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General Article

Flexible Electronic Skin

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Abstract

Electronics plays a very important role in developing simple devices used for any purpose. In every field electronic equipments are required. The best achievement as well as future example of integrated electronics in medical field is Artificial Skin. It is ultrathin electronics device attaches to the skin like a sick on tattoo which can measure electrical activity of heart, brain waves & other vital signals. Artificial skin is skin grown in a laboratory. It can be used as skin replacement for people who have suffered skin trauma, such as severe burns or skin diseases, or robotic applications. This paper focuses on the Artificial skin(E-Skin) to build a skin work similar to that of the human skin and also it is embedded with several sensations or the sense of touch acting on the skin. This skin is already being stitched together. It consists of millions of embedded electronic measuring devices: thermostats, pressure gauges, pollution detectors, cameras, microphones, glucose sensors, EKGs, electronic holographs. This device would enhance the new technology which is emerging and would greatly increase the usefulness of robotic probes in areas where the human cannot venture. The sensor could pave the way for a overabundance of new applications that can wirelessly monitor the vitals and body movements of a patient sending information directly to a computer that can log and store data to better assist in future decisions. This paper offers an insight view of the internal structure, fabrication process and different manufacturing processes.

Keywords: *Organic light emitting diode (OLED), Electronic Skin (E-Skin), Gallium Indium (GaIn), Nanowires, Organic transistors, Artificial Skin.*

1. Introduction

Electronics plays a very important role in developing simple devices used for any purpose. In every field electronic equipments are required. The best achievement as well as future example of integrated electronics in medical field is Artificial Skin. It is ultrathin electronics device attaches to the skin like a sick on tattoo which can measure electrical activity of heart, brain waves & other vital signals. Evolution in robotics is demanding increased perception of the environment. Human skin provides sensory perception of temperature, touch/pressure, and air flow. Goal is to develop sensors on flexible substrates that are compliant to curved surfaces. Researcher's objective is for making an artificial skin is to make a revolutionary change in robotics, in medical field, in flexible electronics. Skin is large organ in human body so artificial skin replaces it according to our need. Main objective of artificial skin is to sense heat, pressure, touch, airflow and whatever which human skin sense. It is replacement for prosthetic limbs and robotic arms.

Artificial skin is skin grown in a laboratory. There are various names of artificial skin in biomedical field it is called as artificial skin, in our electronics field it is called as electronic skin, some scientist it called as sensitive skin, in other way it also called as synthetic skin, some people says that it is fake skin. Such different names are available but application is same it is skin replacement for people who have suffered skin trauma, such as severe burns or skin diseases, or robotic applications & so on. An artificial skin has also been recently demonstrated at the University of Cincinnati for in-vitro sweat simulation and testing, capable of skin-like texture, wetting, sweat pore-density, and sweat rates.

Fig. 1 Artificial Skin

2. History

Electronic skin or e-skin is a thin material designed to mimic human skin by recognising pressure and temperature. In September 2010, Javey and the University

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of California, Berkeley developed a method of attaching nanowire transistors and pressure sensors to a sticky plastic film. In August 2011, Massachusetts-based MC10 created an electronic patch for monitoring patient's vital health signs which was described as 'electric skin'. The 'tattoos' were created by embedding sensors in a thin film. During tests, the device stayed in place for 24 hours and was flexible enough to move with the skin it was placed on. Javey's latest electronic skin lights up when touched. Pressure triggers a reaction that lights up blue, green, red, and yellow LEDs and as pressure increases the lights get brighter.

Artificial skin identified by different name in a same way it is developed in different laboratories such as in MIT (Massatucetes institute of technology), in Tokyo led by Takao Someya, The Fraunhofer Institute for Interfacial Engineering and Biotechnology, and so on. In this report we see the different methods of manufacturing of artificial skin of different scientist & its application with its future scope.

Another form of “artificial skin” has been created out of flexible semiconductor materials that can sense touch for those with prosthetic limbs. The artificial skin is anticipated to augment robotics in conducting rudimentary jobs that would be considered delicate and require sensitive “touch”. Scientists found that by applying a layer of rubber with two parallel electrodes that stored electrical charges inside of the artificial skin, tiny amounts of pressure could be detected. When pressure is exerted, the electrical charge in the rubber is changed and the change is detected by the electrodes. However, the film is so small that when pressure is applied to the skin, the molecules have nowhere to move and become entangled. The molecules also fail to return to their original shape when the pressure is removed.

Sensitive skin, also known as sensate skin, is an electronic sensing skin placed on the surface of a machine such as a robotic arm. The goal of the skin is to sense important environmental parameters—such as proximity to objects, heat, moisture, and direct touch sensations. Examples of a sensitive skin have been made by a group in Tokyo led by Takao Someya.

3. Architecture of e-skin

With the interactive e-skin, demonstration is takes place an elegant system on plastic that can be wrapped around different objects to enable a new form of HMI. Other companies, including Massachusetts-based engineering firm MC10, have created flexible electronic circuits that are attached to a wearer's skin using a rubber stamp. MC10 originally designed the tattoos, called Biostamps, to help medical teams measure the health of their patients either remotely, or without the need for large expensive machinery.

Fig 2 shows the various parts that make up the MC10 electronic tattoo called the Biostamp. It can be stuck to the body using a rubber stamp, and protected using spray-on bandages. The circuit can be worn for two weeks and Motorola believes this makes it perfect for authentication purposes.

Biostamp use high-performance silicon, can stretch up to 200 per cent and can monitor temperature, hydration and strain, among other medical statistics.

Javey's study claims that while building sensors into networks isn't new, interactive displays; being able to recognize touch and pressure and have the flexible circuit respond to it is 'breakthrough'. His team is now working on a sample that could also register and respond to changes in temperature and light to make the skin even more lifelike.

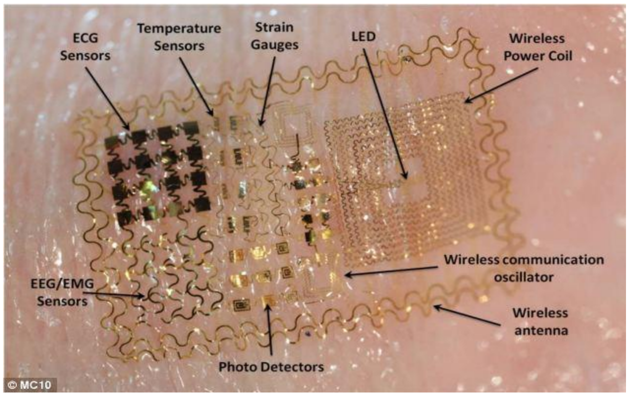

Fig. 2 Architecture of artificial skin

Large-area ultrasonic sensor arrays that could keep both robots and humans out of trouble. An ultrasonic skin covering an entire robot body could work as a 360-degree proximity sensor, measuring the distance between the robot and external obstacles. This could prevent the robot from crashing into walls or allow it to handle our soft, fragile human bodies with more care. For humans, it could provide prosthetics or garments that are hyperaware of their surroundings. Besides adding multiple functions to e-skins, it’s also important to improve their electronic properties, such as the speed at which signals can be read from the sensors. For that, electron mobility is a fundamental limiting factor, so some researchers are seeking to create flexible materials that allow electrons to move very quickly. Ali Javey and his colleagues at the University of California, Berkeley, have hadsome success in that area. They figured out how to make flexible, large-area electronics by printing semiconducting nanowires onto plastics and paper. Nanowires have excellent electron mobility, but they hadn’t been used in large-area electronics before. Materials like the ones Javey developed will also allow for fascinating new functions for e-skins. My team has developed electromagnetic coupling technology for e-skin, which would enable wireless power transmission. Imagine being able to charge your prosthetic arm by resting your hand on a charging pad on your desk. In principle, any sort of conductor could work for this, but if materials with higher electron mobility are used, the transmission frequency could increase, resulting in more efficient coupling. Linking sensors with radio-frequency communication modules within an e-skin would also allow the wireless transmission of information from skin to computer—or, conceivably, to other e-skinned people. At the University of Illinois at Urbana-Champaign, John Rogers’s team has taken the first step toward this goal. His latest version of an "electrical epidermis" contained the antenna and ancillary components needed for radio-frequency communication. What's more, his electronics can be laminated onto your skin in the same fashion as a temporary tattoo. The circuit is first transferred onto a water-soluble plastic sheet, which washes away after the circuit is pressed on. Doctors could use these tiny devices to monitor a patient's vital signs without the need for wires and bulky contact pads, and people could wear them discreetly beyond the confines of the hospital. Rogers and his colleagues tried out a number of applications for their stick-on electronics. In their most astonishing iteration, they applied circuitry studded with sensors to a person's throat where it could detect the muscular activity involved in speech. Simply by monitoring the signals, researchers were able to differentiate among several words spoken by the test subject. The user was even able to control a voice-activated video game. Rogers suggested that such a device could be used to create covert, subvocal communication systems.

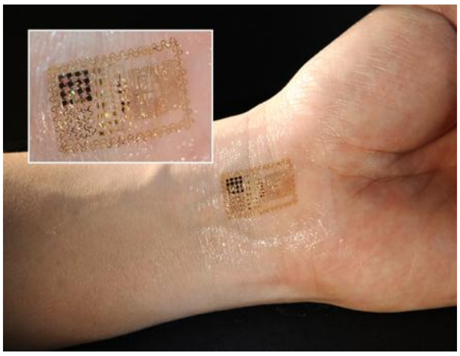

Fig. 3 E-Skin attaches to hand

Skins that know what we're saying without having to say it, skins that can communicate themselves, skins that extend our human capacities in directions we haven't yet imagined—the possibilities are endless. And while some readers may worry about e-skins being used to invade the privacy of their bodies or minds, I believe the potential benefits of this technology offer plenty of reasons to carry on with the work. For example, the car company Toyota has already demonstrated a smart steering wheel that measures the electrical activity of the driver's heart; imagine a smart skin that can warn a patient of an oncoming heart attack hours in advance. Human skin is so thin, yet it serves as a boundary between us and the external world. My dream is to make responsive electronic coverings that bridge that divide. Instead of cold metal robots and hard plastic prosthetics, I imagine machines and people clothed in sensitive e-skin, allowing for a two-way exchange of information. Making our mechanical creations seem almost warm and alive and placing imperceptible electronics on humans will change how people relate to technology. The harmonization of people and machines: This is the cyborg future that e-skins could bring. Bendable sensors and displays have made the tech rounds before, but a team of engineers at the University of California-Berkeley have found a way to combine the two. Ali Javey and his lab have successfully created e-skin, a pressure-sensitive circuit array that is thin, flexible, and luminescent. His research can be found in the journal Nature Materials.

4. Fabrication of e-skin

a. By using zinc oxide with vertical nanowires

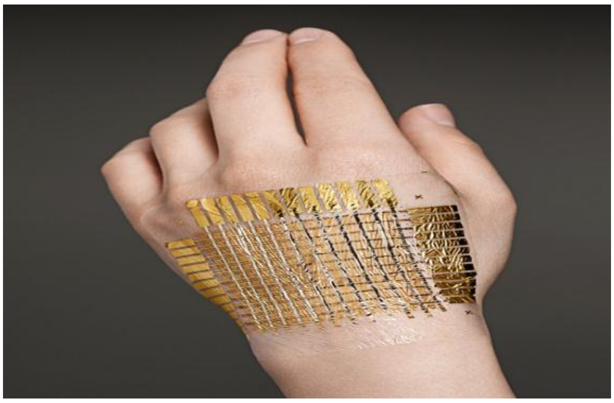

Fig. 4 Zinc oxide with vertical nanowires e-skin

U.S. and Chinese Scientists used zinc oxide vertical nanowires to generate sensitivity. According to experts, the artificial skin is "smarter and similar to human skin." It also offers greater sensitivity and resolution than current commercially available techniques. A group of Chinese and American scientists created experimental sensors to give robots artificial skin capable of feeling. According to experts, the sensitivity is comparable to that experienced by humans. Trying to replicate the body's senses and indeed its largest organ, the skin, has been no mean feat but the need for such a substitute has been needed for a while now, especially in cases of those to whom skin grafts have not worked or indeed its use in robotics. To achieve this sensitivity, researchers created a sort of flexible and transparent electronics sheet of about eight thousand transistors using vertical nanowires of zinc oxide. Each transistor can directly convert mechanical motion and touch into signals that are controlled electronically, the creators explained."Any mechanical movement, like the movement of an arm or fingers of a robot, can be converted into control signals," the Professor Georgia Institute of Technology (USA), Zhong Lin Wang. This technology "could make smarter artificial skin similar to human skin," said Zhong, after stating that it provides greater sensitivity and resolution. The system is based on piezoelectricity, a phenomenon that occurs when materials such as zinc oxide are pressed. Changes in the electrical polarization of the mass can be captured and translated into electrical signals thereby creating an artificial touch feeling.

b. By using Gallium Indium

The development of highly deformable artificial skin with contact force (or pressure) and strain sensing capabilities is a critical technology to the areas of wearable computing, haptic interfaces, and tactile sensing in robotics. With tactile sensing, robots are expected to work more autonomously and be more responsive to unexpected contacts by detecting contact forces during activities such as manipulation and assembly. Application areas include haptics humanoid robotics, and medical robotics.

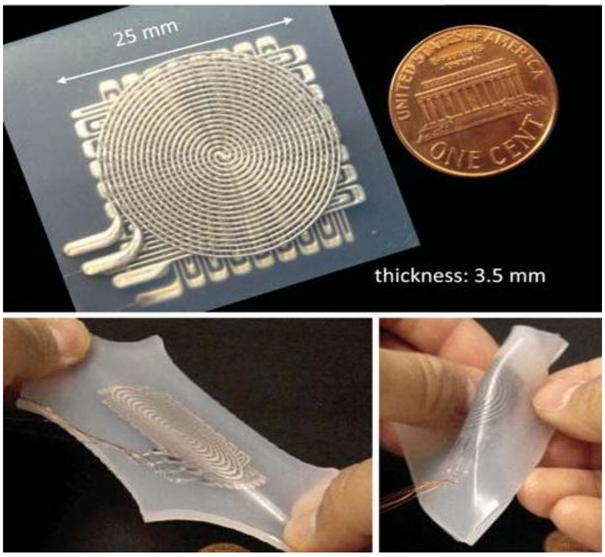

Fig. 5 By using Gallium indium (GaIn) e-skin

We describe the design, fabrication, and calibration of a highly compliant artificial skin sensor. The sensor consists of multilayered mircochannels in an elastomer matrix filled with a conductive liquid, capable of detecting multiaxis strains and contact pressure. A novel manufacturing method comprised of layered molding and casting processes is demonstrated to fabricate the multilayered soft sensor circuit. Silicone rubber layers with channel patterns, cast with 3-D printed molds, are bonded to create embedded microchannels, and a conductive liquid is injected into the microchannels. The channel dimensions are 200 μm (width) × 300 μm (height). The size of the sensor is 25 mm × 25 mm, and the thickness is approximately 3.5 mm. The prototype is tested with a materials tester and showed linearity in strain sensing and nonlinearity in pressure sensing. The sensor signal is repeatable in both cases. The characteristic modulus of the skin prototype is approximately 63 kPa. The sensor is functional up to strains of approximately 250%

A highly elastic artificial skin was developed using an embedded liquid conductor. Three hyper-elastic silicon rubber layers with embedded microchannels were stacked and bonded. The three layers contain different channel patterns for different types of sensing such as multi-axial strain and contact pressure. A novel manufacturing method with layered molding and casting techniques was developed to build a multi-layered soft sensor circuit.

For strain sensing, the calibration results showed linear and repeatable sensor signal. The gauge factors of the skin prototype are 3.93 and 3.81 in x and y axes, respectively, and the minimum detectable displacements are 1.5 mm in x-axis and 1.6 mm in y-axis. For pressure sensing, the prototype showed repeatable but not linear sensor signals. The hysteresis level was high in a high pressure range (over 25 kPa). The sensor signal was repeatable in both cases.

c. By using Organic Transistors

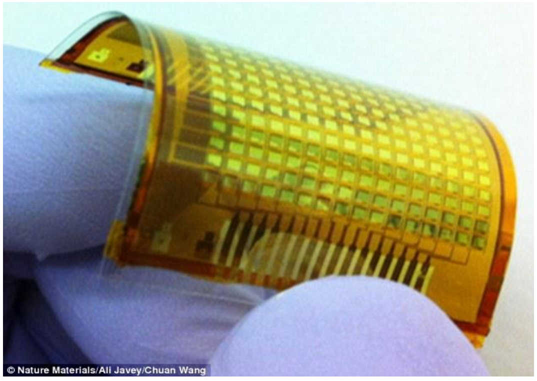

Fig. 6 E-Skin by using organic transistors

By Nature Journal

In July they reported the success of our experiments in the journal *Nature*. They fabricated organic transistors and tactile sensors on an ultrathin polymer sheet that measured 1 micrometer thick—one-tenth the thickness of plastic wrap and light enough to drift through the air like a feather. This material can withstand repeated bending, crumple like paper, and accommodate stretching of up to 230 percent. What's more, it works at high temperatures and in aqueous environments—even in saline solutions, meaning that it can function inside the human body. Flexible electronics using organic transistors could serve a range of biomedical applications. For example, they've experimented with electromyography, the monitoring and recording of electrical activity produced by muscles. For this system, they distributed organic transistor-based amplifiers throughout a 2-μm-thick film. This allowed us to detect muscle signals very close to the source, which is key to improving the signal-to-noise ratio, and thus the accuracy of the measurements. Conventional techniques typically use long wires to connect sensors on the skin with amplifier circuits, which results in a pretty abysmal signal-to-noise ratio. And they can imagine more medically urgent applications of such a system. In collaboration with the medical school at the University of Tokyo, we're working on an experiment that will place our amplifier matrix directly on the surface of an animal's heart. By detecting electric signals from the heart with high spatial resolution and superb signal-to-noise ratios, we should be able to zoom in on the exact location of problems in the heart muscle that can lead to heart attacks.

Skin is essentially an interface between your brain and the external world. It senses a tap on the shoulder or the heat from a fire, and your brain takes in that information and decides how to react. If we want bionic skins to do the same, they must incorporate sensors that can match the sensitivity of biological skins. But that is no easy task. For example, a commercial pressure-sensitive rubber exhibits a maximum sensitivity of 3 kilopascals, which is not sufficient to detect a gentle touch. To improve an e-skin's responsiveness to such stimuli, researchers are experimenting with a number of different techniques. Zhenan Bao and her colleagues at Stanford University created a flexible membrane with extraordinarily good touch sensitivity by using precisely molded pressure-sensitive rubber sandwiched between electrodes. A novel design of the thin rubber layer, using pyramid-like structures of micrometer size that expand when compressed, allowed the material to detect the weight of a fly resting on its surface. With such structures embedded in it, a bionic skin could sense a breath or perhaps a gentle breeze. This kind of sensitivity would be a great benefit in a prosthetic hand, for example, by giving the wearer the ability to grip delicate objects. In the most recent application of Bao’s technology, her team turned the pressure sensors around so that instead of detecting external stimuli, they measured a person’s internal functions. The researchers developed a flexible pulse monitor that responds to each subtle surge of blood through an artery, which could be worn on the inner wrist under a Band-Aid. Such an unobtrusive monitor could be used to keep track of a patient’s pulse and blood pressure while in the hospital or during surgery.

d. By Organic Light Emitting Diode

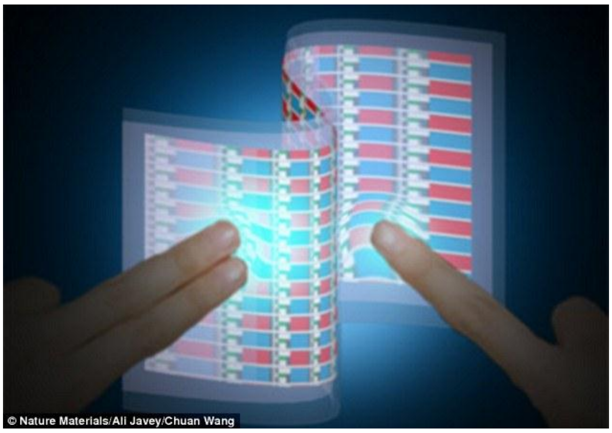

Fig. 7 E-skin using OLED

Javey and colleagues set out to make the electronic skin respond optically. The researchers combined a conductive, pressure-sensitive rubber material, organic light emitting diodes (OLEDs), and thin-film transistors made of semiconductor-enriched carbon nanotubes to build an array of pressure sensing, light-emitting pixels. Whereas a system with this kind of function is relatively simple to fabricate on a silicon surface, “for plastics, this is one of the more complex systems that has ever been demonstrated,” says Javey. The diversity of materials and components that the researchers combined to make the light-emitting pressure-sensor array is impressive, says John Rogers, a professor of materials science at the University of Illinois at Urbana-Champaign. Rogers, whose group has produced its own impressive flexible electronic sensors (see “Electronic Sensors Printed Directly on the Skin”), says the result illustrates how research in nanomaterials is transitioning from the fundamental study of components and simple devices to the development of “sophisticated, macroscale demonstrator devices, with unique function.” In this artist's illustration of the University of California, Berkeley's interactive e-skin, the brightness of the light directly corresponds to how hard the surface is pressed. Semiconducting material and transistors are fitted to flexible silicon to mimic pressure on human skin. The team is working on samples that respond to temperature. Scientists have created what's been dubbed the world's first interactive 'electronic skin' that responds to touch and pressure. When the flexible skin is touched, bent or pressed, built-in LED’s light up - and the stronger the pressure, the brighter the light. The researchers, from the University of California, claim the bendy e-skin could be used to restore feeling for people with prosthetic limbs, in smart phone displays, car dashboards or used to give robots a sense of touch. Scientists from the University of California have created what's been dubbed the first 'electronic skin' that responds to touch and pressure by lighting up using built-in lights.

5. Result & Analysis by Application

In this paper general information about electronic skin is shown and also a fabrication of electronic skin is given. From them we can say that electronic skin

1. Reduces number of wires
2. Compact in size
3. Attachment and detachment is easy
4. More flexible
5. Light in weight
6. It replaces present system of ECG and EEG
7. It gives sense to a robot
8. Wearable
9. Ultrathin
10. Twistable & stretchable
11. Easy to handle

So, some applications are given below to know the depth and use of electronic skin

- When the skin has been seriously damaged through disease or burns then human skin is replaced by Artificial skin.
- It is also used for robots. Robot senses the pressure, touch, moisture, temperature, proximity to object.
- It can measure electrical activity of the heart, brain waves, muscle activity and other vital signals.

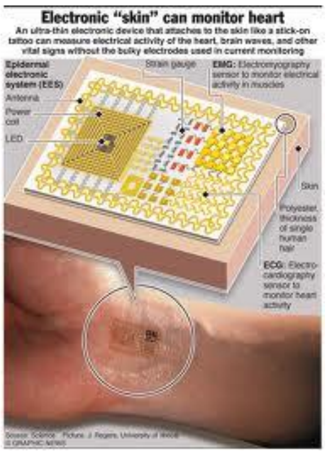

Fig. 8 E-Skin can monitor heart

- By using interfacial stress sensor we also measure normal stress & shear stress.
- Localized electrical stimulation: This is a “smart bandage’’. Temperature is changes across a wound.

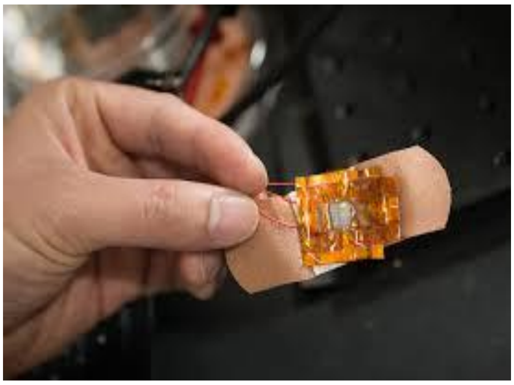

Fig. 9 Smart bandage using e-skin

Future Scope

- Bendable sensors and displays have made the tech rounds before.
- We can predict a patient of an oncoming heart attack hours in advance.
- In future even virtual screens may be placed on device for knowing our body functions.
- Used in car dashboard, interactive wallpapers, smart watches.

Conclusion

The electronics devices gain more demand when they are compact in size and best at functioning. The Artificial Skin is one such device which depicts the beauty of electronics and its use in daily life. Scientists create artificial skin that emulates human touch. According to experts, the artificial skin is "smarter and similar to human skin." It also offers greater sensitivity and resolution than current commercially available techniques. Bendable sensors and displays have made the tech rounds before. We can predict a patient of an oncoming heart attack hours in advance. In future even virtual screens may be placed on device for knowing our body functions. Used in car dashboard, interactive wallpapers, smart watches.

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