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ANALYSIS ON ELECTRONIC SKIN

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ABSTRACT:

The latest advancements in electronic skin (e-skin) research are discussed in detail, with an emphasis on the technology required for three key applications: skin-attachable electronics, robotics, and prosthetics. Electronics are crucial in the development of simple devices for a variety of applications. Electronic equipment is necessary for all fields. Artificial Skin is the finest achievement as well as a future example of integrated electronics in the medical industry. It's a super-thin electronic gadget that adheres to the skin like a tattoo and measures the electrical activity of the heart, brain waves, and other critical information. Artificial skin is a skin created in a laboratory. It can be utilised in robotic applications or as a skin substitute for persons who have had serious burns or skin illnesses. This study focuses on the Artificial Skin (E-Skin), which is used to create a skin that works similarly to human skin and is also implanted with many feelings or senses of touch that operate on the skin. This skin is being put together right now. It is made up of millions of implanted electronic measuring devices, including thermostats, pressure gauges, pollution detectors, cameras, microphones, glucose sensors, EKGs, and electronic holography. This gadget would boost developing technologies and considerably expand the use of robotic probes in locations where humans unable to go. The sensor might open the way for a slew of new apps that can remotely monitor a patient's vitals and bodily movements, sending data directly to a computer where it can be logged and stored to help with future choices. These issues are discussed, with an emphasis on progress, present obstacles, and future potential.

INTRODUCTION:

Skin is the largest organ in the human body and has a wide variety of interesting properties such as stretchability, self-healing ability, high mechanical toughness, and tactile sensing capability. Electronic skin, or e-skin, are devices that imitate the qualities of human skin while also adding extra functions. Wearable or skin-attachable devices, robotics, and prosthetics are among the most prevalent applications for e-skin. [1]

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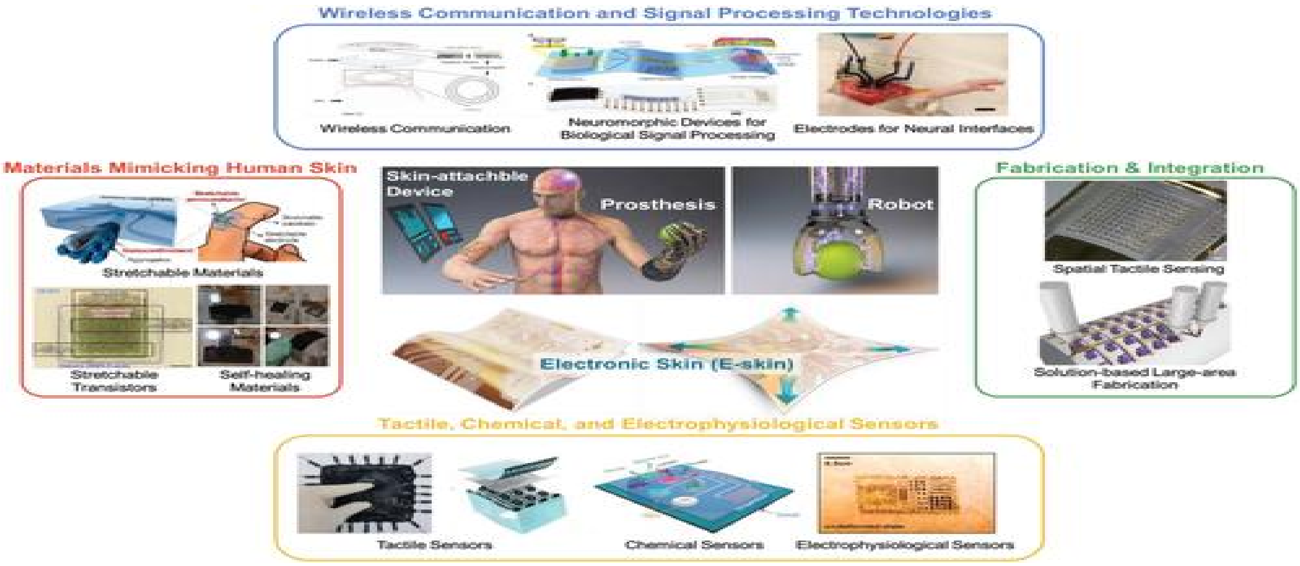

Figure 1

Figure 1 depicts the current state of research in the three application areas.

Electronics are particularly significant in the development of essential gadgets that may be utilised for any purpose. Artificial Skin is the finest achievement in the field of integrated electronics as well as a future example. It's a super-thin electronics device that adheres to the skin like a tattoo and measures electrical activity in the heart, brain waves, and other vital signs. Robotics evolution necessitates enhanced sensing of the surroundings. Human skin provides the sensory perception of temperature, touch/pressure, and airflow. The goal is to create sensors on flexible substrates adaptable to curved surfaces. The goal of the researchers in developing an artificial skin is to create a dramatic shift in robotics, medicine, and flexible electronics. Skin is a large organ in the human body so artificial skin replaces it according to our needs. Artificial skin's main aim is to detect heat, pressure, touch, airflow, and other sensations that human skin detects. It is a substitute for prosthetic limbs and robotic arms[2].

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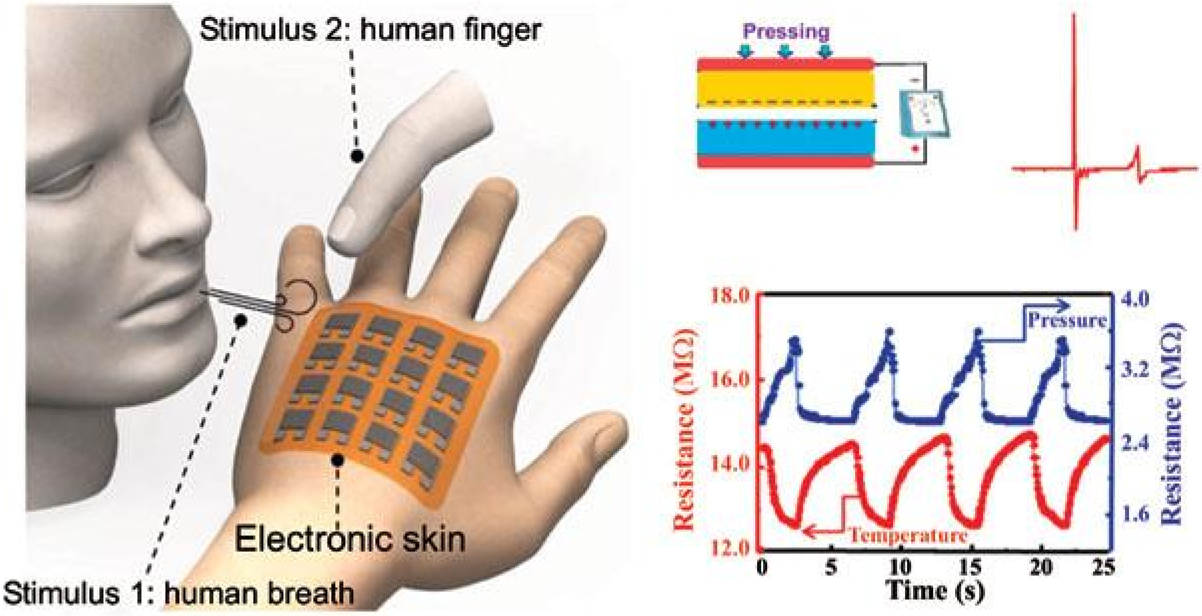

FLEXIBLE AND ELECTRONIC STRECHY SKIN:

Electronic skin's capacity to tolerate mechanical deformation, such as stretching and bending, without losing functionality is critical for applications such as prosthetics, artificial intelligence, soft robotics, health monitoring, bio-compatibility, and communication devices. Electronic materials are frequently deposited on flexible polymer substrates in flexible electronics, depending on an organic substrate to give advantageous mechanical characteristics. Stretchable e-skin materials have been explored from two perspectives. Inorganic particles or sensors that are not naturally stretchy can be embedded in hybrid materials that rely on an organic network for stretchiness. Other research has focused on developing stretchable materials that also have favourable electronic or sensing capabilities.[5].

The presence of "serpentine" linkers in the polyimide matrix. The e-skin sensors may flex with movement and distortion thanks to these linkers. Alkyl spacers have also been proven to enhance flexibility without reducing charge transfer mobility in polymer-based materials. As a source of hydrogen bonding, 3,6-di(thiophene-2-yl)-2,5-dihydropyrrolo[3,4-c]pyrrole-1,4-dione (DPP) and non-conjugated 2,6-pyridine dicarboxamide (PDCA) are used to create a stretchy and flexible material. [6]. (Figure 3).

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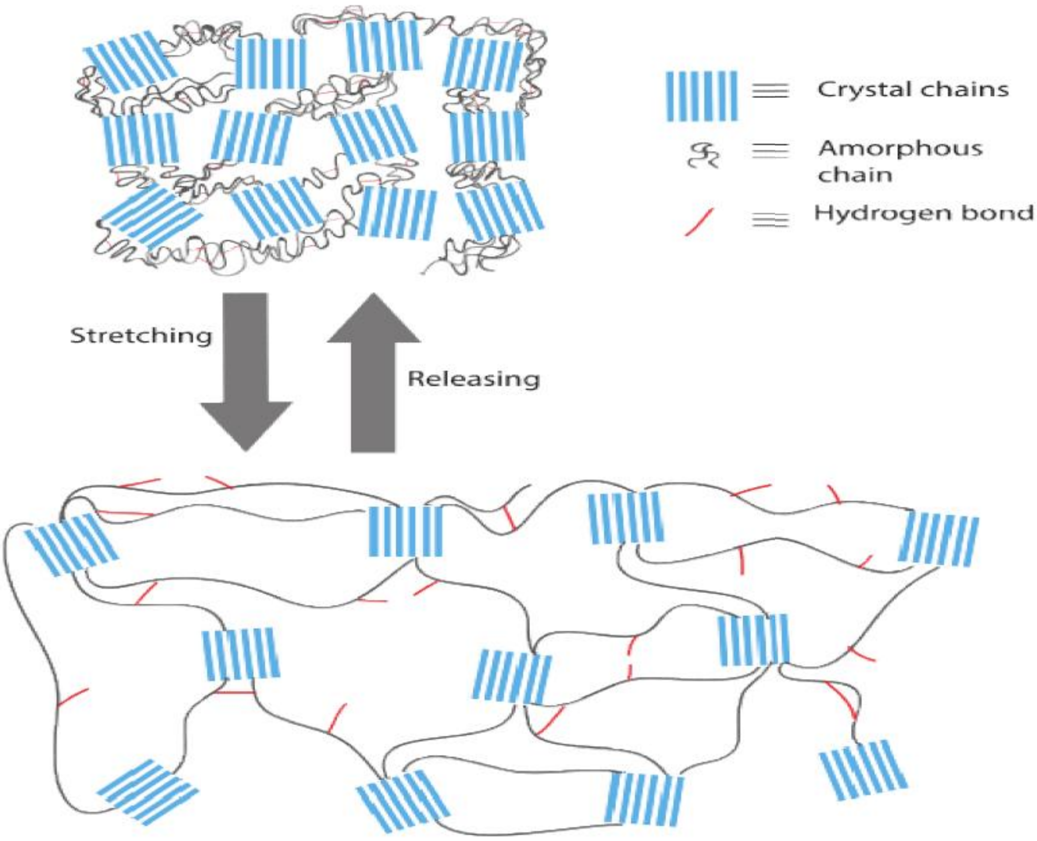
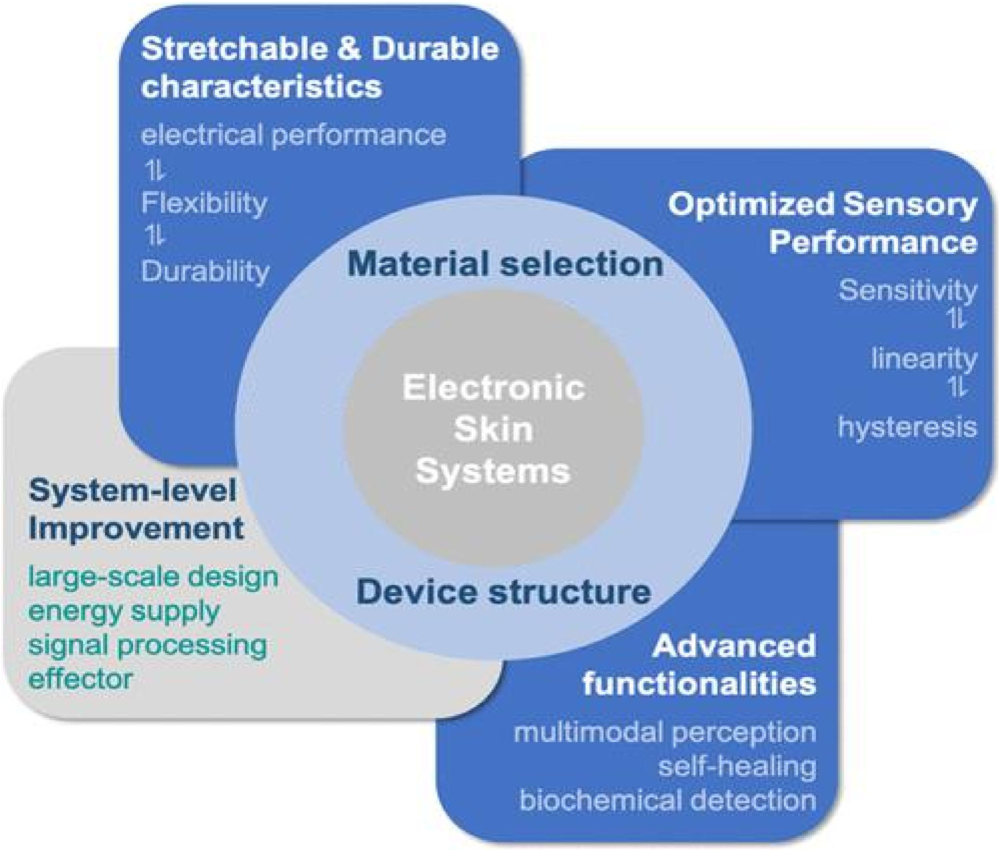


Figure 3. A semiconducting polymer-based material that is stretchy and self-healing.

Due to its rigidity and tensile strength, graphene has also been shown to be a viable material for electronic skin applications. The manufacture of graphene on flexible substrates is scalable and cost-effective, making it an enticing material. [7].



Electronic skin is a flexible and wearable electronic device that mimics the functions and mechanical qualities of biological skin and has gotten a lot of attention in recent years. Despite efforts to use skin-like electronics in applications ranging from routine healthcare to sophisticated robotics,[8]. The commercialization process is hampered by significant hurdles such as immature material selection and imbalanced device performance. The effects of deformation on electrical characteristics, issues in measuring accuracy and stability, constructively integrating multisensory, and manufacturing skills and processes for large-scale production are all covered in this Perspective. Work on material modification, device preparation, and system design, as well as possible research prospects, are highlighted in each section. [9].

ARCHITECTURE:

Electronic skins for robotics and medical prostheses—multifunctional structures with sensors and actuators tightly integrated with microelectronic circuits—increase the versatility of electronics. Large deformation stresses may be experienced by shaped electronics and skin-like electronics. A hemispherical detector array may be formed by doubling the surface area of a disc detector array. The skin may be stretched and relaxed 15 per cent more when wrapped over elbow joints. Semiconductor integrated circuits and MEMS technologies employ hard and stiff substrates that aren't designed for flexible structures, as well as thin active device materials that shatter at a 1% critical strain. Tensile strains on the order of 1% can also break free-standing thin metal sheets. [3].

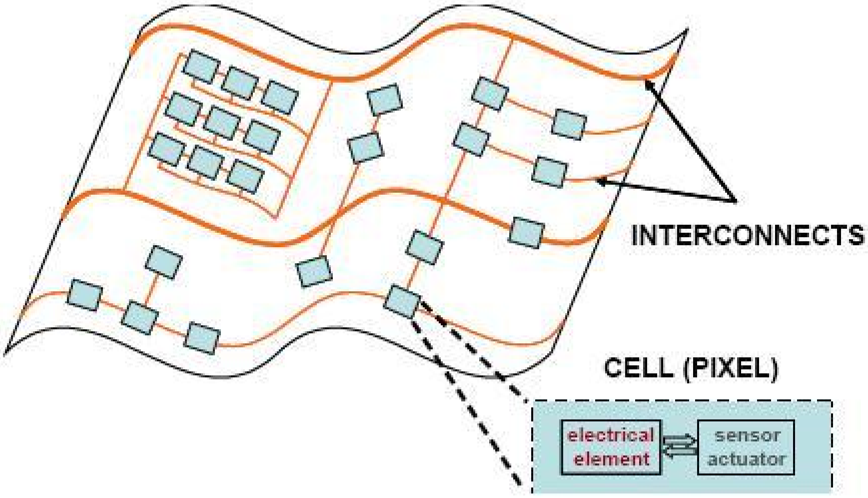


Figure: electrical surface on an island

Subcircuit cells made up of a transducer and an electronic circuit will be put on mechanically separated islands that are produced on a deformable substrate that absorbs the majority of the overall strain to achieve flexible and elastic skin. The illustration above depicts a hypothetical island with an electronic surface. When the circuit is stretched once or repeatedly, the islands are sufficiently stiff to prevent them from breaking. Stretchable metal wires link the subcircuits electrically. Producing deformable interconnects may be done in three ways: making thin metal films that can tolerate substantial plastic deformation, deforming a sacrificial mask for lift-off metallization, and making stretchy metallization.[4].

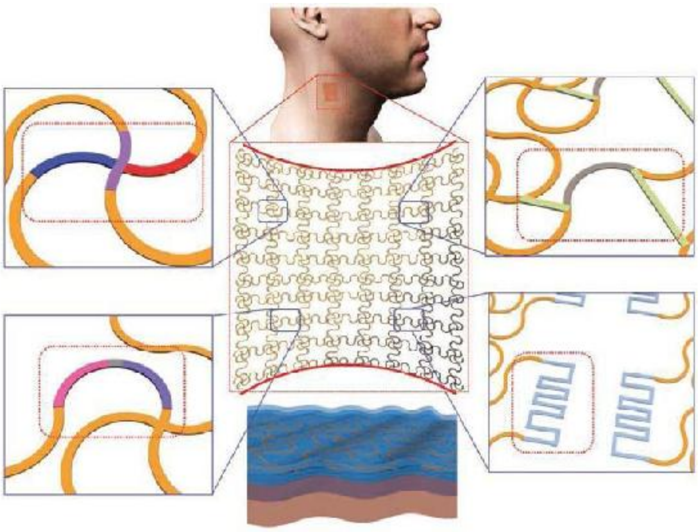


Figure 7: Architecture of E-skin

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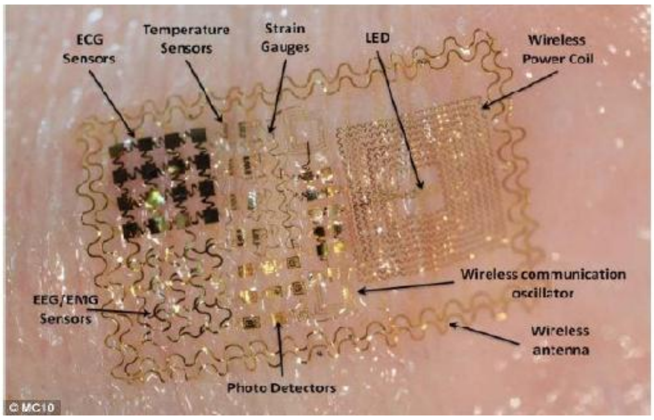

Figure 6: Detailed view of inner circuit of electronic skin.

FEATURES:

The electronic skin idea was first explored for robotics applications. Pressure sensing (touch) might be added to robots, allowing them to grab items securely without hurting them (the "picking up an egg" problem). These electronic skins, which primarily comprise pressure-sensing materials and related electrical equipment for pressure reading, might also supply touch sensation to prosthetic devices like artificial legs or arms. The transistors (and the semiconductors in them) that amplify weak signals must be flexible in order to operate like skin, which is a hurdle in the development of these devices. The capacity of transistors to magnify signals, known as gain, is determined by the mobility of charge carriers in the semiconductor underneath the gate layer (or in their gated semiconductor layer). Because of their high carrier mobility, which permits operation at the low applied voltage and low power, doped single-crystalline silicon wafers are utilised in most computer processors. Alternative materials have been investigated since the wafers are fragile. Conducting polymers, for example, have substantially lower carrier mobility than other possible flexible semiconductors. Higher voltages are required to utilise these materials as transistors may not be ideal for electronic skin that comes into direct touch with a patient's skin, and a tiny power supply may soon run out[9]. Converting brittle semiconductors to more flexible versions is another option. As nanowires, silicon and germanium, for instance, are very bendable. However, although being substantially higher than conducting polymers, their carrier mobility is still much lower than doped silicon[10]. It is difficult or impossible to attain the performance required to amplify very weak signals received from real skin with these materials. The electronic skin is made of thin single-crystal silicon, which is more flexible and mobile than the silicon used in personal portable devices. Inking and printing is a process developed earlier by Rogers' group. A silicon dioxide release layer adheres to a thin silicon layer. A transfer stamp layer is then added to the top of the split silicon, which is subsequently sliced into a lattice of micrometre-scale chiplets. The chiplets and transfer layer are then raised and placed on a flexible substrate. It's more difficult to connect electronic skin to human skin than to robots or prostheses. Natural skin is smooth and sensitive, with touch-sensing capabilities built-in [11]. To minimise any pain caused by lengthy use, the electronic skin that may be utilised for physiological monitoring must include a supporting layer with mechanical qualities that are similar to those of normal skin.

The electronic skin must have conformal contact, close integration, and appropriate adhesion with the natural skin and not be overly thick, inflexible, hard, or heavy. To attain these qualities, special materials that were correctly created through accurate modelling were required. The electronic skin's support layer is made of an elastomeric (rubbery) polyester with mechanical qualities similar to those of real skin. The electronic skin's circuitry is made up of two protective layers sandwiching a multipurpose middle layer. Because the protective layers are of the same thickness, they produce opposing stresses that cancel out, resulting in minimal stress on the central circuit layer regardless of which way the device is bent. The metal, semiconductor, and insulator components required for sensors, electronics, power supply, and light-emitting components are all in the serpentine shape that creates a stretchy net in the intermediate layer. The serpentine forms enable the net to deform dramatically while maintaining its effectiveness. All of the required components are contained in an ultrathin layer around the thickness of human hair in this unique design. The electronic skin may be easily applied to or removed from normal skin, much like bandage tape[12]. Physiological data from the heart, brain, and skeletal muscles have been acquired with a quality comparable to that obtained with bulky sensors and gear. Other types of physiological data collecting based on the electronic skin are simple to implement since they may employ components with more advanced functionality. In this demonstration, the transfer-printing fabrication technique has proven to be feasible and low-cost, which would substantially simplify the actual clinical application of the electronic skin. Given previous demonstrations of this capacity in other devices, wireless communication straight from the electronic skin should be possible due to the greater quality of the transferrable thin silicon. Other forms of electronic skins with uses outside of physiology, such as body heat harvesting and wearable radios, might potentially hint at promising future research avenues. [9].

IMPLEMENTATION:

The next section demonstrates how E-skin is implemented.

A. Organic field-effect transistors:A field-effect transistor with an organic semiconductor in its channel is called an organic field-effect transistor (OFET). OFETs can be made by vacuum evaporating tiny molecules, solution casting polymers or small molecules, or mechanically applying a peeling single-crystalline organic layer on a substrate. Biodegradable electronics have been constructed using these devices [13]. Various device geometries have been used to construct OFETs.Using a combination of low-cost solution-processing and direct-write printing, all of the layers of an OFET may be deposited and patterned at room temperature, making them appropriate for realising low-cost, large-area electronic functionality on flexible substrates.

***B. Flexible array sensors*:**Non-volatile memory arrays on flexible plastic substrates are created using organic transistors with a floating gate embedded in hybrid dielectrics that include a 2-nanometer-thick molecular self-assembled monolayer and a 4-nanometer-thick plasma generated metal oxide. The dielectrics' thinness enables for a non-volatile, reversible threshold voltage change. A sensor matrix that recognises the distribution of applied mechanical pressure and retains the analogue sensor input as a two-dimensional picture over lengthy periods of time is achieved by merging a flexible array of organic floating gate transistors with a pressure sensitive rubber sheet.

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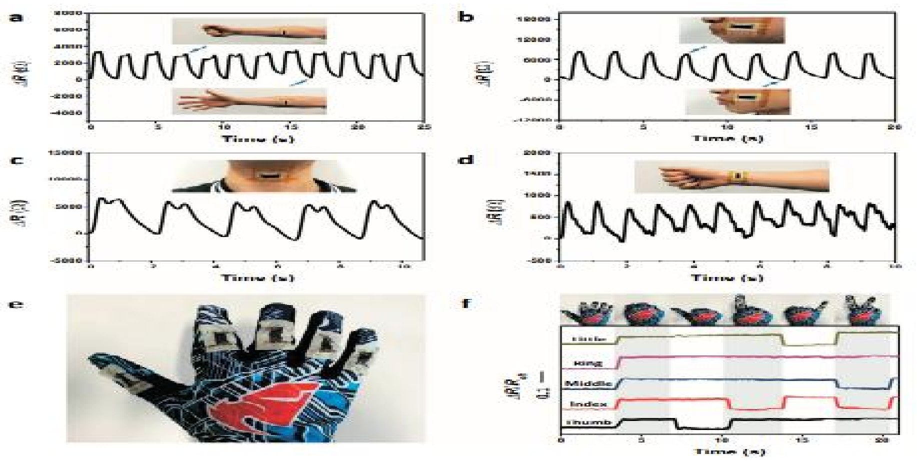
C. Nanowire arrays: Germanium and silicon nanowire arrays were used (semi-conductors). High-performance, bendable transistors and sensors are made possible with semiconductor nanowires.[13].



D.Fabrication:

•The production of micro-structured PDMS films is depicted in this diagram. A PET substrate coated with an ITO-coat is bonded to the mould, and the PDMS film is cured under pressure. The flexible substrate is removed from the mould when it has cured.

•Micro-structured PDMS films having pyramid or line characteristics in scanning electron micrographs. On a variety of flexible, plastic substrates, the pressure sensitive structured PDMS films may be formed at full wafer size with remarkable uniformity and fidelity.

•Distinct types of microstructured PDMS films have different pressure-response curves. The pressure sensitivity of structured PDMS films is substantially higher than that of unstructured PDMS films of the same thickness.

•After loading and unloading, the relaxation and steady state curves for various sorts of features. While both structured and unstructured PDMS films respond swiftly to pressure, only structured PDMS films have relaxation times in the millisecond range.

•The microstructure PDMS films have the ability to detect very tiny pressures. The capacitance change when a bluebottle fly (20 mg) is placed and removed on a 64mm2 surface at a pressure of merely 3 Pa is shown. PDMS Substrate Fabrication Array

•As previously described, pressure sensing organic single-crystal transistors are constructed from thin rubrene single crystals and microstructured PDMS dielectric layers.

•The accompanying graph also shows the output curves of a transistor-based sensor when varied external pressures are applied. The applied loads are listed in the sequence of the initial loading cycle in the legend.[14].

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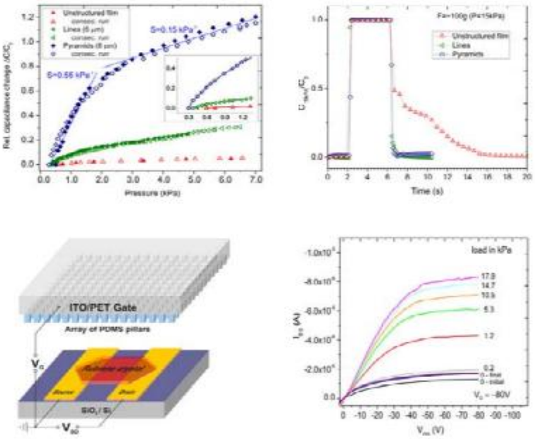

WIRELESS TECHNOLOGY FOR E-SKIN:

We all utilise wireless communication in our everyday lives. This communication method eliminates the limitations of disordered wires and cables and allows data to be sent across disconnected items. Certain research groups have studied applications of e-skin sensors for wireless sensor arrays, wireless energy transfer, and wireless data communication in order to make use of wireless technologies. Bao and colleagues showed a wireless sensor array that can track and record pressure variations in real-time (Figure 10 a). The device's resonant circuit consists of a pressure-dependent capacitive element and an inductive antenna, with the resonant frequency decreasing as applied pressure increases owing to a rise in effective coupling capacitance. This lower-frequency wireless detection approach opens up new possibilities in human-machine interactions, intracranial pressure monitoring, and biological research. Rogers and colleagues coupled the wireless energy transfer module with epidermal electronics, such as small commercial chips, integrated circuits, and other sensors, allowing accurate monitoring and exact measurement in clinical situations utilising a wireless mode (Figure 10 b). Recently, an implantable and biodegradable electronics-based device based on an Mg wireless heater was created, which may be totally decomposed in water to implement remote-control treatment in vivo, potentially allowing for heat disinfection near an operation site and medication release triggering. Bao and co-workers developed a versatile and extremely sensitive temperature sensor based on a wireless data connection to remotely monitor the temperature of the human body. A passive RF identification antenna and a resistance-responsive composite film made up of Ni particles packed in a polyethylene/polyethylene oxide binary matrix polymer make up the device. To complete the medication delivery function of the wearable and flexible device, a smart bandage based on MEMS with multiple sensors and a wireless signal transmission component was studied (Figure 10 c) [16]. Other flexible and wearable systems with transistors and electromyogram and electrocardiogram sensors have been described to monitor human body health and to provide the groundwork for large-scale integrated wearable device applications in human-machine interactions via wireless communication [17].

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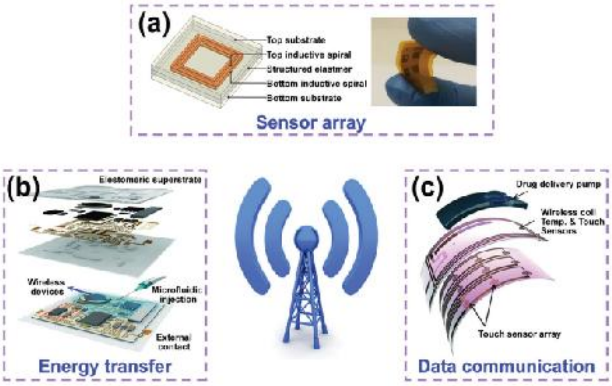

Figure 10.

DEDICATED EMBEDDED ELECTRONIC SYSTEMS:

Embedded electronic systems have become much more prevalent in recent years, both in business and in our daily lives. As a result, an increasing amount of work is being put into developing systems that are meant to carry out specialised and dedicated duties and interact with the external world via sensors and actuators. Design restrictions are unique to each embedded electronic system. However, these systems are intended to have certain similar characteristics, such as high computational capability, real-time operation, low power consumption and perhaps cheap cost, small size, and a long life cycle. Small size is critical in e-skin, as the electrical system must be implanted into the skin itself. Furthermore, real-time performance is important when dealing with human/e-skin or environment/e-skin interaction activities that need tactile feedback.

CHALLENGES:

The challenge for electronic skin, which is being developed for use in artificial skin or Humanoids, is to make it sense temperature and motions as closely as possible to human skin. Which results that, while electronic skins can sense movement and temperature independently, none can identify both at the same time like human skin. [19]

Wearable electronics are light years ahead of the wristbands that many of us wear to track our daily walks. True skin-based sensitivity necessitates extended and intimate skin contact, which is hard to achieve with these inflexible, brittle commercial gadgets.

This presents materials scientists with a fascinating set of difficulties. How all of these materials work together and integrate?. He also mentions how to deal with interactions and mechanical mismatches between hard and soft materials. [20]

However, attempts to solve this problem [20] this study are yielding positive results. His lab's platforms are used in a variety of clinical contexts, in addition to the scientists' work on COVID-19 and newborn care. Devices for monitoring sweat biomarkers in cystic fibrosis patients, measuring skin hydration in particular skin conditions, and UV exposure is detected in melanoma patients among them. His research group has also created wearable sensors that monitor pressure and temperature between the skin and a prosthesis.

They claim that his prolific production is due to his hybrid technique, which allows him to employ current fabrication technologies. In contrast, she and her colleagues had to devise new approaches. "It's a lengthier

Journal of Current Research in Engineering and Science
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Volume 5- Issue 1, Paper 41 January 2022

process. But we can see how this will fundamentally alter the way we use technology in the future," she says.

Whatever methods researchers choose, they see the recent rise in interest in wearable electronics research as a turning point that might lead to more investigation. "Once establishing some use cases is started that are truly touching and enhancing the lives of patients," he added that itprovided a strong drive for further resources to flow into the underlying research that was happened.

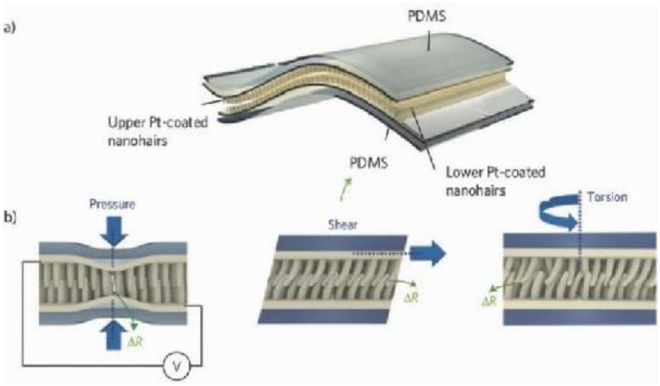

Figure 11: Timeline of the growth of electronic skin

Large sensor-to-sensor variability would necessitate independent calibration of each sensor, making operation extremely difficult due to the complexity of the circuitry required. The tolerance for sensor-to-sensor variability reduces as the number of sensors in the array grows, rendering operation almost impossible. The aggregation and nonuniform dispersion of conducting material in the elastomer matrix would produce sensor-to-sensor variability in bulk composite-type piezo-resistive sensors. Variability will become more prevalent as sensor sizes drop. [21]

In the case of a failure, the system must be able to be restored to its operational condition in the shortest period of time with the least amount of impact on the operating applications. Fault tolerance is must. Early identification and treatment of defects is critical when pre-processing near to sensors, in order to reduce their impact on the entire system and avoid the replacement of problematic parts as much as feasible. Active redundancy and other fault-tolerance strategies are commonly used. [22].

RESULT & ANALYSIS BY APPLICATION:

- In this paper common information of electronic skin is shown and also electronic skin's is given. From them we can say that in electronic skin [23]

1. Numberof wires is reduced
2. Compact in size
3. Easy attachment and detachment
4. Flexibility is more
5. Less in weight
6. Replacement of ECG and EEG of present system
7. It gives sense to a robot
8. Wearable and ultrathin
9. Stretchable and twistable
10. Easy to handle

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The following applications will help you understand the depth and applicability of electronic skin. Electronic skin is used to replace human skin when it has been severely damaged by illness or burns. It is also used for robots. Pressure, touch, wetness, temperature, and closeness to an item are all sensed by the robot. It could also detect cardiac electrical activity, brain waves, muscular activity, other vital signs etc. [24]

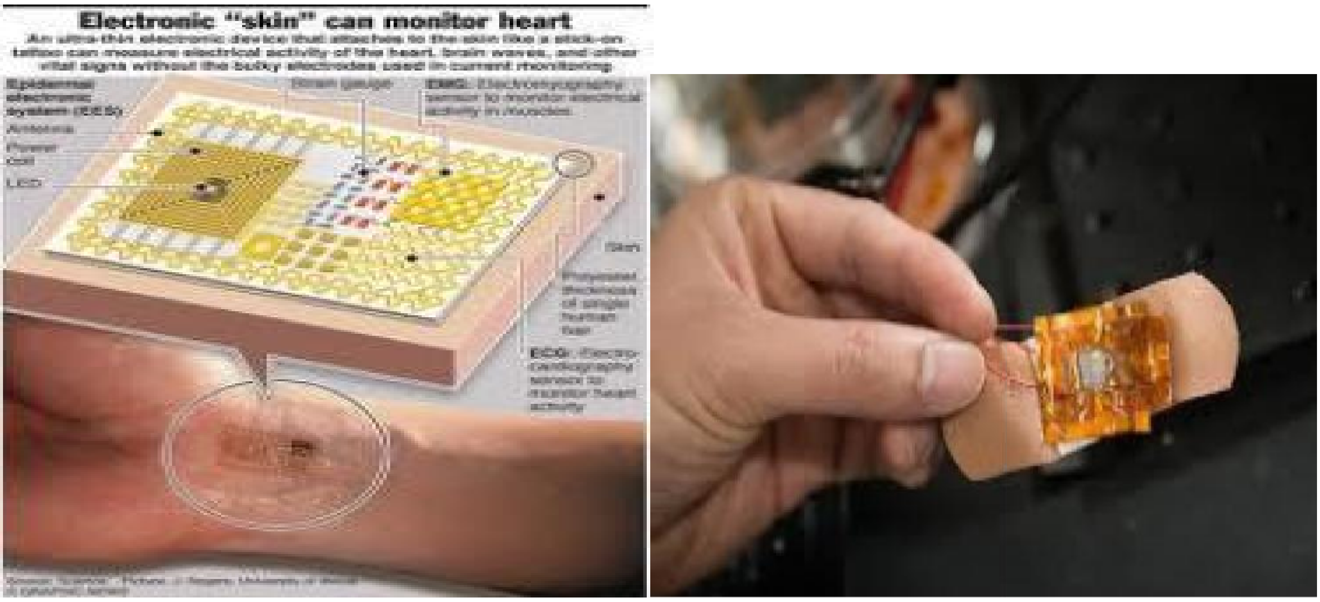

Figure 12: Smart bandages using E-skin

We can also detect normal and shear stress with the help of interfacial stress sensor. Localised electrical stimulation is used in smart bandages. There is the variation in the temperature of a wound.

- **Transfer of functional oxides onto polymer substrates process**

A procedure for transferring high-temperature functional oxides onto PDMS substrates was developed by combining microfabrication, thin film processing, and photolithography technique. The approach is presented utilising ITO thin films to demonstrate the transfer technique and to establish functioning. To make these thin films conductive and transparent, they must be annealed at temperatures above 400 °C, which is above polymer limitations. Figure 13 shows a schematic of an acid-free technique for transferring high-temperature-processed oxides (or compounds) onto flexible PDMS substrates[25].

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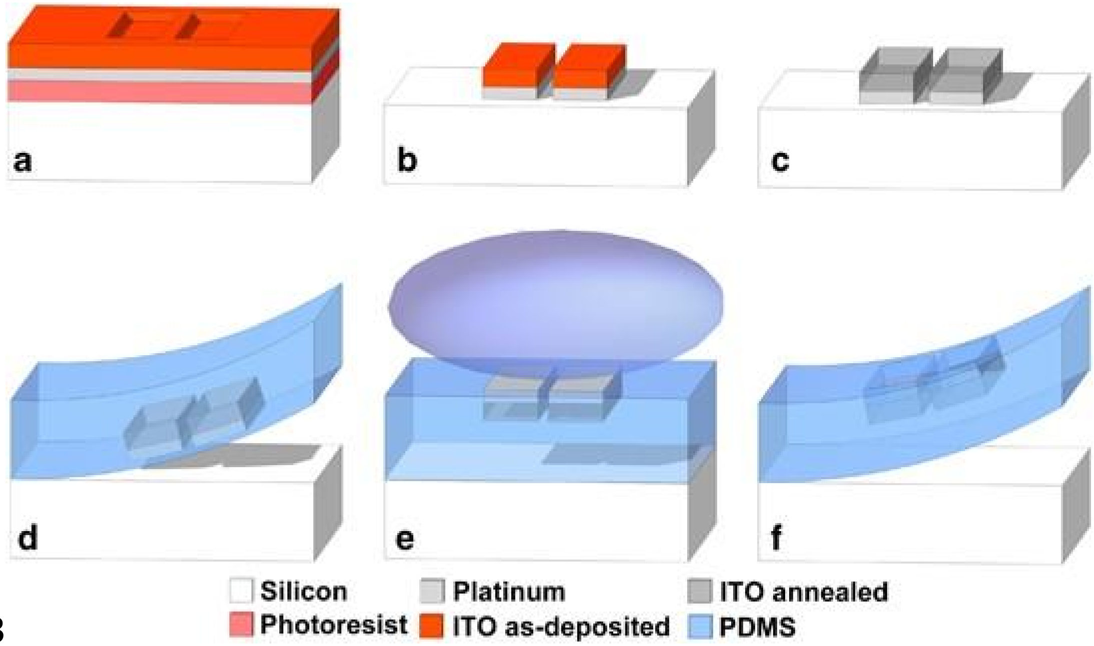

Figure 13

Transferring a high-temperature-processed oxide thin film onto a flexible polydimethylsiloxane (PDMS) substrate is shown in this diagram. (a) A lift-off pattern is used to photolithographically define a silicon substrate, which is then followed by the deposition of platinum and ITO layers. (b) Lift-off in solvents is finished, allowing ITO stripes to be defined for resistance measurements. (c) To make the ITO transparent, it is annealed at 400 degrees Celsius. (d) After the PDMS has been spin-coated and hardened, the complete structure may be peeled away. (e) The liberated structure is flipped over and put on silicon for plasma-assisted dry etching to remove the platinum layer. (f) The completed structure is peeled away to reveal a flexible substrate with oxide that has been treated at high temperatures.

FUTURE SCOPE:

• Flexible sensors and screens have previously made the rounds in the IT world.

• We can foresee an impending heart attack in a patient hours ahead of time.

• Virtual displays on devices may be used in the future to monitor our bodily functions.

• Smart watches, interactive backgrounds, and automobile dashboards

CONCLUSION:

When electronic equipment are small in size and perform well, they are in more demand. The Artificial Skin is an example of a technology that exemplifies the beauty of electronics and its use in everyday life. Electronic skin that mimics human touch is being developed by scientists. The artificial or electronic skin is smarter and more human-like,according to specialists. It also has higher sensitivity and resolution than currently available commercial technologies. The fundamental characteristics of future electronic skin will be flexibility and stretchability. This might be accomplished by clever structural engineering or the usage of innovative materials, as discussed above. The application influences material selection in addition to mechanical toughness. Also, sensors produced using PDMS techniques would allow for improved system integration, which makes easy to integrate with circuits for data collecting, signal condition, and data processing. Sensors and displays that bend have already made the tech rounds. We can anticipate an impending heart attack in a patienthours in advance. In the future, virtual displays on devices may be used to monitor our physiological functioning. Car dashboards, interactive backgrounds, and smart watches all use it.

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