

ENERGY STORAGE BRICKS

Submitted in partial fulfilment of the requirements for the award of Bachelor of
Engineering degree in Electronics and Communication Engineering

by

SHIVANGI BAKSHI (37130377)



**DEPARTMENT OF ELECTRONICS AND COMMUNICATION
ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of SHIVANGI BAKSHI (37130377) who carried out the project entitled "**ENERGY STORAGE BRICKS**" under my supervision from September 2020 to April 2021.

Internal Guide

Mrs. L. MAGTHELIN THERASE M.E.,

Head of the Department

Dr. T. RAVI M.E., Ph.D.,

Submitted for Presentation held on _____

Internal Examiner

External Examiner

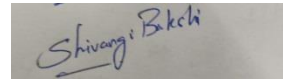
DECLARATION

I, **SHIVANGI BAKSHI (37130377)** hereby declare that the Project Report entitled "ENERGY STORAGE BRICKS" done by us under the guidance of **Mrs. L. Magthelin Therase M.E.**, at Sathyabama Institute of Science and Technology is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electronics and Communication Engineering.

DATE :19-04-2021

PLACE:CHENNAI

1.

A rectangular box containing a handwritten signature in blue ink that reads "Shivangi Bakshi".

SIGNATURE OF THE CANDIDATE

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I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. We are grateful to them.

I convey my thanks to **Dr. N. M. Nandhitha, M.E, Ph.D.**, Dean, School of Electrical and Electronics and **Dr. T Ravi, M.E. Ph.D.**, Head of the Department, Dept. of Electronics and Communication Engineering for providing us necessary support and details at the right time during the progressive reviews.

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ABSTRACT

Red brick is a universal building material produced by thousand-year-old technology that has seldom served any other purpose throughout history. Typically used for construction and architectural esthetics, now these bricks can be used to store energy that will be converted into electricity. For the energy they require some outer source to charge them first, so in this case the solar panels are required. These solar panels will work as a source to charge them per 50 bricks there will be one panel. Here's how the solar panel and bricks will be connected there will be gasses passing through the maze inside the bricks. Now, To allowing the bricks to store electricity there will be some chemical reaction will take place .The bricks comprised of fused particles of silica (SiO_2), alumina (Al_2O_3) and hematite ($\alpha\text{-Fe}_2\text{O}_3$). The red color of a brick originates from hematite. State-of-the-art energy storage materials are also produced from hematite this way they will store energy in to the bricks .Now if there will be any charge leakage the brick needs to be to make it leakage free ,then there will be a web of plastic nanofiber known as PEDOT electrode and stationary super capacitor that readily stack into module ,which is a good conductor of electricity and no leakage of electricity .To making it waterproof five minute of epoxy serves as a waterproof case enabling the operation of super capacitor. And further all electrical equipment will be connect to the bricks and no need of wires to connect or collect the energy.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Man has used brick for building purposes for thousands of years. Bricks date back to 7000 BC, which makes them one of the oldest known building materials. They were discovered in southern Turkey at the site of an ancient settlement around the city of Jericho. The first bricks, made in areas with warm climates, were mud bricks dried in the sun for hardening. Ancient Egyptian bricks were made of clay mixed with straw. The evidence of this can be seen today at the ruins of Harappa, Buhen and Mohenjo-daro. Paintings on the tomb walls of Thebes portray Egyptian slaves mixing, tempering and carrying clay for the sun dried bricks. The greatest breakthrough came with the invention of fired brick in about 3,500 Bc . From this moment on, bricks could be made without the heat of sun and soon became popular in cooler climates. Bricks were made by hand until about 1885. Once the Industrial Revolution broke out, the brick making machinery was introduced. Consequently, the number of bricks that could be made into brick was greatly increased which influenced the production capacity. Handmade brick production ranged up to 36,000 bricks per week but by 1925 a brick making machine made 12,000 bricks a day. As brick structures could be built much quicker and cheaper, they replaced other raw materials like stone or rock. During the building boom of the 19th century, when more than 10 billion bricks were produced annually, many American cities like Boston and New York favoured locally made bricks. Red Bricks are one of the strongest building materials that have been widely used in construction for more than 6,000 years. The term brick initially referred to the block that consisted of dry clay.

Currently, bricks are mainly utilized in walls and are usually joined together using mortar. Fired bricks are highly resistant to weather conditions. Moreover, they tend to absorb heat transferred during the day and release it during the night, a fact that is beneficial for preserving temperature conditions in a building. Nevertheless, according to a new study, in Nature Communication, red bricks can also be used to store energy and act like batteries.

In particular, chemist researchers from St. Louis University, have created a technique that makes bricks capable of storing power and using it to power devices. The bricks can be connected to solar panels and store renewable energy.

Bricks have a porous structure that enables the storing process. Those pores are filled with an acid vapor which acts as a dissolved for the iron oxide (or rust) from which bricks are composed. A gas is transferred through the cavities of bricks which are filled with a sulfur-based material that reacts with iron. As a result, a conductive plastic, polymer PEDOT, surrounds the bricks' porous. "In this work, we have developed a coating of the conducting polymer PEDOT, which is comprised of nanofibers that penetrate the inner porous network of a brick; a polymer coating remains trapped in a brick and serves as an ion sponge that stores and conducts electricity," Julio M. D'Arcy, co-author of the study and an Assistant Professor of Chemistry at the Washington University in St. Louis, stated.

According to the scientific team, the proposed method could generate substantial amounts of renewable energy. Researchers estimated that 50 capacitor bricks would take 13 minutes to charge and could provide enough energy to power the emergency lighting of a building for at least 50 minutes.

Among other advantages, D'Arcy mentioned that the brick capacitors can be recharged multiple times within short time periods without any deficiencies.

Researchers emphasize the fact that iron oxide, a waste material has been turned into a useful product that can be utilized in the process of generating renewable energy. "Inert materials hold the potential to be transformative in chemical manufacturing," the team suggested.

The team's future goals are to increase the capacity of the energy storage by, at least, 10 times and decrease the cost and time of producing the polymer-coated bricks.

1.2 NANOTECHNOLOGY

Nanotechnology, also shortened to **nanotech**, is the use of matter on an atomic, and superscalar scale for industrial purposes. The earliest, widespread description of nanotechnology referred to the particular technological goal of precisely manipulating

atoms and molecules for fabrication of macro scale products, also now referred to as molecular nanotechnology. A more generalized description of nanotechnology was subsequently established by the National nanotechnology Initiative, which defined nanotechnology as the manipulation of matter with at least one dimension sized from 1 to 100 nanometer. This definition reflects the fact that quantum mechanical effects are important at this quantum realm scale, and so the definition shifted from a particular technological goal to a research category inclusive of all types of research and technologies that deal with the special properties of matter which occur below the given size threshold. It is therefore common to see the plural form "nanotechnologies" as well as "nanoscale technologies" to refer to the broad range of research and applications whose common trait is size.

CHAPTER -2

LITERATURE SURVEY

The humble house brick has been turned into a battery that can store electricity, raising the possibility that buildings could one day become literal powerhouses. The new technology exploits the porous nature of fired red bricks by filling the pores with tiny nano fibres of a conducting plastic that can store charge. The first bricks store enough electricity to power small lights. But if their capacity can be increased, they may become ;a low-cost alternative to the lithium-ion batteries currently used. The humble house brick has been turned into a battery that can store electricity, raising the possibility that buildings could one day become literal powerhouses.

The new technology exploits the porous nature of fired red bricks by filling the pores with tiny nano fibres of a conducting plastic that can store charge. The first bricks store enough electricity to power small lights. But if their capacity can be increased, they may become a low-cost alternative to the lithium-ion batteries currently used.

Strictly speaking, the power bricks are super capacitors rather than batteries. Super capacitors store electricity as a static charge in solids, rather through chemical reactions as in batteries. The advantage of super capacitors is that they charge and discharge far faster than batteries, but to date they can only hold a small fraction of the energy.

Researchers around the world are working to increase the energy density of super capacitors, as well as the charging speed of batteries. Finding better ways to store electricity is a crucial part of fighting the climate crisis, as it would allow abundant but intermittent renewable energy to be stored until it is needed. “a solar cell on the roof of your house has to store electricity somewhere and typically we use batteries,” said julio d’arcy, at washington university in st louis, us, who was part of the research team. “what we have done is provide anew ‘food-for-thought’ option, but we’re not there yet.”

The energy density of the first power bricks, reported in the journal Nature Communications, is just 1% of that of lithium ion batteries. D’Arcy believes this can be increased tenfold by adding materials such as metal oxides to store more charge in the brick,

which would also make the power bricks a commercial proposition. But the hope is to eventually match the energy density of lithium ion batteries. "If so, this technology is way cheaper than lithium ion batteries," D'Arcy said. "It would be a different world and you would not hear the words 'lithium ion battery' again." Dan Brett, a professor of electrochemical engineering at University College London, UK, said: "It has been the overriding area of interest when considering energy storage within the fabric of buildings. This study shows there is potential to store electrical energy as well. The performance is a long way short of bespoke super capacitors, but the principle is proven and there is significant scope for improvement. The researchers created small prototypes of the power bricks using chemical vapours to react with the red iron oxides in the bricks and then to form a network of plastic nanofibres. A special plastic, called PEDOT, was used as it is a very good conductor of electricity.

Another advantage of super capacitors is that they can be charged and recharged many more times than batteries before losing their ability to store electricity. The power bricks can be cycled 10,000 times before their capacity falls significantly. The charge stored by the first bricks is too small to give a shock when touched. But a wall of connected bricks would need an insulating coating and the scientists demonstrated this using epoxy resin, which even allowed the bricks to work underwater. The reactions used to create the power bricks may have a small weakening effect on their structural properties, D'Arcy said, but in any case bricks were most commonly used today in houses as decorative facades.

Richard McMahon, a professor of power electronics at the University of Warwick, UK, said the research was intriguing. "Energy storage is of great contemporary interest, especially in the electrical form. [But] although this work is an interesting demonstration of a possibility, it is a long way from practical

application. "The cost of lithium ion batteries has plummeted by 90% since 2010, and pumped hydro power schemes are effective where there are mountains. But storing large amounts of electricity remains a challenge, prompting a search for alternatives. One company uses gravity to store energy by stacking large bricks into a tower, then releasing the energy by dropping the bricks back to the ground. Similar schemes using heavy weights and mineshafts are also being explored. Compressing air into a liquid to store energy is another option, with a large plant now

in construction near Manchester, UK. Some experts are backing hydrogen, which can be produced by splitting water using renewable energy.

Nature, the scientific journal published its research shedding light on 'fired bricks,' which are chemically processed to become super capacitors that can hold enough energy to light an LED lamp. Super capacitors are electrical devices that are used to store a large amount of electrical charge. Although the research is at its early stages, the bricks are found to have far-reaching potential. Since bricks are the building blocks of any construction, a large amount of space it occupies can be utilized for storing energy

The research team developed a conducting polymer poly (3,4-ethylene-dioxythiophene), called-PEDOT- and coated the bricks with it. The nanofibers in the polymer seep into the porous brick where the coating is trapped. This coating stores and conducts electricity. The research focuses on red bricks as it contains iron oxide (rust), which triggers the polymerization reaction. The red color of a brick originates from hematite, a pigment, and serves as a low-cost naturally abundant inorganic precursor for catalysts, magnets, and alloys. The bricks can also be made waterproof by using a five-minute epoxy which enables the operation of the super capacitors while submerged underwater and a gel electrolyte extend cycling stability to 10,000 cycles with ~90% capacitance retention.

CHAPTER 3

AIM AND SCOPE

In this System ,We used nanotechnology which will change the nanoparticle of the Brick and its Electro sensitivity to store electricity as we all know on the level of the nano the material changes its property and everything and it will change the bricks property and help to get in to get the desired capacity to store electricity

The future scope of this methodology is to use renewable sources of energy save the non renewable source such as metals we use to waste it or use it for storing purposes .

CHAPTER 4

MATERIALS AND METHODS

4.1 EXISTING SYSTEM

The process of manufacturing of bricks from clay involves preparation of clay, molding and then drying and burning of bricks. The bricks are building materials which are generally available as rectangular blocks. The bricks do not require any dressing and brick laying is very simple compared to stone masonry.

For the manufacturing of bricks, the site should be selected based on some important considerations such as:

The bricks required are in large quantity, then machine molding is economical and also saves more time. Here also we are having two types of machines,

1. Plastic clay machines
2. Dry clay machines

Plastic clay machines These machines contain an opening in rectangular shape and when we place the tempered clay into this machine it will come out through this opening. Now, the rectangular strips coming out the opening are cut by wires to get the required thickness of brick. So, these are also called wire cut bricks. Now these raw bricks are ready for the drying process.

Dry clay machines Dry clay machines are more time saving machines. We can put the blended clay into these machines directly without tempering. Means tempering is also done in this machine by adding some water. When the required stiffness is obtained the clay is placed in mold and pressed hard and well-shaped bricks are delivered. These are called pressed bricks and these do not require drying; they may be directly sent to the burning process



Fig 4.1 Drying of raw bricks

4.1 Drying of raw bricks

- After the molding process the bricks contain some amount of moisture in it. So, drying is to be done otherwise they may crack while burning. The drying of raw bricks is done by natural process.
- The bricks are laid in stacks. A stack consists of 8 to 10 stairs. The bricks in these stacks should be arranged in such a way that circulation of air in between the bricks is free.
- The period of drying may be 3 to 10 days. It also depends upon the weather conditions.
- The drying yards are also prepared on a higher level than the normal ground for the prevention of bricks from rain water.
- In Some situations artificial drying is adopted under special dryers or hot gases.



Fig 4.2 Burning of bricks

4.2 Burning of bricks

- In the process of burning, the dried bricks are burned either in clamps (small scale) or kilns (large scale) up to certain degree temperature. In this stage, the bricks will gain hardness and strength so it is an important stage in manufacturing of bricks.
- The temperature required for burning is about 1100oC. If they burnt beyond this limit they will be brittle and easy to break. If they burnt under this limit, they will not gain full strength and there is a chance to absorb moisture from the atmosphere.
- Hence burning should be done properly to meet the requirements of good brick.

4.1 Nanotechnology

4.1.1 Nanotechnology on Non-Living Thing

Studying chemo mechanical coupling at interfaces is important for fields ranging from lubrication and tribology to microfluidics and cell biology. Several polymeric macro- and microscopic systems and cantilevers have been developed to image forces at interfaces, but few materials are amenable for molecular tension sensing. To address this issue, we have developed a gold nanoparticle sensor for molecular tension-based fluorescence microscopy. As a proof of concept, we imaged the tension exerted by integrin receptors at the interface between living cells and a substrate with high spatial ($<1\ \mu\text{m}$) resolution, at 100 ms acquisition times and with molecular specificity. We report integrin tension values ranging from 1 to 15 pN and a mean of ~ 1 pN within focal adhesions. Through the use of a conventional fluorescence microscope, this method demonstrates a force sensitivity that is 3 orders of magnitude greater than is achievable by traction force microscopy or polydimethylsiloxane micropost arrays,(1) which are the standard in cellular biomechanics.

Many benefits of nanotechnology depend on the fact that it is possible to tailor the structures of materials at extremely small scales to achieve specific properties, thus greatly extending the materials science toolkit. Using nanotechnology, materials can effectively be made stronger, lighter, more durable, more reactive, more sieve-like, or better electrical conductors, among many other traits. Many everyday commercial products are currently on the market and in daily use that rely on nanoscale materials and processes:

- Nanoscale additives to or surface treatments of fabrics can provide lightweight ballistic energy deflection in personal body armor, or can help them resist wrinkling, staining, and bacterial growth.
- Clear nano scale films on eyeglasses, computer and camera displays, windows, and other surfaces can make them water- and residue-repellent, antireflective, self-cleaning, resistant to ultraviolet or infrared light, antifog, antimicrobial, scratch-resistant, or electrically conductive.
- Nano scale materials are beginning to enable washable, durable “smart fabrics” equipped

with flexible nano scale sensors and electronics with capabilities for health monitoring, solar energy capture, and energy harvesting through movement.

- Light weighting of cars, trucks, airplanes, boats, and space craft could lead to significant fuel savings. Nano scale additives in polymer composite materials are being used in baseball bats, tennis rackets, bicycles, motorcycle helmets, automobile parts, luggage, and power tool housings, making them lightweight, stiff, durable, and resilient. Carbon nanotube sheets are now being produced for use in next-generation air vehicles. For example, the combination of light weight and conductivity makes them ideal for applications such as electromagnetic shielding and thermal management.

4.3 POLYMER – SILICATE

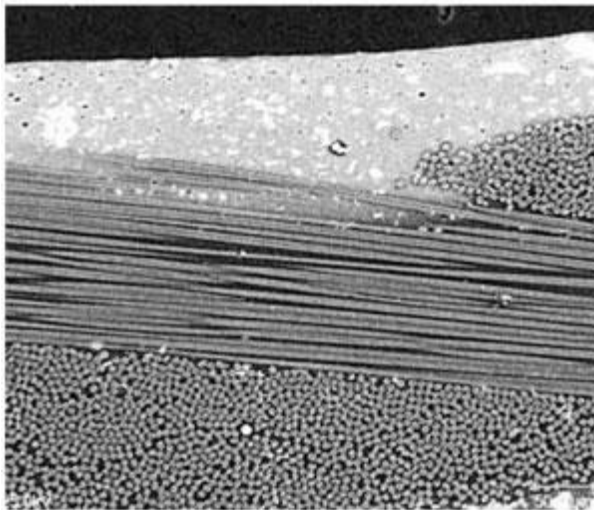


Fig 4.3 Polymer silicate nano composite

Nano-bioengineering of enzymes is aiming to enable conversion of cellulose from wood chips, corn stalks, unfertilized perennial grasses, etc., into ethanol for fuel. Cellulosic nano materials have demonstrated potential applications in a wide array of industrial sectors, including electronics, construction, packaging, food, energy, health care, automotive, and defense. Cellulosic nano materials are projected to be less expensive than many other

nano materials and, among other characteristics, tout an impressive strength-to-weight ratio.

- Nano-engineered materials in automotive products include high-power rechargeable battery systems; thermoelectric materials for temperature control; tires with lower rolling resistance; high-efficiency/low-cost sensors and electronics; thin-film smart solar panels; and fuel additives for cleaner exhaust and extended range.
- Nanostructured ceramic coatings exhibit much greater toughness than conventional wear-resistant coatings for machine parts. Nanotechnology-enabled lubricants and engine oils also significantly reduce wear and tear, which can significantly extend the lifetimes of moving parts in everything from power tools to industrial machinery.
- Nanoparticles are used increasingly in catalysis to boost chemical reactions. This reduces the quantity of catalytic materials necessary to produce desired results, saving money and reducing pollutants. Two big applications are in petroleum refining and in automotive catalytic converters.
- Nano-engineered materials make superior household products such as degreasers and stain removers; environmental sensors, air purifiers, and filters; antibacterial cleansers; and specialized paints and sealing products, such as self-cleaning house paints that resist dirt and marks.
- Nano scale materials are also being incorporated into a variety of personal care products to improve performance. Nano scale titanium dioxide and zinc oxide have been used for years in sunscreen to provide protection from the sun while appearing invisible on the skin.

Electronics and IT Applications

Nanotechnology has greatly contributed to major advances in computing and electronics, leading to faster, smaller, and more portable systems that can manage and store larger and larger amounts of information. These continuously evolving applications include:

- Transistors, the basic switches that enable all modern computing, have gotten smaller and smaller through nanotechnology. At the turn of the century, a typical transistor was 130 to 250 nanometers in size. In 2014, Intel created a 14 nanometer transistor, then IBM created the first seven nanometer transistor in 2015, and then Lawrence Berkeley

National Lab demonstrated a one nanometer transistor in 2016! Smaller, faster, and better transistors may mean that soon your computer's entire memory may be stored on a single tiny chip.

- Using magnetic random access memory (MRAM), computers will be able to “boot” almost instantly. MRAM is enabled by nanometer-scale magnetic tunnel junctions and can quickly and effectively save data during a system shutdown or enable resume-play features.
- Ultra-high definition displays and televisions are now being sold that use quantum dots to produce more vibrant colors while being more energy efficient.



Fig 4.4 Wafer made of chips

SUNY College of Nanoscale Science and Engineering's Michael Liehr, left, and IBM's Bala Haranand display a wafer made of 7nm chips in a NFX clean room in Albany, New York. (Image courtesy of IBM.)

SUNY College of Nanoscale Science and Engineering's Michael Liehr, left, and IBM's Bala Haranand display a wafer made of 7nm chips in a NFX clean room in Albany, New York. (Image courtesy of IBM.)

- Flexible, bendable, foldable, rollable, and stretchable electronics are reaching into various sectors and are being integrated into a variety of products, including wearables, medical applications, aerospace applications, and the Internet of Things. Flexible electronics have been developed using, for example, semiconductor nano membranes for applications in smartphone and e-reader displays. Other nano materials like graphene and cellulosic nano materials are being used for various types of flexible electronics to enable wearable and “tattoo” sensors, photovoltaics that can be sewn onto clothing, and electronic paper that can be rolled up. Making flat, flexible, lightweight, non-brittle, highly efficient electronics opens the door to countless smart products.
- Other computing and electronic products include Flash memory chips for smartphones and thumb drives; ultra-responsive hearing aids; antimicrobial/antibacterial coatings on keyboards and cell phone casings; conductive inks for printed electronics for RFID/smart cards/smart packaging; and flexible displays for e-book readers.
- Nanoparticle copper suspensions have been developed as a safer, cheaper, and more reliable alternative to lead-based solder and other hazardous materials commonly used to fuse electronics in the assembly process.

4.1.2 Chemical Composition on bricks

- Bricks are rectangular units of construction material. Bricks are used in masonry construction, walls, and pavements. It is used as a substitute of stone, where the stone is not readily available. Brick chips are often used as coarse aggregate in the concrete mix.
- Raw-Green-Bricks
- Figure: Raw (Green) Bricks
- Percentage of Constituents of Brick (Weight Basis)
- There are six major ingredients of brick. The general percentage of these ingredients in brick is given below:
- Ingredient
- Percentage in brick

- Silica (SiO_2) 55%
- Alumina (Al_2O_3) 30%
- Iron Oxide (Fe_2O_3) 8%
- Magnesia (MgO) 5%
- Lime(CaO) 1%
- Organic Matter 1%
- Chief Ingredients of Brick and Their Functions
- Silica (Sand) and Alumina (Clay), these two are the most prominent ingredients in brick clay. When mixed with water in proper proportions, it gains plasticity. The plastic mass can be easily molded and dried. It should not go through cracking, shrinkage or warping.
- Alumina
- Alumina is the main constituent of clay. It acts as a cementing material in raw brick. Brick clay is plastic due to the presence of alumina. This plasticity ensures that bricks can be molded. An excess amount of alumina in clay may cause the bricks to shrink, warp or crack on drying and burning as any other cementing material.
- Clay-for-Brick-formation
- Figure: Clay for Brick formation
- Silica
- Good quality bricks contain 50-60% silica. It is present in both free and combined form. As free sand, it remains mechanically mixed with clay. In combined form, it reacts with alumina to form aluminosilicates. Silica prevents raw bricks from cracking, shrinking and warping. The higher the proportion of sand, the more shapely and uniform in texture will be the brick. Although, excess silica destroys cohesion between the brick clay particles and makes brick brittle and weak. The durability of bricks largely depends upon the proper proportion of silica and alumina.
- sand
- Figure: Sand

- Lime
- Bricks should contain a little amount of finely powdered lime. It enables silica (of a required portion) to melt at the furnace temperature of 1650oC and binds the particles of brick together resulting in strong and durable bricks. At about 1100o C, lime acts as a catalyst to elevate the furnace temperature to 1650oC at which silica fuses. This slightly fused silica works as a strong cementing material. Excess lime in brick clay will cause vitrification of bricks. It causes bricks to melt, as more than the required amount of silica will fuse. The bricks then lose their shape and become disfigured.

- powdered-lime
- Figure: Powdered Lime
- Iron Oxide
- Bricks contain a small quantity of Iron Oxide. Iron Oxide acts a flux like lime, thus helps silica to fuse at low temperature. It imparts a red color to bricks upon burning. Iron also increases the durability and impermeability of the bricks.
- iron-oxide-3
- Figure: Iron Oxide powder
- Magnesia
- A small proportion of magnesium decreases shrinkage and gives a yellow tint to the bricks. An excess amount of it causes bricks to decay.
- Harmful Ingredients of Brick
- Lime
- Excess lime melts the bricks and disfigures it. If CaCO_3 exists (in the purest form, i.e., if it contains at least 95% CaO) in lime-lump in brick clay, it converts into quicklime on burning. When these bricks come in contact with water, quicklime slakes and expands. And causes disintegration of bricks.
- disintegration-of-bricks

Alkalis

- Alkalis are mainly salt of Sodium (Na) and Potassium (K). It acts as a flux in the kiln and causes fusion, warping, and twisting of bricks. Alkalis absorb moisture from the

atmosphere and cause dampness & efflorescence in bricks (because of the presence of hygroscopic salts, e.g., CaCl_2 , MgCl_2 , etc.).

- Pebbles, Stones & Gravels
- Their presence does not allow thorough mixing of earth, thus the bricks produced are weaker. Such bricks cannot be broken at the desired section and they break very irregularly.
- Pebbles-Stones-and-Gravels
- Figure: Pebbles, Stones, and Gravels
- Iron Pyrites (FeS)

Iron Pyrites causes crystallization & disintegration of bricks while burning. It discolors bricks in the form of black slag.

Organic Matter

Organic matter in bricks makes bricks porous resulting in low density and weaker bricks.

4.1.3 Nanotechnology performed on bricks

Red bricks are the most commonly available, cheap building material that has been in use for more than 1,000 years. Buildings and walls made of bricks occupy a lavish amount of space, which could be effectively modified and utilized differently through the storage of electric power, similar to that of batteries.

Several designers and architects have recognized the capability of red bricks to absorb and store solar heat, and this property is used as a thermal mass for maintaining a heating and cooling effect.

The team of researchers at Washington University published a proof-of-concept in *Nature Communications*, stating how a brick could directly power a green LED light. Their publication showed how an ordinary red brick could be converted into an energy storage device, known as a supercapacitor.

Supercapacitors store electricity as a static charge in solids, unlike batteries that store electricity via an array of chemical reactions. The main advantages of supercapacitors are that they can be charged and recharged much faster than in the case of batteries.

They also always hold a small fraction of energy, unlike batteries.

Related Stories

- New Nanoengineered Batteries Charging More Than 40 Times Faster Than Today's Lithium-ion Batteries
- Nanotechnology and Rechargeable Batteries
Nanotechnology and Developing Countries - Part 2: What Realities?

Julio D'Arcy, an Assistant Professor of Chemistry and one of the authors of the study, said that their method for the development of smart bricks can also be effectively employed on regular bricks or recycle bricks. D'Arcy further stated that their research was conducted on bricks bought at Home Depot in Brentwood (Missouri), and each brick cost around \$0.65.

Conversion of a Normal Brick to an Energy Storing Brick

Scientists have developed a coating made up of conducting polymer PEDOT (3,4-ethylene dioxythiophene). PEDOT is composed of nanofibers that can penetrate the internal porous network of a brick. The polymer coating remains confined in a brick and acts as an ion sponge that could store and conduct electricity. The iron oxide or rust imparts the red color to the bricks.

This metal oxide plays an essential role in stimulating the polymerization reaction. The reactions turn the red bricks into a dark blue color. The researchers stated that these smart bricks could store a substantial amount of energy.

As mentioned earlier, scientists utilize the porous nature of the fired bricks in the development of the new technology. These pores are filled with nanofibres of a conducting plastic that can store charge. The researchers at Washington University are optimistic that with an increase in the energy density of the smart bricks, they can establish a low-cost alternative to the commonly used lithium-ion batteries in the future. At present, as reported in *Nature Communications*, the energy density of the first power bricks is 1% of that of the lithium-ion batteries. The research team believes that the capacity can be increased tenfold by the amendment of specific metal oxides. They can be used commercially by increasing the charge storage capacity of the bricks.

4.2. Powerhouses

4.2.1 Electricity Source

the farthest people have gone in 'thinking outside the brick box' has been to utilize the materials thermal mass for heating and cooling by taking advantage of its ability to absorb and store the sun's heat. Other than that, bricks have been used for thousands of years merely to enclose spaces and hold up roofs.

4.4 BRICK AS ELECTRIC STORAGE



Credit: Washington University in St. Louis

The team's proof of the context demonstrates a brick directly powering an LED light. The

breakthrough development could potentially transform buildings into giant supercapacitors. Imagine being able to use brick walls – which occupy vast amounts of space – for an additional purpose! Supercapacitors can store more energy and be charged more quickly than batteries. They can be stacked to save more energy, so the bigger the wall, the bigger the storage unit. The final product could be connected to a power source to charge and store enough energy to power a light. Three bricks together kept a 3-volt green LED lit for about ten minutes on a single charge. It also worked underwater. After charging 10,000 times, the blocks lost no more than 10% of their storage capacity.



Fig 4.4 BRICK AS ELECTRIC STORAGE

The team envisions the ‘smart bricks’ being hooked up to a renewable source of electricity, such as solar cells, to run lights and an array of microelectronic sensors.

4.2.2 Storage Market

The India battery energy storage systems market is expected to rise at a CAGR of approximately 10% during the forecast period of 2020-2025. Factors such as fulfilling electricity requirements in the country during the peak hours of the day where battery energy storage systems serve as a backup is likely going to drive the India battery energy storage systems market. However, the high cost of investments in large scale projects is expected to restrain the market during the forecast period.

- The lithium-ion segment, due to its high energy density, stores a large amount of energy per unit area in the batteries and is likely to grow at the fastest rate in India battery energy storage systems market over the forecast period.
- India's target to install 450 gigawatts (GW) renewable energy by 2030 is expected to create several opportunities for India's battery energy storage systems market in the future.
- Increasing energy demand in the country is expected to drive the India battery energy storage systems market during the forecast period.

Lithium-ion Segment Expected to Grow at the Fastest Rate

- Lithium-ion batteries are a rechargeable type of battery that is commonly used in electronic devices and energy vehicles. These batteries are also being used for the storage of energy from renewable energy sources such as solar and wind.
- The energy densities of these batteries are quite high and have a round trip efficiency of 85% to 95%, which means the ratio of energy output/released to energy input/stored. The lithium-ion battery is a low maintenance battery, and the cells of the battery cause little harm to the environment when disposed of. The government institutes in India are also planning to replace lead-acid batteries with lithium-ion batteries as they are less expensive and are lightweight than the former.
- Majority of the lithium-ion batteries in India are imported from China, Japan, and South Korea. The government's 'Make in India' scheme is trying to attract domestic investment in battery energy storage systems sector.
- In 2018, Exide Industries Ltd signed a joint venture (JV) with Leclanché SA, one of the world's leading energy storage solution companies, headquartered in Switzerland. This

joint venture was done to build lithium-ion batteries and provide energy storage systems for India's electric vehicle market and grid-based applications.

- In 2018, the Indian Space Research Organization (ISRO) signed a technology transfer agreement (TTA) with Bharat Heavy Electricals Limited (BHEL). The TTA was signed for the manufacture of space-grade Li-Ion cells. ISRO has successfully developed the technology to produce space grade Li-ion cells, which are being used for various satellite and launch vehicle applications.
- Hence, owing to the above points, the lithium-ion segment is likely to grow at the fastest rate India battery energy storage systems market during the forecast period.

Increasing Energy Demand Expected to Drive the Market

- Increasing electricity demand, due to the increase in population, industrialization, and urbanization in the country, is likely to drive the India battery energy storage systems market. Several industries and plants are using these batteries as a backup source for the time of energy shortage.
- Many areas in the country face several power cuts during the day, which creates hindrance in the workflow. For such purposes, the battery energy storage systems (BESS) are of much value as they can provide energy when there is a shortage of it, thus making the workflow smooth.
- An increase in electricity generation from renewable energies such as solar and wind also opens a new door for the BESS. These batteries can also hold extra power that the solar and wind energies produced for its later use, thus maximizing the use of energy generated.
- In 2019, the total electricity generated in India was 1561.1 terawatt-hours (TWh), which was higher than what is produced in 2017, 1470.3 terawatt-hours (TWh).
- In 2019, Tata Power, AES Corporation, and Mitsubishi Corporation inaugurated India's first grid-scale battery-based energy storage system in Rohini, Delhi. The 10 megawatts (MW) grid-connected system, owned by AES and Mitsubishi Corporation. Battery-based energy storage enables electricity to be stored and then delivered within milliseconds, reducing the instability of the electric grid and enabling more energy to be captured and delivered on-demand.

- Hence, owing to the above points, increasing energy demand is expected to drive the India battery energy storage systems market during the forecast period.

4.2.3 Storage Technology

Since the discovery of electricity, we have sought effective methods to store that energy for use on demand. Over the last century, the energy storage industry has continued to evolve, adapt, and innovate in response to changing energy requirements and advances in technology.

Energy storage systems provide a wide array of technological approaches to managing our power supply in order to create a more resilient energy infrastructure and bring cost savings to utilities and consumers. To help understand the diverse approaches currently being deployed around the world, we have divided them into five main categories:

- Batteries – a range of electrochemical storage solutions, including advanced chemistry batteries, flow batteries, and capacitors
- Thermal – capturing heat and cold to create energy on demand or offset energy needs
- Mechanical Storage – other innovative technologies to harness kinetic or gravitational energy to store electricity
- Hydrogen – excess electricity generation can be converted into hydrogen via electrolysis and stored
- Pumped Hydropower – creating large-scale reservoirs of energy with water

4.3. Energy Storage

4.3.1 Renewable Energy

- The last few years have demonstrated that the skepticism around energy storage technology is rapidly evaporating as storage transitions to a state of deployment.

4.7 RENEWABLE ENERGY

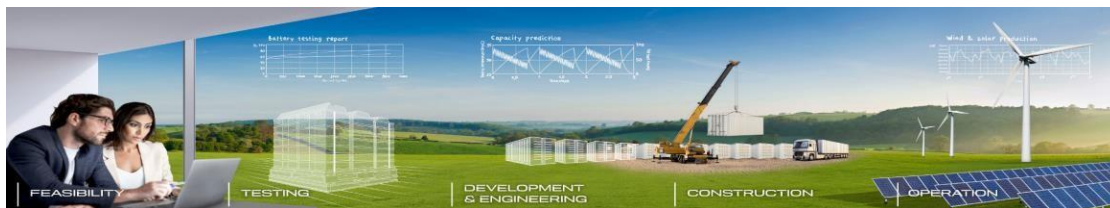


Fig 4.7 Renewable Energy

- Energy storage is pivotal to meeting the challenges facing economies worldwide. Are you ready to navigate the maze of storage applications and multiple benefits offered by tried-and-true—and new—technologies? Learn how we can help you navigate the landscape and help you adopt the right technology—and solutions—for your needs.
- Our energy storage experts work with manufacturers, utilities, project developers, communities and regulators to identify, evaluate, test and certify systems that will integrate seamlessly with today's grid, while planning for tomorrow. Through our dedicated labs and expertise around the world, we have created an industry-leading combination of analytical and testing experience that gives us a unique advantage in finding energy storage solutions. We provide support across the entire energy storage value chain
- Utility-scale batteries, for example, can enable a greater feed-in of renewables into the grid by storing excess generation and by firming renewable energy output. Furthermore, particularly when paired with renewable generators, batteries help provide reliable and cheaper electricity in isolated grids and to off-grid communities, which otherwise rely on expensive imported diesel fuel for electricity generation.
- At present, utility-scale battery storage systems are mostly being deployed in Australia, Germany, Japan, United Kingdom, the United States and other European countries. One of the larger systems in terms of capacity is the Tesla 100 MW/ 129 MWh Li-ion battery storage project at Hornsdale Wind Farm in Australia. In the US-State of New York, a high-level demonstration project using a 4 MW/40 MWh battery storage system showed that the operator could reduce almost 400 hours of congestion in the power grid and save up to USD 2.03 million in fuel costs.
- In addition, several island and off-grid communities have invested in large-scale battery storage to balance the grid and store excess renewable energy. In a mini-grid battery project in Martinique, the output of a solar PV farm is supported by a 2 MWh energy storage unit, ensuring that electricity is injected into the grid at a constant rate, avoiding the need for back-up generation. In Hawaii, almost 130 MWh of battery storage systems have been implemented to provide smoothening services for solar PV and wind energy.
- Globally, energy storage deployment in emerging markets is expected to increase by over

40% each year until 2025.

4.1 Stationary battery storage’s energy capacity growth, 2017-2030

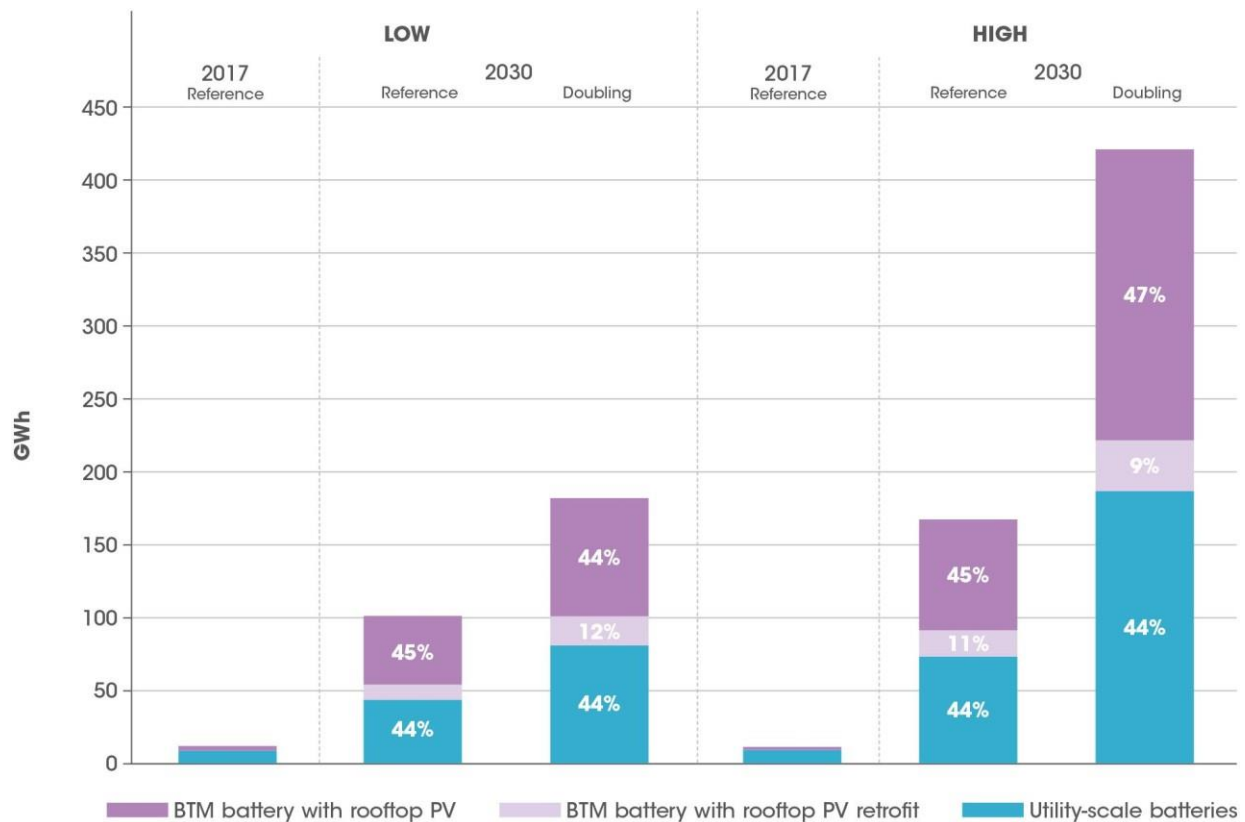


Table 4.1 Stationary battery storage’s energy capacity growth, 2017-2030

- Currently, utility-scale stationary batteries dominate global energy storage. But by 2030, small-scale battery storage is expected to significantly increase, complementing utility-scale applications.
- The behind-the-meter (BTM) batteries are connected behind the utility meter of commercial, industrial or residential customers, primarily aiming at electricity bill savings. Installations of BTM batteries globally is on the rise. This increase has been driven by the falling costs of battery storage technology, due to the growing consumer market and the development of electric vehicles (EVs) and plug-in hybrid EVs (PHEVs), along with the deployment of distributed renewable energy generation and the development of smart grids. In Germany, for example, 40% of recent rooftop solar PV applications have been installed with BTM batteries. Australia aims to reach one million BTM batteries

installations by 2025, with 21 000 systems installed in the country in 2017.

4.2 Services provided by BTM battery storage systems

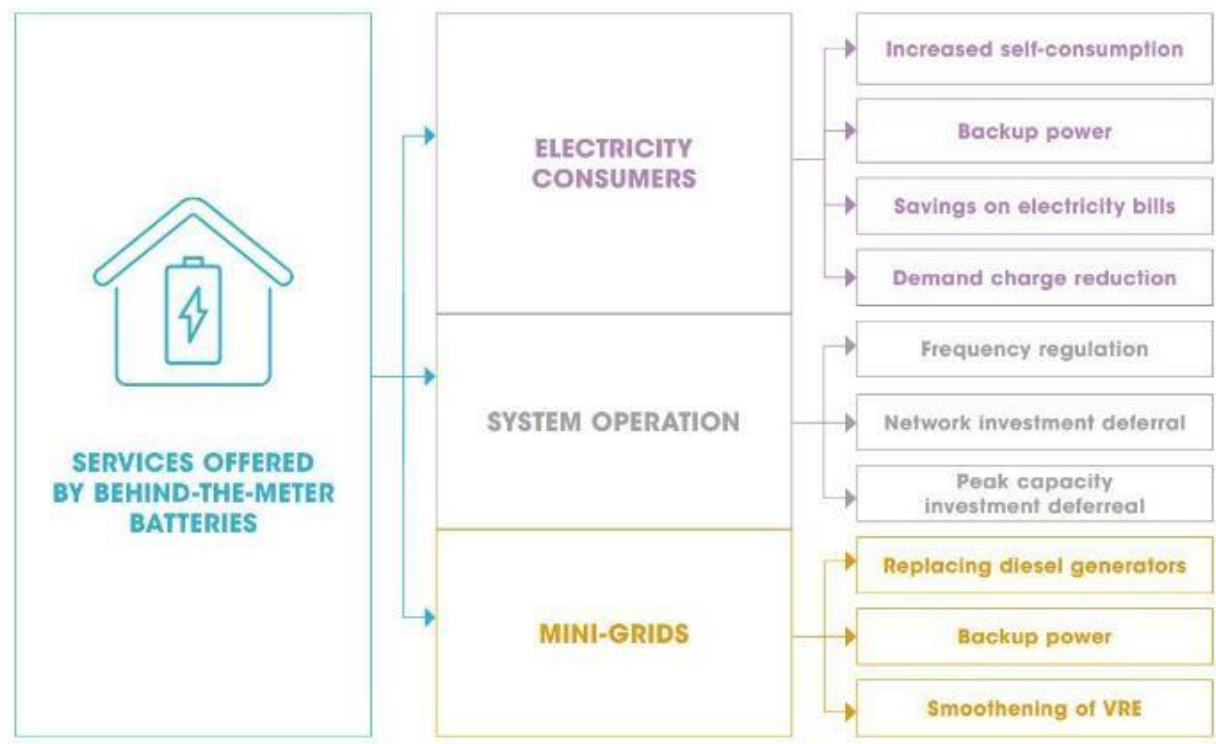


Table 4.2 Services provided by BTM battery storage systems

- Overall, total battery capacity in stationary applications could increase from a current estimate of 11 GWh to between 180 to 420 GWh, an increase of 17- to 38-fold.

4.3.2 Non Renewable Energy

- Due to growing concerns about the environmental impacts of fossil fuels and the capacity and resilience of energy grids around the world, engineers and policymakers are increasingly turning their attention to energy storage solutions. Indeed, energy storage can help address the intermittency of solar and wind power; it can also, in many cases, respond rapidly to large fluctuations in demand, making the grid more responsive and reducing the need to build backup power plants. The effectiveness of an energy storage facility is determined by how quickly it can react to changes in demand, the rate of energy lost in the storage process, its overall energy storage capacity, and how quickly it can be

recharged.

- Energy storage is not new. Batteries have been used since the early 1800s, and pumped-storage hydropower has been operating in the United States since the 1920s. But the demand for a more dynamic and cleaner grid has led to a significant increase in the construction of new energy storage projects, and to the development of new or better energy storage solutions.
- Fossil fuels are the most used form of energy, partly due to their transportability and the practicality of their stored form, which allows generators considerable control over the rate of energy supplied. In contrast, the energy generated by solar and wind is intermittent and reliant on the weather and season. As renewables have become increasingly prominent on the electrical grid, there has been a growing interest in systems that store clean energy
- Energy storage can also contribute to meeting electricity demand during peak times, such as on hot summer days when air conditioners are blasting or at nightfall when households turn on their lights and electronics. Electricity becomes more expensive during peak times as power plants have to ramp up production in order to accommodate the increased energy usage. Energy storage allows greater grid flexibility as distributors can buy electricity during off-peak times when energy is cheap and sell it to the grid when it is in greater demand.
- As extreme weather exacerbated by climate change continues to devastate U.S. infrastructure, government officials have become increasingly mindful of the importance of grid resilience. Energy storage helps provide resilience since it can serve as a backup energy supply when power plant generation is interrupted. In the case of Puerto Rico, where there is minimal energy storage and grid flexibility, it took approximately a year for electricity to be restored to all residents.
- The International Energy Association (IEA) estimates that, in order to keep global warming below 2 degrees Celsius, the world needs 266 GW of energy storage by 2030, up from 176.5 GW in 2017. Under current trends, Bloomberg New Energy Finance predicts that the global energy storage market will hit that target, and grow quickly to a cumulative 942 GW by 2040 (representing \$620 billion in investment over the next two decades).

- In 2017, the United States generated 4 billion megawatt-hours (MWh) of electricity, but only had 431 MWh of electricity storage available. Pumped-storage hydropower (PSH) is by far the most popular form of energy storage in the United States, where it accounts for 95 percent of utility-scale energy storage. According to the U.S. Department of Energy (DOE), pumped-storage hydropower has increased by 2 gigawatts (GW) in the past 10 years. In 2015, the United States had 22 GW of PSH storage incorporated into the grid. Yet, despite the widespread use of PSH, in the past decade the focus of technological advancement has been on battery storage.
- By December 2017, there was approximately 708 MW of large-scale battery storage operational in the U.S. energy grid. Most of this storage is operated by organizations charged with balancing the power grid, such as Independent System Operators (ISOs) and Regional Transmission Organizations (RTOs). ISOs and RTOs are “independent, federally-regulated non-profit organizations” that control regional electricity pricing and distribution.
- PJM, a regional transmission organization located in 13 eastern states (including Pennsylvania, West Virginia, Ohio and Illinois), has the largest amount of large-scale battery installations, with a storage capacity of 278 MW at the end of 2017. The second biggest owner of large-scale battery capacity is California’s ISO (CAISO). By the end of 2017, CAISO operated batteries with a total storage capacity of 130MW.
- Most of the battery storage projects that ISOs/RTOs develop are for short-term energy storage and are not built to replace the traditional grid. Most of these facilities use lithium-ion batteries, which provide enough energy to shore up the local grid for approximately four hours or less. These facilities are used for grid reliability, to integrate renewables into the grid, and to provide relief to the energy grid during peak hours.
- There is also a limited market for small-scale energy storage. While a minor portion of the small-scale storage capacity in the United States is for residential use, most of it is for use in the commercial sector—and most of these commercial projects are located in California.

- In the past decade, the cost of energy storage, solar and wind energy have all dramatically decreased, making solutions that pair storage with renewable energy more competitive. In a bidding war for a project by Xcel Energy in Colorado, the median price for energy storage and wind was \$21/MWh, and it was \$36/MWh for solar and storage (versus \$45/MWh for a similar solar and storage project in 2017). This compares to \$18.10/MWh and \$29.50/MWh, respectively, for wind and solar solutions without storage, but is still a long way from the \$4.80/MWh median price for natural gas. Much of the price decrease is due to the falling costs of lithium-ion batteries; from 2010 to 2016 battery costs for electric vehicles (similar to the technology used for storage) fell 73 percent.

4.4 Micro-generation

4.4.1 On Bricks

In ceramic production, the high energy expenditures for operating the kiln and drying the wares are a crucial cost driver. In Germany, the financial burden of rising outlays for energy is increasing continuously. Apart from optimizing a plant's dryers and kilns, the available options include the adoption of combined heat and power generation (CHP) as a way to reduce the impact of rising energy prices on the economic efficiency of production. Considering the high process temperatures required for making structural clay building products, micro gas turbine technology is very well. Scientists have developed a coating made up of conducting polymer PEDOT (3,4-ethylene dioxythiophene). PEDOT is composed of nanofibers that can penetrate the internal porous network of a brick. The polymer coating remains confined in a brick and acts as an ion sponge that could store and conduct electricity. The iron oxide or rust imparts the red color to the bricks.

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At present, as reported in *Nature Communications*, the energy density of the first power bricks is 1% of that of the lithium-ion batteries. The research team believes that the capacity can be increased tenfold by the amendment of specific metal oxides. They can be used commercially by increasing the charge storage capacity of the bricks.

4.4.2 Smart Grid

- As the demand for energy steadily increases, it can no longer be met by building more fossil fuel power stations, because of their pollution and contribution to global warming. Therefore, renewable energy is used instead – but it is a distributed, unpredictable resource that must be managed within a smart grid infrastructure.

4.8 SMART GRID



Fig 4.8 Smart Grid

- Smart grids enable real-time data to be collected from line sensors, users, and generators and transmitted to a central control point that can perform analysis and control functions. This allows for power load balancing, failure recovery and distribution management.
- For decades, our electricity needs have been adequately met by a traditional National Grid model which is conceptually quite simple. A small number of large-scale fossil fuel - or sometimes nuclear – power stations deliver power over long distances to where it's needed; homes, commercial premises, factories and many other environments.
- However, the energy market is a highly dynamic place, with many powerful factors of change. Some of these are leading to the demise of traditional grids, while others are facilitating the smart grids that are replacing them. If we look at both sets of factors, we

will see why smart grids are essential, as well as how they can improve our access to and use of electrical energy.

limitations of the traditional grid

Fossil fuel power stations have served us well for so many years because they are predictable and reliable. Operators can bring them online whenever they're needed – unlike renewable energy generators, whose performance depends on prevailing weather conditions. However, these stations are highly polluting, and make significant contributors to global warming. Accordingly, many European countries have made commitments and set deadlines for phasing out fossil fuels.

Meanwhile, demand for electricity is steadily growing, as we live more of our personal and working lives online, and increase our uptake of electric vehicles. So, without making technological advances, we would have been left with a diminishing pool of fossil power stations endeavouring to support a relentlessly increasing electric load.

This stress would have led to an increasing incidence of power anomalies and blackouts on aging networks, with limited ability to detect faults and respond to them in real time.

Fortunately, new technologies have been becoming available, and are being deployed, to address these issues. These technologies, and especially the way in which they work with one another, can be grouped under the umbrella term Smart Grid..

4.4.3 City plan

" Smart grid cities" after the energy regulator set aside £500m from customers' utility bills to start rewiring the nation's electricity system.

to choose several towns or cities where it will pay for households to have smart energy technologies installed to monitor how it works on a large scale.

The idea is to start an overhaul of the ageing electricity grid, which is centralised and depends on large fossil fuel powered plants, and make it more localised using more renewable forms of generation.

Mini "smart grids" will be built that will be able to handle more unpredictable large volumes of power from intermittent wind farms. The grids will also make it easier for households that have their own micro-generation – such as solar panels on their roofs – to supply electricity back to the grid. Smart meters will be fitted in homes, which are better able to

manage demand unpredictable supply peaks from renewable forms of generation, such as wind and solar power.

The Smart Cities are at the Forefront of the Future Internet

The smart city vision does involve hard infrastructure such as introducing smart grids alongside various forms of renewable energy generation and building new systems of mobility based on distributed networks but is perhaps primarily articulated through ‘soft infrastructure’ i.e. social networks and communities, legal and cultural systems, and various forms of ICT. Equally, the output of such thinking, through the emerging medium of urban informatics, can often be engaging, informative, even beautiful, realized in the form of increasingly refined audio-visual displays and interfaces, installations, websites and systems, all driven via these real-time learning layers overlaid onto the existing city. This has the effect of ‘making the invisible visible’ thus raising awareness about urban infrastructure, activity and ecosystem.

"The future development of Smart Cities will be only achievable in conjunction with a technological leap in the underlying ICT infrastructure"

The successful development of the ‘Smart Cities paradigm’ will “require a unified ICT infrastructure to allow a sustainable economic growth”), and this unified ICT platform must be suitable to “model, measure, optimize, control, and monitor complex interdependent systems of dense urban life”. Once major challenges of unified urban-scale ICT platforms are identified, it is clear that the future development of Smart Cities will be only achievable in conjunction with a technological leap in the underlying ICT infrastructure. In this work one would tend to advocate that this technological leap can be done by considering Smart Cities at the forefront of the recent vision of the Future Internet (FI). Although there is no universally accepted definition of the Future Internet, it can be approached as “a socio-technical system comprising Internet-accessible information and services, coupled to the physical environment and human behavior, and supporting smart applications of societal importance” (http://ec.europa.eu/information_society/activities/foi/library/docs/fipp-research-challenges-for-coreplatform-issue-1-1.pdf). Thus the FI can transform a Smart City into an open innovation platform supporting vertical domain of business applications built upon horizontal enabling technologies. The most relevant basic FI pillars for a Smart City environment are the following (http://ec.europa.eu/information_society/activities/foi/

events/fippp3/fi-ppp-workshop-report-final.pdf):

- **The Internet of Things (IoT):** defined as a global network infrastructure based on standard and interoperable communication protocols where physical and virtual “things” are seamlessly integrated into the information network (Sundmaeker, et al, 2010).
- **The Internet of Services (IoS):** flexible, open and standardized enablers that facilitate the harmonization of various applications into interoperable services as well as the use of semantics for the understanding, combination and processing of data and information from different service providers, sources and formats.
- **The Internet of People (IoP):** envisaged as people becoming part of ubiquitous intelligent networks having the potential to seamlessly connect, interact and exchange information about themselves and their social context and environment.

E-Bricks: The Foundation of Smart Cities

E-Bricks of the smart cities -the core conceptual domain of this paper- attempts to integrate information from multiple data sources (sensor networks, information systems, internet etc.) and offer on these common data processing infrastructure, value addition and advanced support for third parties to develop services on processed data and make them available openly following a scheme of Open Data System for public consumption. The major thematic content of the chapter, *inter alia*, includes: developing a policy roadmap for smart cities and use of internet, cloud computing , smart cities drivers and ICT applications in search of forging business linkages, smart city architecture and building blocks, mobile applications, Transformational ‘Smart Cities’ for Cyber Security and Resilience etc. At the outset, let us take a look into the near future to see how these trends will affect city development.

The following figure shows how technologies like big data and analytics, mobility, social media, and cloud provide a foundation for meeting city business goals and creating valuable services.

4.9 TECHNOLOGIES

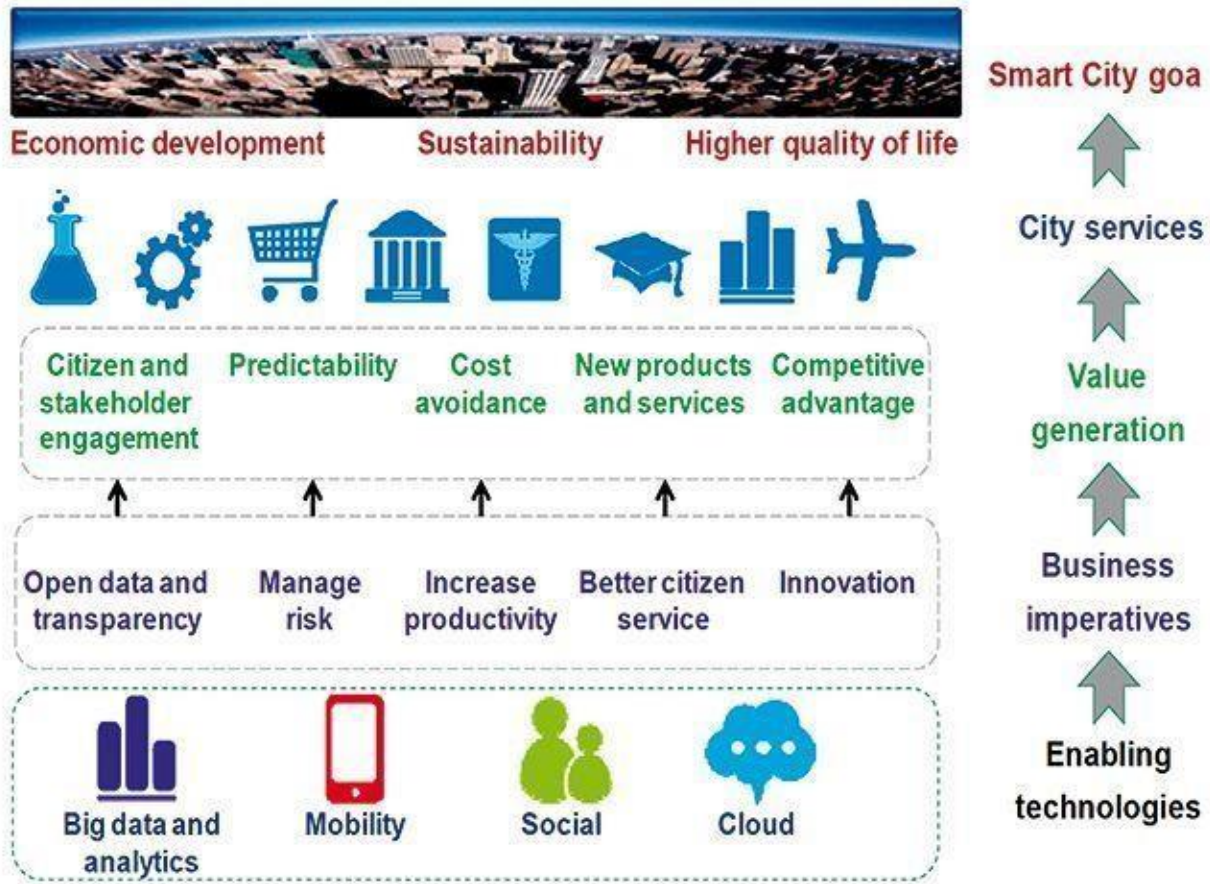


Fig 4.9 Technologies

Today, less than 1% of things that could be connected are connected to the Internet or intelligent systems. IDC projects that by 2020, there will be 212 billion "things" in the world and that by 2017, 3.5 billion people will connect to the Internet, 64% of them via mobile devices.

4.10 SMART CITIES



Fig 4.10 Smart Cities

"Cities are the 80% of the global GDP, but they consume around 75% of global primary energy and are responsible for 70% of the global greenhouse"

Smart City Framework

Smart City Framework (SCF) is conceived to be a high level architecture of a platform that describes the scope of the innovations expected from the *City-Pulse Project* and the way they are integrated together in a coherent conceptual system. The purpose of this Framework concept is to serve as a *reference model and architecture* (RMA) to be used by smart city stakeholders, project partners and any other interested parties when engaged in technical discussions about smart cities services based on real-time information streams. The Smart City Framework is expected to be an initial architecture to set the main concepts, common language and the boundaries for the whole project while the details are expected to change within the course of the project execution. The **Figure 2** presents the architecture in different views, functional, interface and information,

security and privacy view and thus explains respectively what the framework does, how components interact with each other, the generation and flow of information, and the necessary mechanisms to address security and privacy concerns about city and citizen relevant data. In the presentation of the interface and information view each *City-Pulse Work package* (WP) has provided more detailed descriptions of their individual architectures, which, inter alia, includes High-level view of *Smart City Framework*.

4.11 SMART CITY FRAMEWORK

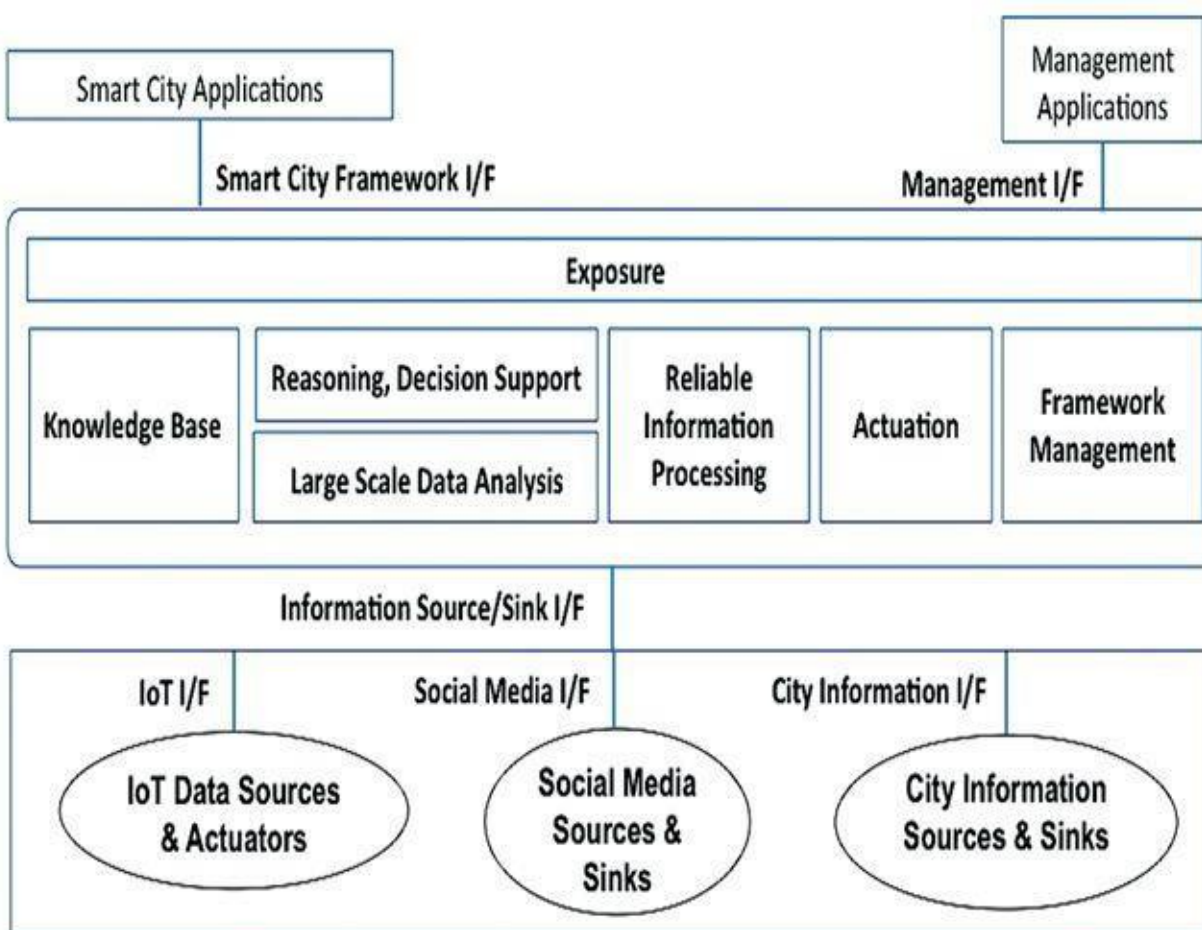


Fig 4.11 Smart City Framework

Digital City: A Case Study for a Digital Smart City

Digital City Design and ICT Master Planning project determines a best fit Digital City design, expected ROI and impact on operating costs, by integration of technologies for core Digital City services.

Wipro Technologies defines a Digital City (Smart or Techno City) as a city that monitors

and integrates conditions of all of its critical infrastructures, better optimizes its resources, plans its preventive maintenance activities, and monitors security aspects while maximizing services to its citizens. The concept of a Digital City is rapidly gaining momentum across many different urban areas, with various stakeholders trying to determine the right approach to deliver the vision of a Smarter City. At the core of the success of any Digital City program is the impact on the citizen. All capabilities provided by the Digital City are focused around empowering citizens and enabling citizen leaders. In addition, these capabilities provide City Governments a clearer picture of the needs of a city, enabling more precise intervention and more efficient execution of citizen services. The crux to realizing this vision of a Digital City is Information and Communication technology (ICT). Digital cities depend on ICT to operate a diverse range of city functions and services. Technology ensures that elements of physical infrastructure are able to transmit real-time data on a city's status, by way of sensors and processors applied within real-world infrastructure. This Physical to Digital integration brings about a convergence of processes that enables a digital city to function as an independent intelligence unit.

Developing a Policy Roadmap for Smart Cities and use of Internet

The future Internet technologies and expected impact on cities will allow defining an innovation roadmap towards smart cities. Cities are increasingly aware of the concept of "smart city" and actively developing strategies towards the goal of becoming "smart" and manage more efficiently city resources and addressing development and inclusion challenges. Part of the development towards smart cities is the co-creation/crowd sourcing paradigm, people-led testing and implementation of technologies and ICT-based applications in sectors such as health and assisted living, participative government, energy management, and new work environments. The roadmap summarized here is based on a two-dimensional mapping of layers and time periods. The vertical dimension considers the following layers: technological change, business change, policy change and social change. The time dimension includes the short term, mid-term and longer term developments. In order to enhance the policy relevance of the road mapping approach, we focus on the systemic character of innovations related to smart cities, which require concurrent processes of socioeconomic and technological change. To provide guidelines

to this process, the road mapping approach draws from systemic change literature taking into account several characteristics of systemic change which relate to the transformation towards smart cities, e.g. regimes, barriers, transitions, and niches of novel solutions.

4.12 MOBILE ACCESS TECHNOLOGIES



Fig 4.12 Mobile Access Technologies

"In the near-future, the advancement in mobile access technologies will offer high-speed LTE access on all mobile devices"

Cities are engines of economic growth, accounting for 80% of the global GDP. But they also consume around 75% of global primary energy and are responsible for 70% of the global greenhouse gas (GHG) emissions (UN-Habitat, 2015). All sectors associated with urbanization (transport, building construction and maintenance, housing, waste management, energy, etc.) are registering trends that raise sustainability issues. Rapid

and unplanned urbanization has led to growth of slums, sprawl, housing and infrastructure shortages, social segregation, and exclusion. Accompanied by motorization, it has caused congestion and hazardous air pollution. Cities are where inequalities are most acute (one-third of urban dwellers in the developing world, for example, live in slums), where threats to culture and heritage are rising, and where the heavy concentration of people and assets possess high levels of challenges and disaster risks.

4.5. Nanotechnology performed on Bricks

4.5.1 EDOT

The original synthesis proceeded via the diester of 3,4-dihydroxy thiophene-2,5-dicarboxylate.

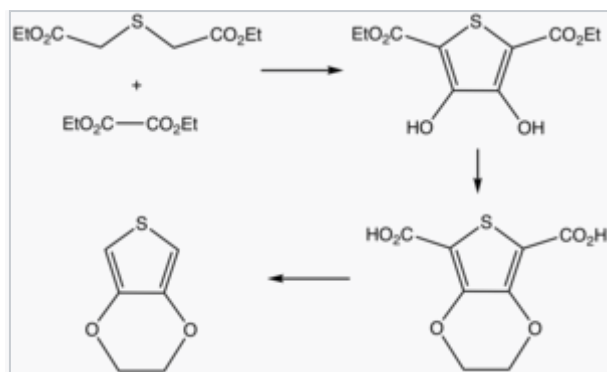
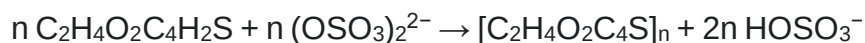


Fig 4.13 One synthesis of EDOT.

One synthesis of EDOT.

EDOT is often prepared from C4 precursors such as butanediol and butadiene via routes that produce the thiophene and dioxane rings in separate steps. Representative is the reaction of 2,3-butanedione, trimethyl orthoformate, and ethylene glycol to form the dioxane. Sulfidization with elemental sulfur gives the bicyclic target.

EDOT is converted into the conducting polymer PEDOT by oxidation. The mechanism for this conversion begins with production of the radical cation [EDOT]⁺, which attacks a neutral EDOT molecule followed by deprotonation. Further similar steps result in the dehydropolymerization. The idealized conversion using peroxydisulfate is shown



4.5.2 PEDOT

Poly(3,4-ethylenedioxy thiophene) containing poly(styrenesulfonic acid) [PEDOT:PSS] is an important commercial polymer and most practical preparation method was developed at Bayer AG under the name 'BAYTRON P synthesis'. In this PEDOT:PSS. Formation of PEDOT:PSS was confirmed from infrared, electronic absorption and XRD pattern. PEDOT:PSS was obtained in paracrystalline form with a very good pellet conductivity (6 S cm^{-1}) and stability (up to 190°C). Also, PEDOT:PSS was prepared in water as aqueous dispersion and this dispersion can be coated on various substrates. Electrochemical characterization of PEDOT:PSS electrode in aq. 1 M H_2SO_4 solution was carried using cyclic voltammetry, charge-discharge and electrochemical impedance spectroscopy. Cyclic voltammetric pattern shows almost rectangular spectrum with specific capacitance value of 150 F g^{-1} . One of the important outputs of this work, i.e. ESR value was very low (0.4Ω) and found independent with cycle numbers.

4.5.3 Electrospinning

Electrospinning produces fibers with diameters ranging from nanometer to micrometer scale when the electrostatic force is applied on solutions or melts. A general electrospinning setup consists of three primary components as shown in a high voltage power supply (usually in the kV range), a syringe with a metallic needle, and a grounded collector (solid substrate or liquid media). In a typical electrospinning process, high voltage is applied on solutions or melts. Subsequently, a pendant droplet forms. When the electrostatic repulsion starts to overcome the surface tension of the fluid, the pendant droplet will deform into a conical droplet known as the Taylor cone at the tip of the needle. As the electrostatic force overcomes the surface tension of the conical droplet, a fine, charged jet of polymer solution is ejected from the tip of the needle. The interaction between the electric field and the surface tension of the fluid stretches the jet stream and makes it undergo a whipping motion leading to the evaporation of the solvent. This causes the jet stream to be continuously elongated as a long and thin filament and then this filament solidifies and is eventually deposited onto a grounded collector, resulting in the

formation of a uniform fiber.

NFs with different orientation and hierarchical structures can be produced by electrospinning. The orientation of NFs includes random and aligned structures as shown in Figure 3. In particular, the well-aligned and highly ordered NFs are often required for energy devices. It is worth noting that the fiber collectors play a crucial role in obtaining aligned orientation. In the past decades, many advances have been achieved in enhancing alignment of electrospun NFs by using special designed collectors, such as rotating drum, metal frame, or two conductive substrates separated by a gap. In addition, Teo et al. developed a liquid system combined with a rotating mandrel where continuous yarn was made from electrospun fibers.

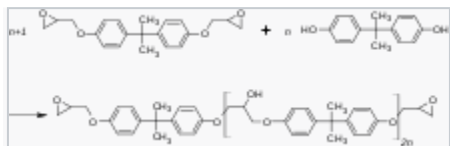
4.6. Electricity passing through Bricks

4.6.1 When EPOXY is not coated

The most common epoxy resins are based on reacting epichlorohydrin (ECH) with bisphenol A, resulting in a different chemical substance known as bisphenol A diglycidyl ether (commonly known as BADGE or DGEBA). Bisphenol A-based resins are the most widely commercialised resins but also other bisphenols are analogously reacted with epichlorohydrin, for example Bisphenol F.

In this two-stage reaction, epichlorohydrin is first added to bisphenol A (bis(3-chloro-2-hydroxy-propoxy)bisphenol A is formed), then a bisepoxide is formed in a condensation reaction with a stoichiometric amount of sodium hydroxide. The chlorine atom is released as sodium chloride (NaCl), the hydrogen atom as water.

Higher molecular weight diglycidyl ethers ($n \geq 1$) are formed by the reaction of the bisphenol A diglycidyl ether formed with further bisphenol A, this is called prepolymerization:

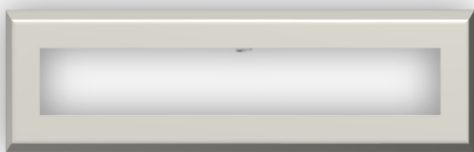


Synthesis of bisphenol-A-diglycidyl ether with a high molar mass

4.6.2 When EPOXY is performed(Waterproofing)

A product comprising a few repeat units ($n = 1$ to 2) is a viscous, clear liquid; this is called a liquid epoxy resin. A product comprising more repeating units ($n = 2$ to 30) is at room temperature a colourless solid, which is correspondingly referred to as solid epoxy resin. Instead of bisphenol A, other bisphenols (especially bisphenol F) or brominated bisphenols (e. g. tetrabromobisphenol A) can be used for the said epoxidation and pre polymerisation. Bisphenol F may undergo epoxy resin formation in a similar fashion to bisphenol A. These resins typically have lower viscosity and a higher mean epoxy content per gram than bisphenol A resins, which (once cured) gives them increased chemical resistance.

Important epoxy resins are produced from combining epichlorohydrin and bisphenol A to give bisphenol A diglycidyl ethers.



Structure of bisphenol-A diglycidyl ether epoxy resin: n denotes the number of polymerized subunits and is typically in the range from 0 to 25

Increasing the ratio of bisphenol A to epichlorohydrin during manufacture produces higher molecular weight linear polyethers with glycidyl end groups, which are semi-solid to hard crystalline materials at room temperature depending on the molecular weight achieved. This route of synthesis is known as the "taffy" process. More modern manufacturing methods of higher molecular weight epoxy resins is to start with liquid epoxy resin (LER) and add a calculated amount of bisphenol A and then a catalyst is added and the reaction heated to circa $160\text{ }^{\circ}\text{C}$ ($320\text{ }^{\circ}\text{F}$). This process is known as "advancement".^[8] As the molecular weight of the resin increases, the epoxide content reduces and the material behaves more and more like a thermoplastic. Very high molecular weight poly condensates (ca. $30\,000 - 70\,000\text{ g/mol}$) form a class known as phenoxy resins and contain virtually no epoxide groups (since the terminal epoxy groups are insignificant compared to the total size of the molecule). These resins do however contain hydroxyl groups throughout the backbone, which may also undergo other cross-linking reactions,

e.g. with aminoplasts, spheroplasts and isocyanates.

Epoxy resins are polymeric or semi-polymeric materials or an oligomer, and as such rarely exist as pure substances, since variable chain length results from the polymerisation reaction used to produce them. High purity grades can be produced for certain applications, e.g. using a distillation purification process. One downside of high purity liquid grades is their tendency to form crystalline solids due to their highly regular structure, which then requires melting to enable processing.

An important criterion for epoxy resins is the epoxide group content. This is expressed as the "*epoxide equivalent weight*", which is the ratio between the molecular weight of the monomer and the number of epoxide groups. This parameter is used to calculate the mass of co-reactant (hardener) to use when curing epoxy resins. Epoxies are typically cured with stoichiometric or near-stoichiometric quantities of hardener to achieve the best physical properties.

Novolaks

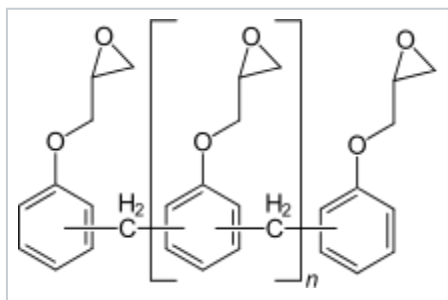


Fig 4.19 Novolaks

General structure of epoxyphenol novolak with n usually in the range from 0 to 4. The compound is present in the form of various constitutional isomers.

Novolaks are produced by reacting [phenol](#) with methanal (formaldehyde). The reaction of epichlorohydrin and novolaks produces novolaks with glycidyl residues, such as epoxyphenol novolak (EPN) or epoxycresol novolak (ECN). These highly viscous to solid resins typically carry 2 to 6 epoxy groups per molecule. By curing, highly cross-linked polymers with high temperature and chemical resistance but low mechanical flexibility are formed due to the high functionality of these resins.^[6]

ALLIPHATIC

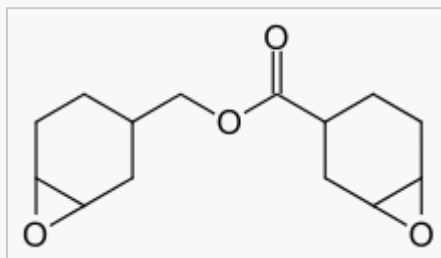


Fig 4.17 Aliphatic

There are two common types of aliphatic epoxy resins: those obtained by epoxidation of double bonds (cycloaliphatic epoxides and epoxidized vegetable oils) and those formed by reaction with epichlorohydrin (glycidyl ethers and esters).

Cycloaliphatic epoxides contain one or more aliphatic rings in the molecule on which the oxirane ring is contained (e.g. 3,4-epoxycyclohexylmethyl-3',4'-epoxycyclohexanecarboxylate). They are produced by the reaction of a cyclic alkene with a peracid (see above). Cycloaliphatic epoxides are characterised by their aliphatic structure, high oxirane content and the absence of chlorine, which results in low viscosity and (once cured) good weather resistance, low dielectric constants and high T_g . However, aliphatic epoxy resins polymerize very slowly at room temperature, so higher temperatures and suitable accelerators are usually required. Because aliphatic epoxies have a lower electron density than aromatics, cycloaliphatic epoxies react less readily with nucleophiles than bisphenol A-based epoxy resins (which have aromatic ether groups). This means that conventional nucleophilic hardeners such as amines are hardly suitable for crosslinking. Cycloaliphatic epoxides are therefore usually homopolymerized thermally or UV-initiated in an electrophilic or cationic reaction. Due to the low dielectric constants and the absence of chlorine, cycloaliphatic epoxides are often used to encapsulate electronic systems, such as microchips or LEDs. They are also used for radiation-cured paints and varnishes. Due to their high price, however, their use has so far been limited to such applications.

Epoxidized vegetable oils are formed by epoxidation of unsaturated fatty acids by reaction with peracids. In this case, the peracids can also be formed in situ by reacting carboxylic acids with hydrogen peroxide. Compared with LERs (liquid epoxy resins) they have very low viscosities. If, however, they are used in larger proportions as reactive diluents, this

often leads to reduced chemical and thermal resistance and to poorer mechanical properties of the cured epoxides. Large scale epoxidized vegetable oils such as epoxidized soy and lens oils are used to a large extent as secondary plasticizers and cost stabilizers for PVC

Aliphatic glycidyl epoxy resins of low molar mass (mono-, bi- or polyfunctional) are formed by the reaction of epichlorohydrin with aliphatic alcohols or polyols (glycidyl ethers are formed) or with aliphatic carboxylic acids (glycidyl esters are formed). The reaction is carried out in the presence of a base such as sodium hydroxide, analogous to the formation of bisphenol A-diglycidyl ether. Also aliphatic glycidyl epoxy resins usually have a low viscosity compared to aromatic epoxy resins. They are therefore added to other epoxy resins as reactive diluents or as adhesion promoters. Epoxy resins made of (long-chain) polyols are also added to improve tensile strength and impact strength.

A related class is cycloaliphatic epoxy resin, which contains one or more cycloaliphatic rings in the molecule (e.g. 3,4-epoxycyclohexylmethyl-3,4-epoxycyclohexane carboxylate). This class also displays lower viscosity at room temperature, but offers significantly higher temperature resistance than the aliphatic epoxy diluents. However, reactivity is rather low compared to other classes of epoxy resin, and high temperature curing using suitable accelerators is normally required. As aromaticity is not present in these materials as it is in Bisphenol A and F resins, the UV stability is considerably improved.

4.7. Storage Capacity

4.7.1 Per 50 bricks

4.7.2 Per 100 Bricks

4.8. Nanotechnology and Industrialisation

4.8.1 Potential Solar energy

The estimate found that solar energy has a global potential of 1,600 to 49,800 exajoules (4.4×10^{14} to 1.4×10^{16} kWh) per year (see table below). Total global annual solar energy potential amounts to 1,575 EJ (minimum) to 49,837 EJ.

In addition to being free as a source of energy (it does cost money to harness it and turn it into electricity), energy from the sun is practically limitless. The surface of the Earth receives solar energy at an average of 343 W/m^2 . If we multiply this times the surface area of the Earth, about $5 \times 10^{14} \text{ m}^2$, we get $1715 \times 10^{14} \text{ W}$. But, 30% of this is reflected, and only 30% of the Earth is above sea level, so the usable solar energy we receive on the land surface is about $360 \times 10^{14} \text{ W}$. We need to reduce this further because not all of the land surface is suited to installation of solar PV panels — we don't want to cut down forests, and ice-covered areas are not suitable, so we reduce the area by about one half. Over the course of a year, this amount of solar energy adds up to $66 \times 10^{22} \text{ Joules}$. In 2018, we used about $600 \times 10^{18} \text{ Joules}$ of energy, which is just a shade less than 0.1% of the harvestable solar energy we receive on the land. This means that even if we got all of our energy from the Sun, we would not make a dent in the total! The potential is vast — 10,000 times what we need!

Let's consider what it would mean for us to get all of our energy from Solar PV — how much of the Earth's surface would we need to cover with panels? The black dots (radii of 100 km) in the figure below represent areas that could generate enough energy from sunlight to completely power the planet for an entire year. Practically, there are barriers to running the planet entirely on sunlight (everything would need to be electrified, we would need very large quantities of battery energy storage, and so forth), but the dots are useful as a demonstration of just how vast the energy production potential from solar is. One of the important differences between Solar PV and CSP is that CSP requires more intense sunlight, and as such, it is not a viable option in many places. In contrast, Solar PV works just about everywhere — it is more versatile. Another important difference is in scale — CSP is really suited to utility-scale power plants, whereas Solar PV works at both the utility-scale and the very small scale.

The map below shows the PV potential for the world. The variability in the map is mainly a function of cloudiness and latitude. Many of the big, utility-scale solar PV plants are located in the red areas, but there is a surprising amount of Solar PV energy being harvested in places like Germany and Japan, both of which are fairly cloudy. But, even in a fairly cloudy place like Pennsylvania, you can see from the map that we could expect about 1460 kWh per year from a 1 kW PV array. From this, you can calculate how many

square meters of PV panels you'd need to provide the electricity for a house that uses the typical 10,800 kWh per year. If you divide 10,800 kWh by 1460, you see that you'd need about 7kW of solar panels, which would fit on a typical house roof. The main point here is that Solar PV is a viable energy source in most parts of the world where people are living. In contrast to Solar PV, energy from CSP is only viable in places where the daily totals in the map above are higher than 6 kWh/day. Nevertheless, there are many regions where CSP viability and human population coincide, so it too can be an important energy resource in the future.

4.8.2 Heat production Halls

The energy levels required in the heating of production halls uses to be lowers than required in productive process, making it possible to use part of the produced heat in the process for the air conditioning. Although full recovery is expected or desired in a process to process application, recovery heat for a process-to-comfort application must be modulated to prevent over heating the make up air [1].

The use of part of the heat generated for the process can be done in two ways:

- Taking part of the heated fluid that outcomes from the process heat generator.
- Using the wasted heat after the fluid has passed through the industrial process.

Heating at process temperature

This heating method uses the boiler or other heating generators for producing hot water at a process temperature that will feed both the process and the space conditioning. The hot water at process temperature passes through a heat exchanger that heat up the water in the distribution system.

Advantages

- A single heat production unit
- Less space requirements
- Less variations in the energy supply (if applicable)
- Easy distribution system
- Lower initial investment (in certain cases)

Disadvantages

- Inefficiency in the heat production for air conditioning.
- Higher heat production costs
- Higher energy distribution losses due to the higher temperature and the heat exchanger efficiency.

4.9. Mechanism Of Storing Bricks

4.9.1 Development of Super Capacitor

Fired brick, typically used for construction and architectural esthetics, is one of the most durable materials with a 5000-year history dating back to Neolithic China¹. This masonry building block is commonly found in various red tones and mostly comprised of fused particles of silica (SiO_2), alumina (Al_2O_3) and hematite ($\alpha\text{-Fe}_2\text{O}_3$)². The red color of a brick originates from hematite, a pigment first utilized by humans 73,000 years ago^{3,4} and serving today as a low-cost naturally abundant inorganic precursor for catalysts⁵, magnets⁶, and alloys⁷. State-of-the-art energy storage materials are also produced from hematite. For example, FeN_x , FeP , and Li_5FeO_4 are synthesized via anionic or cationic exchange for potassium-ion batteries, Zn–air batteries, pseudocapacitors, and lithium-ion batteries; electrochemical transformation of hematite leads to FeOOH supercapacitor anodes.

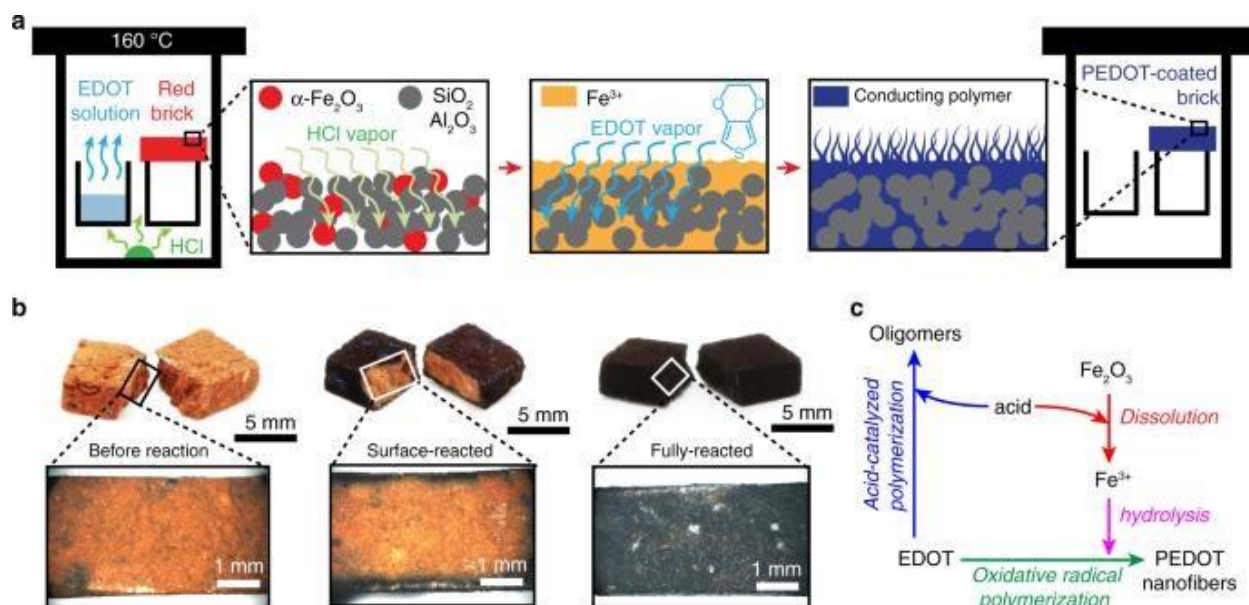
This work is inspired by our recently published rust-assisted vapor phase polymerization. Chemistries enabled by hematite provide an opportunity for developing cutting-edge functionalities on a fired brick where 8 wt% $\alpha\text{-Fe}_2\text{O}_3$ content and a 3D porous microstructure afford an ideal substrate for engineering a mechanically robust electrode. Here, we develop a supercapacitor using a brick's hematite microstructure as reactant to vapor-deposit a nanofibrillar coating of the conducting polymer poly(3,4-ethylenedioxythiophene) (PEDOT). Vapor-phase synthesis leads to PEDOT coatings exhibiting a high electronic conductivity and facile charge transfer, making it an ideal route for producing electrode. This synthesis utilizes a brick's open microstructure and thermal stability to permeate acid and monomer vapor through its pores at 160 °C to control α -

Fe₂O₃ dissolution and Fe³⁺ hydrolysis with concomitant oxidative radical polymerization. A symmetric brick-based supercapacitor shows an areal capacitance of 1.60 F cm⁻² and energy density of 222 μWh cm⁻² at a current density of 0.5 mA cm⁻². This two-electrode-based measurement is collected using 1 M H₂SO₄ aqueous electrolyte under 1 V operating voltage window. To mimic a “brick-mortar-brick” structure, a supercapacitor is modified using a quasi-solid-state electrolyte (poly(vinyl alcohol)/1M H₂SO₄) that also plays the role of binder and separator. Our devices are water-resistant because they are coated with an epoxy encapsulating layer that protects them enabling charge storage at temperatures between -20 and 60 °C. A supercapacitor is stable in ambient conditions undergoing 10,000 charge–discharge cycles with ~100% coulombic efficiency and ~90% capacitance retention. Moreover, a supercapacitor brick module is produced reaching a 3.6 V voltage window by connecting three devices in series.

Conversion of a fired brick's α-Fe₂O₃ to a PEDOT coating

Deposition of PEDOT nanofibers is initiated by dissolving α-Fe₂O₃ at 160 °C with HCl vapor; this process liberates Fe³⁺ ions, promotes hydrolysis and initiates precipitation of colloidal 1D FeOOH nuclei . As previously reported, partially dissolved FeOOH nuclei serving as templates oxidize 3,4-ethylenedioxythiophene (EDOT) monomer vapor and control oxidative radical polymerization. Control of both stoichiometry and reaction time leads to PEDOT coatings with different thicknesses . We advance previous findings by demonstrating here that the synthesis utilizes two potential polymerization initiators, i.e., oxidant (Fe³⁺) and acid (HCl) where the former leads to oxidative radical polymerization and the latter, to acid-catalyzed polymerization . We readily control the polymerization mechanism as an acid-catalyzed polymerization typically produces nonconductive oligomers stemming from active chain termination. Only PEDOT synthesized via oxidative radical polymerization exhibits long conjugation length, ordered chain packing, low electrical resistance, as well as high chemical and physical stability.

4.18: Deposition of a nanofibrillar PEDOT coating on brick.



a In a one-step reaction, a brick's $\alpha\text{-Fe}_2\text{O}_3$ microstructure is partially dissolved by acid vapor to liberate Fe^{3+} , promote hydrolysis and precipitation of FeOOH spindles that control oxidative radical polymerization. As previously reported, monomer vapor reacts with partially dissolved FeOOH nuclei resulting in preferential directional growth of high aspect ratio PEDOT nanofibers. b The thickness of a PEDOT coating is controlled by reaction time and stoichiometry enabling a reaction to generate surface-polymerized PEDOT-coated bricks (core/shell architecture) or fully polymerized bricks (monolithic PEDOT architecture). c A reaction diagram shows the competition between acid-catalyzed polymerization and oxidative radical polymerization mechanisms present in our reactions.

In our polymerization mechanism, the acid concentration determines both dissolution rate and synthetic pathways. A high H^+ concentration facilitates the liberation of Fe^{3+} as well as oxidative radical polymerization while promoting acid-catalyzed polymerization that consumes EDOT and results in PEDOT of low conjugation length. To investigate the effect of H^+ concentration, different volumes of concentrated HCl are added to the reactor and the HCl vapor concentration is calculated by dividing moles of HCl with reactor volume (assuming total evaporation). Using a HCl vapor concentration less than 4.8 mM leads to an incomplete reaction because both oxidative radical polymerization and acid-catalyzed polymerization are impeded. Increasing concentration to 14 mM liberates Fe^{3+}

and promotes oxidative radical polymerization resulting in PEDOT of low electrical resistance, whereas concentrations above 14mM activate the acid-catalyzed polymerization pathway resulting in uncontrolled reactions. When oxidative radical polymerization dominates, the EDOT vapor concentration determines the thickness of a polymer coating and its electrical resistance.

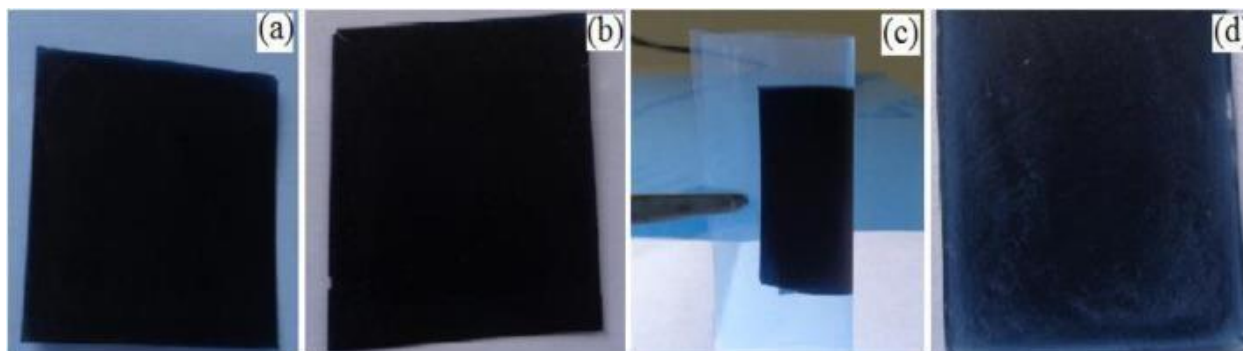
Synthesis starts when a brick and chemical reactants are heated together in a sealed vessel; chemical and physical changes on a brick are monitored by collecting sample aliquots at different time intervals. Notably, there is no color change on a brick's red surface during the first 4h of reaction because brick dissolution is the rate-limiting step in our mixed synthetic mechanism that consists of (1) evaporation, (2) dissolution, (3) hydrolysis, and (4) polymerization. A blue PEDOT coating is visible on a brick 4h after initiating a reaction and its thickness increases inversely proportional with electrical resistance until the end of reaction at 14h. An extended polymerization time increases the polymer coating's two-point probe electrical resistance because PEDOT loses dopant during heating¹⁸; fortunately, post-synthetic doping lowers the electrical resistance. Our synthesis produces a 400 μ m thick nanofibrillar PEDOT coating (2.8wt%) exhibiting 2 Ω two-point probe electrical resistance and nanofibers characterized by a $\sim$ 30 μ m length and $\sim$ 190nm diameter. Polymer, purified by repeated rinses in methanol, is comprised of S, C, O, and doped by Cl⁻ in situ during polymerization as shown in energy-dispersive X-ray spectra.

Our synthesis is general and applicable to different types of bricks. Here, three types of bricks (type 1–3) with different gravel (SiO₂) sizes and porosities are investigated. Type 1 brick shows the most open microstructure that facilitates reagent vapor diffusion, therefore utilized for the synthesis study in Fig. 1 and Supplementary Figs. 1–3. Powder X-ray diffraction of pulverized type 1 brick shows that SiO₂ is the major phase while α -Fe₂O₃ and Al₂O₃ are minor phases. These three types of bricks possess similar inorganic composition and concentration as shown by powder X-ray diffraction patterns. Porosity differences between brick types stem from various gravel sizes and manufacturing variables such as water content before sintering, sintering temperature and duration. Vapor-phase synthesis produces a contiguous polymer coating over the entire brick surface because dissolution generates an aqueous Fe³⁺ layer that coats inert

gravel sites. Under identical reaction stoichiometries and time, PEDOT nanofibers of high aspect-ratio coat all types of bricks homogeneously. Our polymer coating technology is scalable and patternable as demonstrated using type 1 brick. Nanofibrillar PEDOT coatings on all types of bricks show linear current–voltage curves with slopes that indicate ohmic behaviors and similar electrical resistances ($\sim 7\Omega$). Note that a two-point probe multimeter measurement leads to a lower value (2Ω) because of a wide tip diameter that lowers contact resistance

4.9.2 Microstructure

PEDOT:PSS dispersion in water medium was coated on L-folder, transparency sheet and glass plate and the coating has very good adhesion and flexibility. Resistivity was measured on the coated portion and it showed resistivity value of $104 \Omega/\text{sq}$ in all the substrates, which is very well within the range of ESD.



3.1.2. Powder form of PEDOT:PSS for supercapacitor

PEDOT:PSS samples in powder form were prepared by varying the amount of PSS. Physical, spectral, thermal and electrochemical properties of PEDOT:PSS samples are discussed here. The values of yield, [conductivity](#) and density of PEDOT:PSS samples are reported in [Table 3](#). Yield or conductivity value of the PEDOT:PSS increases with increasing the amount of PSS in the reaction, attaining a maximum with 3.8mL of PSS (PEDOT:PSS-4) and then decreases. Pellet density was nearly the same with the amount PSS used in the reaction. Hence, PEDOT:PSS-4 sample was further subjected to various characterization.

4.4 Yield, [conductivity](#) and density of PEDOT:PSS salts.

Sample	Amount of PSS	Yield	Conductivity (S	Pellet Density* (g
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	(mL)	(g)	cm ⁻¹)	cm ⁻³)
PEDOT:P SS-1	1.6	0.70	0.4	1.31
PEDOT:P SS-2	2.4	0.97	2.2	1.29
PEDOT:P SS-3	3.2	0.95	3.1	1.34
PEDOT:P SS-4	3.8	1.12	6.2	1.27
PEDOT:P SS-5	4.6	0.97	5.2	1.25

*

±0.05g cm⁻³.

3.2. Spectral, thermal and electrochemical characterization

Formation of PEDOT:PSS was confirmed from the measurements of FT-IR and UV-Vis spectra. XRD was recorded to find out the crystalline nature. Stability of PEDOT:PSS was found from TG measurement. These results are discussed here.

3.2.1. FT-IR spectroscopy

FTIR spectrum for PEDOT:PSS-4 was carried to confirm the molecular structure. Vibrational bands observed for PEDOT:PSS-4 (Fig. 2) can be assigned as : a peak around 3420 cm⁻¹ (O—H str.), 2925 & 2851 cm⁻¹ (C—H str. freq.) 1530 and 1315 cm⁻¹ (C=C and C—C stretching vibration of the thiophene ring of PEDOT), 975, 835 and 690 cm⁻¹ (Vibration modes of C-S bond in the thiophene ring), 1070 and 1135 cm⁻¹ (C O — — C str.) [20], 920 cm⁻¹ (ethylenedioxy ring deformation mode peak), 1200 (symmetric stretching of S=O), 1030–1090 cm⁻¹ (symmetric stretching of O — S—O). The peaks at 1645 and 1750 cm⁻¹ are connected with PSS, which indicates the doping occurred on PEDOT .

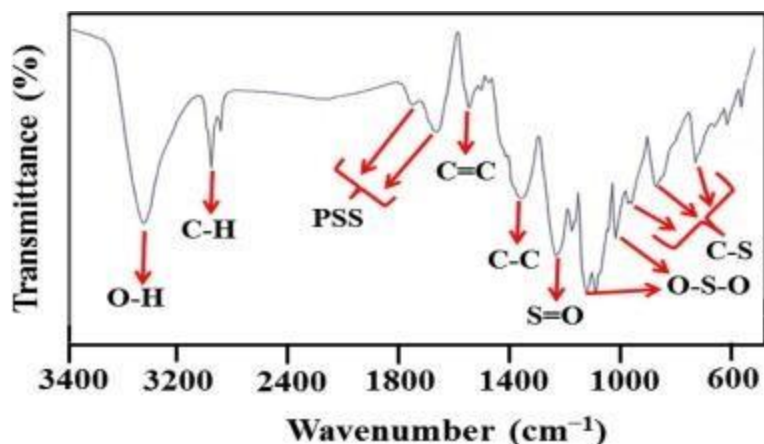


Fig. 2

3.2.2. Electronic absorption spectrum

Electronic absorption spectrum of PEDOT:PSS-4 in aqueous medium at ambient temperature was recorded and is shown in Fig. 3. It shows only one strong band after 700nm arising from the polarons present in the PEDOT chains. A similar spectrum was reported for PEDOT:PSS by Daniele et al.

Fig. 3

3.2.3. X-ray diffraction

X-ray diffraction spectrum of PEDOT:PSS-4 is given in Fig. 4. The material is highly anisotropic in nature. XRD spectrum of PEDOT powder showing three peaks at 6.2, 18 and 26.5° corresponding to the index (100), (200), and (020). By referring the report of XRD of PEDOT reported by Aasmundtveit et al. , it is clear that PEDOT:PSS is paracrystalline. Peak at 6.2° is associated with the dopant –PSS (100 spacing), corresponding to the average distance between the ladder-like PEDOT molecules . The limited degree of order observed in PEDOT sample does not give more definitive information about the nature of the packing in the solid state.

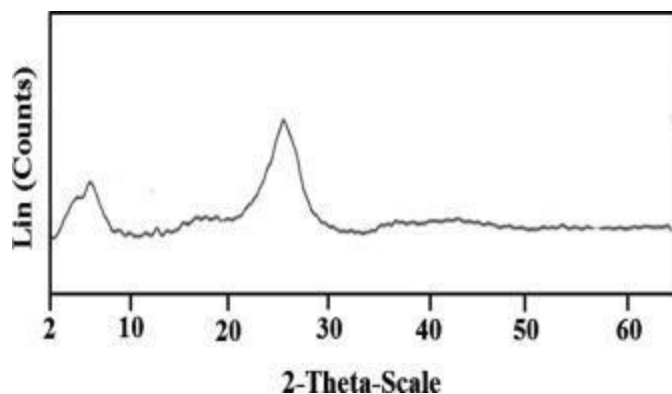
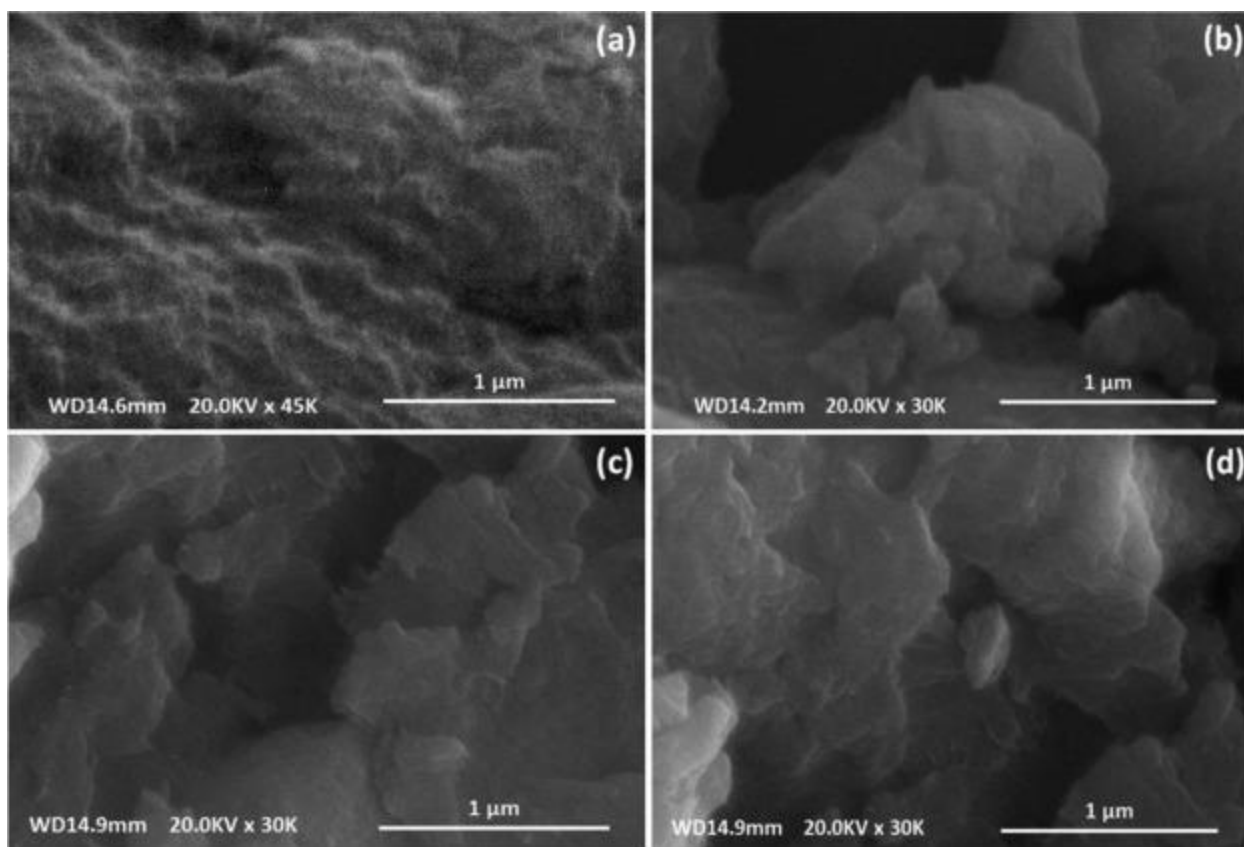


Fig. 4

3.2.4. Scanning electron microscopy

Morphological analyses of the PEDOT:PSS samples prepared with increasing amount of PSS were carried using FE-SEM (Fig. 5). SEM image of PEDOT:PSS-1 (Fig. 5a) prepared with less amount of PSS (PEDOT:PSS-1) shows compact powder particles, with increasing the amount of PSS, morphology changes to flake like morphologies (Fig. 5b & c) and the sample, PEDOT-PSS-4, shows layered flake morphology with smoother surface



4.10. Using Energy

4.10.1 Solar energy

The research team claims that a brick wall supercapacitor can be charged several times within an hour. According to the team, when 50 bricks are connected with solar panels, it can provide emergency lighting for five hours.

4.10.2 Wind energy

Wind energy is a form of solar **energy**. **Wind energy** (or **wind power**) describes the process by which **wind** is used to generate electricity. **Wind** turbines convert the kinetic **energy** in the **wind** into mechanical power. A generator can convert mechanical power into electricity.

4.11. Chemical Reactions

4.11.1 Bricks in to battery

Supercapacitors, like batteries, have two electrodes with an electrolyte in between. But while batteries rely on chemical reactions, supercapacitors store energy by storing charge on the surfaces of their electrodes. Ions move on and off the electrode surface much faster than the chemical reactions of a battery. So supercapacitors can recharge quickly and provide powerful bursts of energy

4.11.2 Electrospinning

Electrospinning is a voltage-driven process governed by the electrohydrodynamic phenomena where fibers and particles are made from a polymer solution. The most basic set up for this technique involves a solution contained in a reservoir (typically a syringe) and tipped with a blunt needle (for needle-based electrospinning), a pump, a high voltage power source and a collector.

CHAPTER-5

RESULT AND DISCUSSION



5.1 DISCUSSION

This proof-of-concept work demonstrates how to store energy on the surface of common brick using $\alpha\text{-Fe}_2\text{O}_3$ as an oxidant precursor to control oxidative radical polymerization and conformally deposit a capacitive nanofibrillar PEDOT coating from the vapor phase. A brick's structural stability and open microstructure result in mechanically robust PEDOT-coated brick electrodes, that when connected in series and coated with epoxy, produce a stable stationary waterproof supercapacitor module. Our supercapacitor technology adds value to a "dirt-cheap" construction material and demonstrates a scalable process affording energy storage for powering embedded microdevices in architectural applications that utilize fired brick.

CHAPTER-6

CONCLUSION

The red pigment in bricks — iron oxide, or rust — is essential for triggering the polymerisation reaction. The authors' calculations suggest that walls made of these energy-storing bricks could store a substantial amount of energy.

“ PEDOT-coated bricks are ideal building blocks that can provide power to emergency lighting,” D’Arcy said. “We envision that this could be a reality when you connect our bricks with solar cells — this could take 50 bricks in close proximity to the load. These 50 bricks would enable powering emergency lighting for five hours.

“Advantageously, a brick wall serving as a supercapacitor can be recharged hundreds of thousands of times within an hour. If you connect a couple of bricks, microelectronics sensors would be easily powered.”

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Red brick is a universal construction material manufactured by a technique that has been thousands of years old and has seldom served another role throughout history. Generally used for architectural esthetics as well as construction, now these bricks can be used to store energy that will be converted into electricity. For the energy, they require some outer source to charge them first, so in this case, the solar panels are required, these solar panels will work as a source to charge them, per 50 bricks there will be one panel.

Here's how the solar panel and bricks will be connected there will be gasses passing through the maze inside the bricks. Now, to allowing the bricks to store electricity there will be some chemical reaction will take place. The bricks consist comprised of hematite ($\alpha\text{-Fe}_2\text{O}_3$), alumina (Al_2O_3) as well as fused particles of silica (SiO_2) fused particles. The red color comes from hematite in a brick. Modern energy storage products are also manufactured from hematite this way they will store energy into the bricks. Now, if there will be any charge leakage the brick needs to be to make it leakage-free, then there will be a web of plastic nanofiber known as PEDOT electrode and stationary supercapacitor that readily stack into a module, which is a good conductor of electricity and no leakage of electricity. To make it waterproof, five minutes of epoxy acts as a waterproof case that allows the supercapacitor to operate. And further all electrical equipment will be connected to the bricks and no need for wires to connect or collect the energy.

"smart grid cities" since the energy authorities have put aside £500m from consumers' bills into the rewiring of the power supply system of the country.

Select different cities or towns to pay households for the installation of intelligent energy technologies that track the way they function on a wide scale.

The aim is to begin a centralized modernization of the aging electricity grid, which relies on massive fossil fuels driven plants, and to localize it further by utilizing sustainable forms of production.

Mini "smart grids" would be constructed, which will manage larger sporadic wind farms with larger unpredictable amounts of electricity. The grids would often facilitate the supply of power back to the grid for households through their own micro-generation — for example, solar panels on their roofs. Smart meters would be equipped in houses and can help handle unpredictable supply peaks from sustainable generation sources like solar and wind power.

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