up to around 25 square meters, and they expect to obtain over 1,400kw per day.

Commuters at the Tokyo station walk on a piezoelectric sheet which generates electricity when pedestrians step on it.

Experiments have started this week at two of the Japanese capitals' busiest stations, with special flooring tiles installed in front of ticket turnstiles. Every time a passenger steps on the mats, they trigger a small vibration that can be stored as energy.

Multiplied many times over by the 400,000 people who use Tokyo Station on an average day, according to East Japan Railway, and there is sufficient energy to light up electronic signboards.

"We are just testing the system at the moment to examine its full potential," said Takuya Ikeba, a spokesman for JR East, adding that the tiles are constructed of layers of rubber sheeting, to absorb the vibrations, and ceramic.

Deeply dependent on imported fuel to power its industries, Japanese companies are at the forefront of research into clean and reusable energy sources.

On the other side of Tokyo, a remarkable 2.4 million people pass through the sprawling Shibuya Station on an average week day, with many of them now treading on Sound-power Corp.'s "Power Generation Floor."

"An average person, weighing 60 kg, will generate only 0.1 watt in the single second required to take two steps across the tile," said Yoshiaki Takuya, a planner with Sound-power Corp. "But when they are covering a large area of floor space and thousands of people are stepping or jumping on them, then we can generate significant amounts of power."

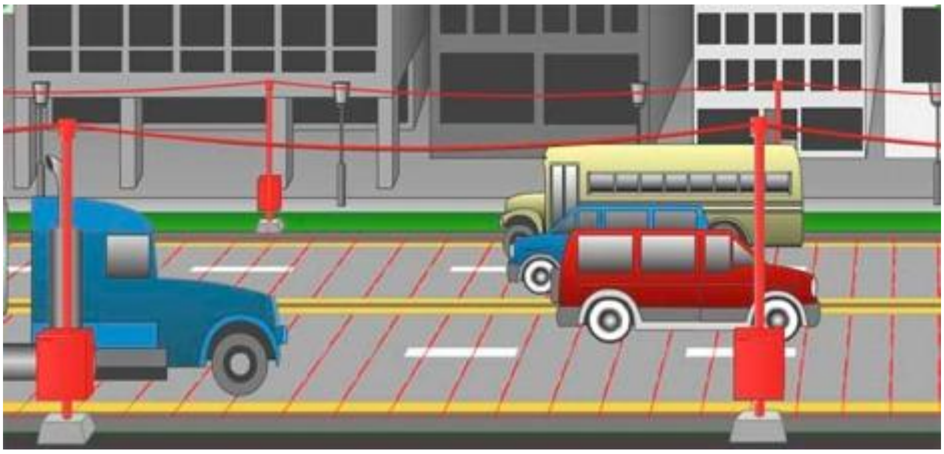
Stored in capacitors, the power can be channeled to energy-hungry parts of the station, he said, including the electrical lighting system and the ticket gates.

Buying a piezoelectric transducer can be quite expensive. Two different suppliers I looked at were Face International Corp. and Active Control experts. Their piezo-transducers sold for about $100 and $200 respectively. Buying piezoelectric cable is much cheaper. One supplier in the UK, Ormal Electronics Ltd., gave a quote of £2.75 per meter for purchases of more than 2000 meters. Another supplier in the US, Measurement Specialties Inc., sells piezo-cable for $8.00/m for more than 1000 m.

4 Conclusion and Recommendations

Energy theft is in the news again, in the guise of turnstiles in Tokyo, revolving doors in the Netherlands, and now piezoelectric generators for road, rail and runway from an Israeli company, Innowattech.

Perhaps a case can be made for revolving doors and turnstiles as most people could use a little more exercise, so a little extra energy expended won't hurt the able-bodied, although the elderly and the disabled might notice the difference and have trouble with them. But roads and rails? It is literally highway robbery, and inefficient at that.



They claim that with the Innowattech Piezo Electric Generator (IPEG), *"1km of roadway or runway can produce up to 0.5mW (500kW) of electricity per hour." [*sic. please no comments on their energy terminology] IPEGs can "harvest energy from weight, motion, vibration and temperature changes."

But there is a certain law called conservation of energy, and what they are doing is converting the energy from gasoline, paid for by the driver and inefficiently converted into forward motion, into electricity by increasing drag. You can't make energy from nothing; better they should put their money into solar cells, where at least the source of the power is free, and is not ultimately expensive fossil fuels.

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