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Driving Monitoring System Application with Stretchable Conductive Inks: A Review

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ABSTRACT

Nowadays the automotive industry is moving towards developing system connected vehicle parameters which can monitor the driver's behaviour before driving. Most drivers lose focus and are emotionally distracted while driving owing to fatigue, drowsiness and alcohol consumption, that can result in a traffic accidents. The device or equipment used to detect the driver's health before driving has always posed a problem in terms of the efficiency of the system especially concerning the cable connecting the equipment. Stretchable conductive ink (SCI) via electronic devices have been widely applied in various industries such as fabric, health, automotive, communications, etc. The flexibility allows a circuit to be placed on an uneven or constantly changing surface. However, till to-date, the effective use of the stretchable conductive ink has yet to be proven in the automotive industry. The current driver monitoring system cannot integrate with many of the driver's health level tracking features at one time. A combination of the driver's monitoring system methods with stretchable conductive ink (SCI) sensors layout design can be used to prevent road accidents as a result of a driver's behavior and will make the driving monitoring system more effective with soft substrates technology that has the advantage of geometric deformation based on appropriate shapes.

Keywords: Driver Monitoring System, Driver Behavior, Conductive Ink, Substrates.

1. INTRODUCTION

A driver is the main character involved, in avoiding an accident. Most drivers are not suited for long-distance driving because of health problems or fatigue especially after a long journey. Among the main causes of a driver's loss of focus, assessment ability, impaired emotional performance is the driver's inability to control the vehicle and this will leads to traffic accidents that are far worse than those caused by fatigue, alcohol and other distractions on the road [1]; [2]. Statistics show that the main cause of fatalities and injuries in traffic accidents is the lack of caution and alertness observed by drivers [3]. The device or equipment to detect driver's health before driving has always been a problem in terms of the efficiency of the system used, especially concerning the cable connecting the equipment. There are some multiple sensors capable of capturing human behavior, health data and feedback to avoid accidents. A combination of printed devices with other forms of stretchable electronics can offer great opportunities in energy, healthcare, defense, and display where high performance under severe

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mechanical strain is essential [4]. However, till to-date the effective use of the stretchable conductive ink (SCI) is yet to be proven in the automotive industry that involves many aspects of driving safety in different driver behavior due to static and dynamic testing.

Figure 1 shows that death statistics from road accidents are still high. This shows that the steps taken to lower the death toll from road accidents have not been that successful. The government's road safety campaigns and driver awareness of hazards without prioritizing safety measures while driving, should make car manufacturers improve aspects of the car safety system especially pertaining to driver behavior.

Government authorities in some countries also emphasize the use of driver behavior monitoring systems in addition to reducing theft and misuse of equipment. Responsible drivers will prioritize the use of driver behavior monitoring systems for safer driving and save on fuel costs and practice going green.

1.1 Driver Monitoring System

Monitoring driver behavior is one of the ways to avoid accidents caused by negligence or fatigue due to long journey driving. To avoid drowsiness while driving, less than 3 hours of driving a day is more appropriate for a normal driver [5]. According to [6], severe drowsiness occur after at least 18 hours of continuously keeping awake. Most of the accidents occur because of dangerous driving or driver losing control due to fatigue. According to [7], there are four categories of driving behavior which is normal behavior, drunk behavior, fatigue behavior, and reckless behavior. For traffic safety and intelligent driving, collecting data during braking, blinking and even pressing the accelerator is crucial as it is correlated with driving behavior [8]. When the driver is drowsy, they tend to look away from the roadway and more likely look towards their lap [9].

Basically, 80 percent of road accidents are closely related to driver behavior [10]. This is because of the fatigue and drowsiness factor which causes the driver to lose focus and contribute to the accident. Vehicle accidents cause fatalities and injuries, financial losses and loss in productivity which also result in legal and insurance costs. The vehicle only monitors the driver and does not communicate any result, problem and/or damage, should there be an incident with the vehicle, at remote sites during troubleshooting, diagnosis or while tracking for data mining. [10]. Many people don't even realize they are high-risk drivers owing to their reckless behavior, like speeding, sudden acceleration and swerving through lanes putting other drivers at risk. Dozens of surveys show that recognizing dangerous driving behavior can be a strong motivator for drivers to improve their behavior. Also, when people see the direct relationship between reckless driving or they know that their behavior is being monitored, their driving improves. Monitoring driver behavior can be a silver bullet that can combat driver distraction, alcohol and drug impairment, and uncorrected or defective eyesight, that can be investigated by law enforcement [11].

In fact, solutions to curb bad driving are being used by several companies as a part of their Fleet Management Systems (FMS). Transportation companies track, benchmark and train their drivers as well as create more economical and environmentally efficient fleets. They can also be used to maintain corporate and regulatory compliance. Insurance companies use devices and applications to track driver behavior to reduce their costs on insurance settlements and offer their customers more flexible coverage terms. To determine potential driver fatigue, there are devices or systems that can detect and track the driver's face, eyes, mouth, eye blinking, and cap openings [12]. There are common tools that are installed on vehicles with software to monitor and analyze the device logs to tracking driver's behavior by using plug & play devices like GSM/GPS OBDII tracking devices, CANBUS devices, RFID devices, and cameras. The systems software can be either web-based or cloud-based. Numerous vision systems have been developed to detect driver behaviors to drive safely and most existing systems are using direct camera mounting to the driver's face to capture high-resolution images [13]. Some companies use ready-made solutions and some develop driver behavior monitoring systems that are customized for their fleet.

There are many safety features related to driver behavior that occur in the vehicle security system at present. Most of the safety features for monitoring driver behaviors are (a) Facial Tracking: Face Recognition, Emotion Recognition; (b) Eye-Tracking: Measuring Drowsiness & Fatigue; (c) Biometrics: Alcohol Detection; (d) Biometrics: Heart-Rate Monitoring and; (e) In-Cabin Intelligence: Occupant Monitoring [106].

Highly Automated Driving (HAD) is a new driver monitoring feature and soon will be commercially available [14]. Human factor issues like the influence of the driver's state can have a critical impact on the success of this driving paradigm, road safety and as well as assessment of their cybersecurity and data privacy due to the increased variety of software and communication interfaces used. In the HAD concept, the human driver still retains the responsibility to resume vehicle control in a situation where the automation cannot handle. The effect of HAD functions on road safety is essential for the homologation of such complex systems [15].

1.2 Printed Circuit

The printed circuit is an electrical device in which the wiring and certain components consist of a thin coat of electrically conductive material applied in a pattern on an insulating substrate by any of the several graphic arts procedures.

1.2.1 Printed Circuit Boards (PCB)

Printed circuit boards or PCBs have become essential to people's daily routines which is a vital role in modern-day as technology is essentially a foundation as they are used in almost everything electronic or electrical. The PCBs also come in various configurations which allow them to serve different purposes and provide various capabilities. PCB substrates and modules contain conductor effects with large cross-sections and/or massive copper and ceramic structures to allow the required heat dissipation [16]. Nowadays, every industry uses the PCBs and continues to evolve into new industries and applications. PCBs are the major functional centers of most electronics in the modern world. Circuit boards connect components to one another through a series of related circuits. Commercial Printed Circuits were introduced in the early 20th Century using one or more patterned metal foil layers. Commercialization of Radio sets, and other electronics, made PCBs a commonplace by the mid-1950's. Copper has been the metal of choice for PCBs. The standard conductors in a PCB is using printed and etched foil (subtractive) and plated (additive) interconnecting vias. Dielectric materials are typically composites of various resins and a reinforcing fabric with the exception of flexible circuits. The PCB can be very complex handling everything from power circuits to high speed interconnects (transmission lines) between processors with patterning and combining in a layered structure.

The principles for using both subtractive and additive conductor formation has been the same for decades because the PCBs are becoming ever more complex in density and layer count. PCB designers need to consider many of these effects for higher frequencies, for example, minimize Dk, copper roughness and thickness variations as it can all negatively impact performance in their design in order to be aware of various tradeoffs with different types of PCB materials and processes. Common-mode noise can affect the PCB signal integrity (ST) and power integrity (PT) and result in unintentional emission that lowers the performance of nearby devices [17]. The conductors, etched copper are remaining unchanged while new dielectrics like Low loss materials continue to increase in use. The basis of the electronics industry, printed circuit boards, is a technological waste of difficult disposal whose recycling is complex and expensive due to the diversity of materials and components and their difficult separation [18]. The large amount of PCB waste generated annually increases with its toxic nature and the high availability of precious metals in its composition reinforces problems related to PCB waste management and recycling [19]. The massive disposal of waste electrical and electronic equipment (WEEE) generates a large stream of waste printed circuit board (WPCB) into municipal solid waste, generated in large quantities annually [20]. Electronics contribute significantly to the medical application or health-care industry, functioning as diagnostic, monitoring and treatment devices. These electronic devices in medical applications continue to grow as electronics evolve to become more efficient and dense, leading to endless new possibilities. PCBs are highly specialized in order to fit the unique constraints of medical devices within the medical industry. Flexible base materials in medical PCBs also has been made to allow PCB to flex during use, which can be essential for both internal and external medical devices.

1.2.2 Printed Electronics

Printed electronics is one of the fastest-growing technologies today and it has become very important to several industries including healthcare, aerospace, media, and transit. Printed electronics technology originally emerged as a potential low-cost replacement to its complementary technology, the silicon-based electronics. As the substrates grow thinner, it is enough to be integrated into existing production lines because the printed materials become thin, light, and flexible. Printed electronics objectives are not only to be cheaper alternatives by replacing the individual electronic layers but also to develop complex materials that deliver additional functionalities which a two-component solution that controlling the viscosity can be used to produce a self-assembled structure based on the affinity of the solution components to each other [21]. Printed electronics used an all-encompassing term for the printing method to create electronic devices by printing on a variety of substrates. Originally, printed electronics related to organic or plastic electronics used one or more inks made of carbon-based compounds. Printed electronics are being used to form flexible keyboards, antennas, electronic skin patches, and more as demand for wearable devices and thinner electronics expands. According to [22], printed electronics play a critical role in facilitating widespread flexible electronics and more recently stretchable electronics.

According to [23], wearable electronic applications' numerous challenges are the unobtrusiveness of the device in which the key technology to minimize obtrusiveness is stretchable electronics. Stretchable electronics is a device that represents an emerging class which can be compressed, twisted and adhered to a very complex shape and the compliances of mechanical and electrical stretchable electronics can pave the way for its use in health care, entertainment, and energy [24]. The main challenge of materials for making stretchable printed electronics is to develop a printable conductor or electrode [25]. Stretchable conductive ink via electronic devices has been widely applied in various industries such as fabric, health, automotive, communications and etc. The flexibility allows a circuit to be placed on an uneven or constantly changing surface. Stretchability gives an advantage providing pervasive and unobtrusive sensing and display applications because the stretchable platform is perpetually exposed to cyclic motion and deformation [26].

Most organic materials are generally flexible and non-stretchable, which is a key mechanism needed for prosthetics, artificial intelligence, robotic systems, personal health monitoring, biocompatibility, and communication devices [27]. The same conductivity over severe bending cycles demonstrated a high electrical conductivity after thermal reduction using graphene-based patterns were printed on plastic substrates [28] According to [29], the routes to integrated circuits provided by advances in mechanics and materials offer the electrical properties of conventional, rigid wafer-based technologies but with the ability to be stretched, compressed, twisted, bent, and deformed into arbitrary shapes. Because of these structures, the flexible electrical circuit must insufficiently be thin form and by virtue of bending strains that decrease linearly with thickness.

Nanoparticle inks can be produced in large quantities, dispersed in high concentrations and produce relatively good electrical conductivities [30]. Most driver seat sensor systems composed of ink and a thin film circuit provides a wiring pattern on the top surface of the substrate. All wiring pattern consist of pairs of wires and each pair of wires defines a capacitive element which is connected to the detector circuit by a connecting wire. The rapid development of the use of electronic devices today requires the conductive matrix to be more flexible and stretchable. Stretchable and conductive materials have been widely used in electronic and healthcare equipment. Flexibility and expandability are the main features of the SCI while maintaining high conductivity levels. According to [31], conductive ink is simple and cost-effective, which is suitable for flexible electronics.

2. MATERIALS

Nowadays the present printed circuit board (PCBs) manufactures incur relatively high cost due to complex and expensive techniques. To overcome these problems, using various conductive fillers such as gold, platinum, carbon nanotube, silver nanoparticles, organic conductive polymers and graphene that has been used in printed electronics market are capable to substitute the PCB technology in order to the manufacturing cost. For both additive and subtractive conductor processing, there are complex manufacturing infrastructure for PCB [32]. To produce a sensor system that uses a wire connection will involve other equipment such as the wire connection boards. The board is physically fragile and it can be easily broken when subjected to high pressure. There are important new electronic features with low manufacturing costs, long-term durability, environmentally sustainable production methods, recycling, lower energy consumption, and higher efficiency, and electronic integration as part of other structures [33].

Graphene has been a major source of research with many desirable properties including high electrical conductivity, mechanical strength, and elasticity [34]. The technology of the internet of things (IoT) can be dominated by the inks based on graphene because of the low cost of the ink and it can be applied directly on materials like textile and paper [35]. The use of conductive nanomaterials for printed electronics must overcome two major challenges: first, similar to bulk metal, the printed patterns need high electrical conductivity and second, the nature of the substrate material is not affected especially for plastic electronics, need to achieve high electrical conductivity under relatively light conditions [36]. Graphene strain sensors have the ability to detect various types of strain caused by stretching, bending, and torsion, which are required for sensors to detect human body motions [37]. In order to achieve high conductivity, there is a wide selection of conductive materials that can be used but there are also disadvantages. Gold has the advantage of being non-oxidative making it ideal for coating and interfacing [38]. Due to the high cost of gold, it is restricted to wider use [39]. According to [40], silver disadvantages are susceptible to electromigration for which its widespread use is barred.

Due to the high cost of materials, copper, aluminum, and nickel are cheaper alternatives but the disadvantages of these materials are easily oxidized in the air which form an insulating barrier on its surface [36]. Carbon is another conductive material in the form of graphite, carbon black and carbon nanotube (CNT) that is graphite rolled into single or multiwall cylinders [41]. The advantage of CNT is that it can act either as metal or semiconductor depending on the chirality and if it can withstand harsh conditions [30].

2.1 Substrates for Conductive Circuit

Modern electronics are based on the integrated circuit, which is an assembly of millions of interconnected components such as resistors and transistors that are built upon a tiny chip of silicon. These circuits depend on insulating materials in order to maintain their reliability that can serve as substrates which is the base of the microscopic electronic component and their connections are built and packaged within the structure itself and sealed in a circuitry away from the environment, making it a single, compact unit.

2.1.1 Substrates for PCB

The PCBs consist of two basic parts: a substrate (the board) and printed wires (the copper traces). The substrate provides a structure that physically holds the circuit components and printed wires in place and provides electrical insulation between conductive parts. Compared to the traditional direct bonded circuit (DBC), the PCB substrates have better electrical properties and mechanical soundness [42]. The advancement in the speed and function of components used on PCBs is the availability of materials for PCB substrates compatible with this product and its process requirements [43]. The PCB materials have two purposes: to conduct electricity and to provide insulation between conducting layers of copper. The materials of a printed circuit board (PCB) contain the transmission lines and components that enable radiofrequency/microwave circuits. It is important to know the success or failure of the PCB; the materials impact thermal behavior, as well as the electrical and mechanical characteristics of the circuit. PCBs are generally made of solder mask, silkscreen, copper and substrate. There are many options to choose from these substrates.

i. Hard/rigid PCB materials:
These PCBs are made from a solid substrate material that prevents the board from bending. For example, a computer motherboard, perhaps the most common application for a rigid PCB. The motherboard is a multilayer PCB which is designed to allocate electricity from the power supply while enabling communication between all of the computer's parts, such as CPU, GPU, and RAM [108]. For the device's lifespan, hard or rigid materials are used whenever the PCB has to retain the shape it was set up to be. Hard circuit materials are typically ceramic based.

ii. Substrate: Soft/flexible materials:
Plastic is often used to enable a PCB to flex and move. Like hard or rigid PCBs, flexible PCBs can be made in single, double or multilayer formats. Soft/flexible materials can be folded over edges and wrapped around corners. Flexible materials can be wearables that allow printed circuitry be inserted into compact spaces. Flexible materials tend to cost more for fabrication but saves cost on weight. Flexible electronics have to be protected against environmental influences because of its increasing usage on flexible electronics recently [44]. One advantage of using flexible materials is that they can be used in areas with environmental hazards. Flexible materials also can be waterproof, shockproof and corrosion resistant. Soft circuit materials such as an epoxy or plastic form a coating around the filler, often causing a glass weave [108]. This form of glass or ceramic filler provides strength and rigidity to the plastic dielectric material.

iii. Flex-rigid PCBs:
There is a third option for PCB substrates: a combination of flexible and rigid materials. Often used in aerospace, medical and military applications, flex-rigid boards consist of multiple layers of flexible PCB, such as polyimide, attached to a rigid PCB layer [108]. Flexible polymer substrates usually can be found in the

field of plastic electronic devices, namely microelectronic devices, including radio frequency identification tags or electrodes for thin-film transistor circuits using inkjet printing for high-resolution conductive features [45].

2.1.2 Substrates for SCI Film

There are three types of substrate conductive films in SCI which are flexible, stretchable and soft [46]. The combination of conductivity and deformability of liquid metals is suitable for identified materials. The mechanical properties of the material cause the deformation limit of the shape of the conductor along the fluid to be limited. There are many advantages of thin-film materials over their counterparts, in terms of properties, applications, and economic considerations which have mechanical flexibility, for instance bendability, when they are in free form or integrated with other thin-film materials [47].

i. Flexible Substrates

Flexible substrates are circuits and electronic devices that can remain functioning while being bent. By using flexible substrates the weight of flat panel displays will significantly reduce and provide the ability to conform, bend or roll a display into any shape. Flexible substrates face problems under humidity and corrosive environment and also have high electrical insulating properties, flexibility, transparency, toughness, smoothness, and it must be highly stable and functional [48] It also will provide the basis for cost-effective mass production and open up the possibility of fabricating displays by continuous roll processing. Aluminum foil is flexible even though bulk aluminum is rigid and this concept has been used commercially to build flexible conductors and transistors on polymeric substrates such as polyimide or polyethylene naphthalene (PEN) [46].

ii. Stretchable Substrates

Stretchable substrates or electronics can be elongated which can be used in a wider application space while providing increased durability [49]. Stretchable substrates become an important unit for circuit connection of working circuits of various stretchable devices. In order to have a high quality stretchable printed circuit, it must able to have good adhesive strength and be exposed to high temperatures with the substrate, while maintaining electrical conductive performance [50]. Stretchable electronic design and fabrication common approach is by connecting hard component through stretchable interconnects [51]. With the help of multiple manufacturing strategies, various stretchable electronic devices are fabricated including stretchable heaters, stretchable energy conversion and storage devices, stretchable transistors, sensors and artificial skin [52]. For close and precise monitoring of "stretched" body organs such as lungs require a stretchable electronics solution [53].

iii. Soft Substrates

Soft and elastic electrically conductive and semi-conductive composite materials can be developed based on nanomaterials/conjugated polymers and elastomers. Soft electronic uses the same concept as stretchable electronics which has the advantage of changing geometric shapes based on the appropriate shape [46]. High-performance functional materials that can sustain large deformations can be achieved by tailoring the properties of the conductive filler and the morphology of the composite. The interaction between the nanostructured conductive filler and the elastomer matrix is of some interest for understanding and developing new materials and devices. According to [54], wrinkles are more suitable under compression, and thin films coherently deform with a soft substrate for strong interfacial bonding. The ability of renewable electronic substrates to adjust the skin's curvilinear surface reduces the need for users to pay attention to the device.

2.2 Stretchable Conductive Ink Sensors

The SCI offers a unique solution for embedding electronics in wearable applications including clothing, accessories, and medical devices. The ink can be used to create a thin stretchable form-fitting circuit that allows for both comfort and freedom in wearable devices. In real-life scenarios, one of the major challenges in wearable chemical sensors that can cause poor deformations of wearable devices, including power sources and sensors, is because of its multiplexed movement [55]. According to users in the sports industry, wrist-worn activity makes an impact on wearable electronics as it helps users to measure their physical activities and it is gaining popularity. The definition of stretchable directions and complex fabrication processes have ~~a~~ limitations to be concerned with where all difficulties can be resolved by printing an alternative strategy to produce stable and stretchable sensing applications [56]. Conductive inks can be printed on lighter substrates that are as diverse as polyester, polycarbonates, polyurethanes, and paper. The use of these lightweight substrates open the door for greater creativity in product development and less complexity in production.

Given the prevalence and low cost of today's printed electronic devices, end users rarely consider the technology that makes these devices tick. Soft sensors typically consist of deformable controls material that is patterned, affixed, or packed in non-stretchable materials [57]. There are a few people who associate the diagnostic electrocardiogram (ECG) with printed electronics. The use of conductive inks has been the catalyst for replacing rigid, inconvenient electrodes with the more comfortable, inexpensive and disposable sensor pads that are in use today. According to [58], the conductive ink was used as a transducer converting pressure into an electric signal. Another rapidly emerging application of ink-driven printed electronics is the broad category of wearables. Devices that use stretchable and washable inks can be heat transferred onto a garment and used to measure electrical impulses triggered by muscle movement. Wearables are already appearing in athletic and medical sectors and are quickly finding their way into other industries. Another conductive ink-based application is Smart Packaging. The embedded polymer thick films (PTF) circuitry in product packaging has greatly enhanced inventory control processes for wholesalers and retailers. The label industry has made stretchable labels an attraction in the industry's marketing.

In clinical application, the important role in guiding timely patient care setting is Point-of-care (POC) diagnostics because they are inexpensive, rapid, simple to use, and instrument independent [59]. The POC diagnostics is used to monitor, prevent and control the patient's condition remotely with no equipment and trained personnel nearby. High stretchability and bendability is required to accommodate body movement where the stretchable strain sensor has the potential application of the textile electrode to wearable human motion detection devices [60]. Figures 1 and 2 show the overview of flexible substrates for POC and application in the medical industry.

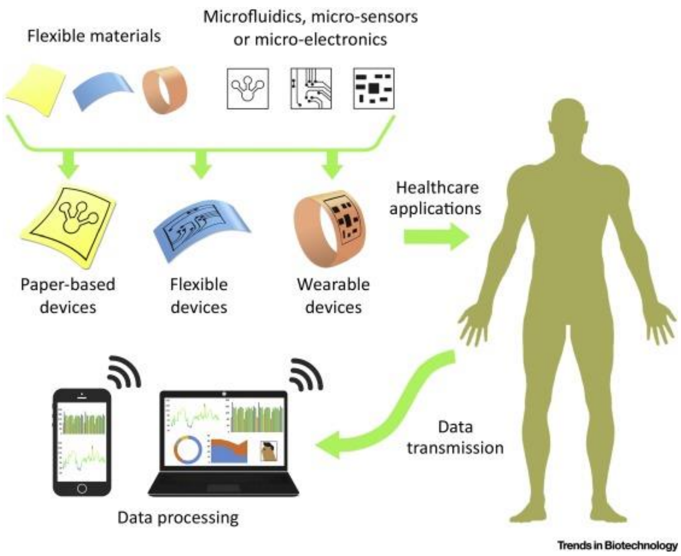

Figure 1. Overview of flexible substrate-based devices for Point-of-Care Diagnostics [59].

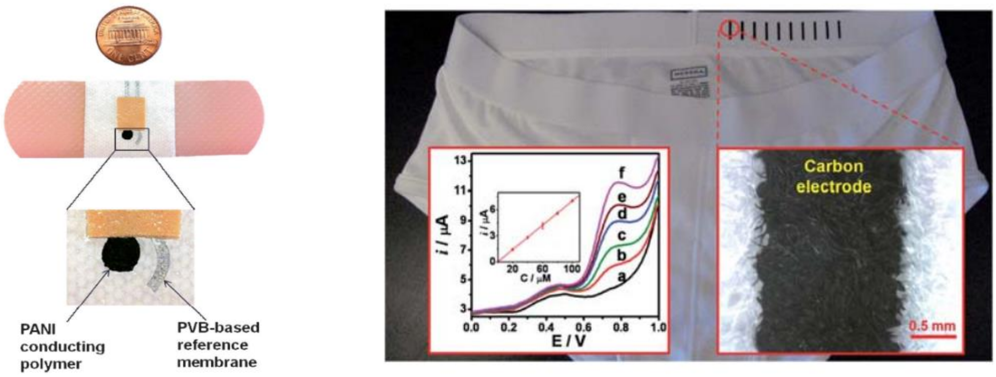

Figure 2. Application in medical industry.
(a) Printed potentiometric sensor on an adhesive bandage [61] with (b) a textile-base, along with the morphology of a single electrode amperometric sensor [62].

3. DRIVING MONITORING SENSOR LAYOUT DESIGN

Transportation is a priority of today's society in communication. It plays an important role in the transport of individuals, the social welfare, the economy and the quality of life of a society [63]. The government has spent a lot of money on public transport, safety and other needs for the convenience of the people. Based on the method to overcome limited wired measurements used to monitor driver's health, the driver's health monitoring system is also a user-friendly system in a private area network environment [64]. Driving activity in some cases implies a risk for the driver and third parties. It is influenced by the environment, the road infrastructure, the mechanical-electrical status of the car, and the health and emotional state of the driver [65].

3.1 Driving Monitoring and Assistance Systems

The driver monitoring and assistance system (DMAS) is a very complex decision system, using aggregate data to calculate a decision or recommendation of certain systems where all decisions are used to detect the different actors respectively to control the car properly [66]. Driving safety is based on the driver's attention when driving. Driver distraction, is defined as a distraction from activities that are critical to driving safely to a competitive activity, that is increasingly recognized as a significant source of injury and death on the road [67]. The driver is distracted while driving due to several reasons such as fatigue, drowsiness, unhealthy, drunkenness and so on. According to [68], secondary tasks may distract the driver while driving such as texting, interacting with passengers, talking on the phone, eating, and adjusting the radio among others. This makes the car manufacturing companies to look for solutions to make driving safer by considering factors associated with the driver, vehicle, and the driving environment.

The DMAS is one system that has been used to help drivers avoid dangerous situations that they are exposed to. DMAS objective is to keep an eye on the driving status of a driver and to provide necessary assistance for safe and comfortable driving [63]. The functionalities for such automation systems such as intelligent vehicle control systems, collision avoidance systems, advanced driver assistance systems, driver's inattention monitoring systems, and so on, is considered as DMAS.

Figure 3 shows the layout of a typical DMAS designed to continuously monitor the parameters associated with the driver, vehicle, and surroundings by acquiring data from multiple sensors taken from the driver's body, interior, and exterior of the vehicle. Then the required features extract the processed data based on what decision is made, and conveyed to the driver. DMAS can help provide alerts to the driver and initiate an intervention to manage the control of the vehicle. The driver monitoring and assistance system ensures that the driver is prepared to take control of the vehicle when the situation dictates.

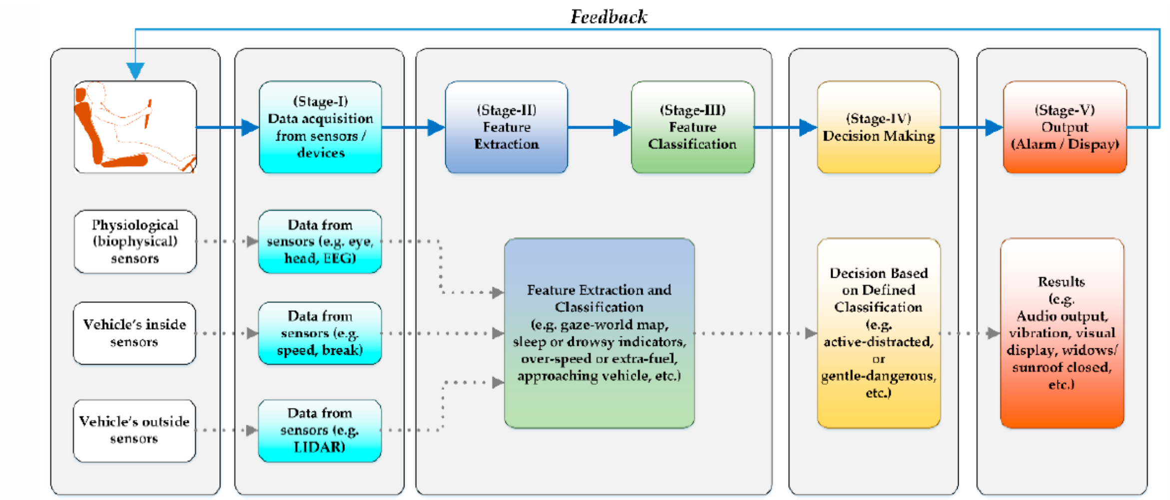

Figure 3. The layout of the typical DMAS [63].

3.2 Health Monitoring Systems for The Monitoring of Bio-Signals

Nowadays the invention to provide a health monitoring system in vehicles is capable of correctly judging the health condition of each person even when there are many people to be monitored [69]. Based on functionalized nano- and micro-materials, flexible and wearable sensors allow the detection of mechanical pressure and strain, temperature variations, and bio-potential changes in human body [70]. The health monitoring systems capability is continuously tracking physiological signals of the human body without conspicuous discomfort and invasiveness [71]. The sensors give signals such as body motion, heart rate, breath, skin temperature and metabolism parameters, which are closely associated with personal health conditions. According to [72] human physiological activities are monitored and recognized by the practical applications which is exhibited by the sensors.

Figure 4 shows the wearable health monitoring system in an ideal composition. Based on figure 4, the IoT is used as a tool to send the signal to the doctor (for monitoring or further action). Because of an increase in the number of elderly people, the combination of the IoT platform and wearable system can efficiently meet the requirement for self-health monitoring and preventive medicine [71]. Smart facial expression recognition can be achieved by placing sensors on the underlying basic muscles on the skin that will provide a universal facial expression. Stretchable and sensitive strain sensors are attached to selected positions on facial skin, which contain the basic muscle groups for most expression movements [73]. Sensors will provide a signal for every movement or change in the skin continuously.

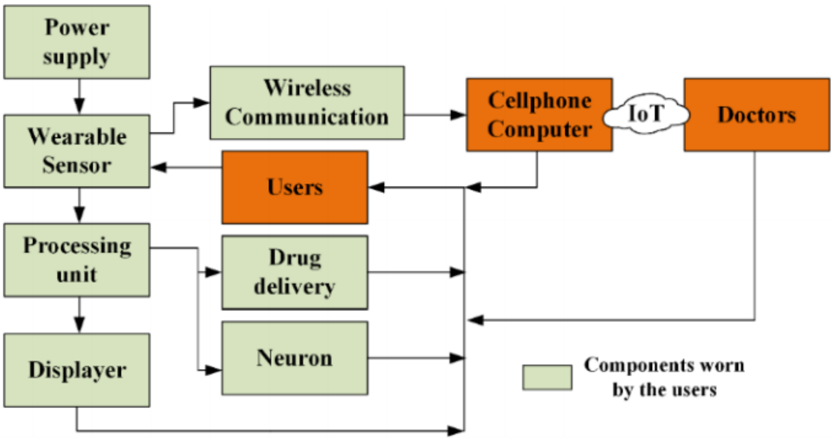

Figure 4. Wearable health monitoring system in an ideal composition [71].

3.3 Vehicle Seat Sensors

All vehicles manufactured today have driver and passenger seats equipped with various sensors. some of these sensors have their own characteristics based on the needs or values that a vehicle should have. These safety features are paramount in the driver's seat because safety is from where people are.

3.3.1 Occupant Classification Systems

There are various names of passenger safety systems designed to detect the actual presence of a passenger in the seat, for example, Occupant Classification Systems (OCS), Seat Occupant Sensors (SOS), Occupant Detection Systems (ODS), Passenger Weight Systems (PWS). Every vehicle manufactured today have these safety systems and each of these systems perform very similar functions. Each Original Equipment Manufacturer (OEM) can have specific and potentially different procedures for repairing and recalibrating their system after an accident. The OEM required seat recalibration steps are necessary to put these systems back in working order after an accident and will always be addressed by the Proper vehicle repair plans (VRPs).

The OCS is a system of sensors that detect who's sitting in the passenger seat by classifying an occupant type into an adult, a child, a child seat, or an object [74]. The need for an on/off switch for airbags in most cases is eliminated by OCS because it uses sophisticated computer technology to identify whether an adult or a child is in the seat. Generally, the occupant characterization method is to allow deployment for a child or small adult and to suppress deployment where there is reduced deployment force for a small child [75]. In addition, OCS are critical to the front passenger's safety. OCS detect the presence of a passenger, the passenger's approximate weight, and the front passenger's seating position within the passenger compartment.

One of the more popular OCS is made by Delphi. Inside the seat, you will find an electronic control unit (ECU), a pressure sensor and a silicone-filler called the bladder. When someone sits on the seat, the pressure sensor signals the occupant's weight to the ECU. The ECU then sends that data to the airbag, which has its own control unit. Based on that information, the vehicle's computer turns the passenger airbag on standby mode. Therefore, the OCS data is used to determine if the airbag should be deployed, and the velocity at which it should be deployed as a result of a collision. Small children (in weight) occupants will have ~~a~~ fatal injuries caused by the airbag [76]. Different deployment velocities are used depending on the weight of the passenger. The OCS doesn't just detect weight, but also reads the passenger's seating position and determines if they're wearing a seat belt. It also has a seat belt tension sensor that allows the OCS to interpret the pressure created when a child seat is fitted. This shows that the system is designed to tell whether a child's safety seat is occupying that seat or whether it is just carrying some heavy object. It is has a light or sign on the instrument panel that tells the driver whether the passenger airbag is on or off.

3.4 Monitoring Human Activity from Driver Seat

Biophysical measurement can give many useful information for drivers by using sensing devices. A person driving a vehicle needs to be healthy and be able to concentrate on driving. A driver's body parameters like body temperature, heart rate, brain activity, muscle motion and other critical data affecting health conditions can be collected and monitored [77]. The human body temperature is kept within certain limits, declared normal, and not influenced by the temperature of the environment [78]. In recent years there are several methods being used to monitor the driver’s health. Some automakers have used systems that have been considered as a necessity for today's vehicle safety. Among the systems used today are Driving Monitoring System (DMS), DMAS, Advance Driving Assistance System (ADAS) and many more. Based on these systems, some inventors have further enhanced the capabilities of the driver monitoring system based on current customer demands or requirements.

There are several devices used to provide information of driver’s biological and physiological status and so on to detect driver’s fatigue. Electroencephalogram (EEG) is extensively used in the field of brain activity research, Electrocardiogram (ECG) provides information of heart rate and respiration rate, Electrooculography (EOG) provides a measure of the cornea-retinal standing potential between the front and the back of the human eye, Electromyography (EMG) for evaluating and recording the electrical signal generated from muscle contraction, Electro-Dermal Activity (EDA) provides a measure of skin conductance which changes due to the secretion from sweat glands because the parasympathetic nervous system activity is triggered and will reduce sweating during drowsiness, and etc. [63]. Most of the information related to the subject's physiological status is carried out by the ECG [79]. People usually have little control over physiological signals which has become an effective way of assessing driver fatigue and make it a reliable source of driver information [80]. Conventional biophysical measurement systems require electrodes to interact with the human body which will interfere with the operations of the driver and it is also not suitable for long-term surveillance purposes [81]. It is often that the emotion-related activity recognition that has been realized using a camera to analyze the facial expressions and gestures and also using electrocardiograms, brain waves and galvanic skin reactions from physiological signals [82]. The EOG blink duration and EEG different ratios between low-frequency range that indicates sleepiness and the high-frequency range that indicate alertness, contribute the most to drowsiness classification results among the physiological features [83].

3.4.1 Non-Contact ECG Monitoring for Automotive Application

There are several methods for measuring driver behaviour and health that can be used in car seats, for example by using capacitive electrocardiogram (cECG), ballistocardiogram (BCG) using piezo-foils for mechanical movement analysis, and inductive impedance monitoring [84]. Capacitive electrode is not used on the body but ECG can be recorded through clothing [85]. Most studies estimate driver behaviour based on image processing using vision-based techniques that need to include complex signal processing levels to limit parameters such as harsh environmental conditions, driver movements, and driving conditions [86]. According to [87], passenger heart function and stress level monitoring device is ECG because it provides the most prominent vital signal. Driving stress changes the driver's mood, and major disruptions to driving sometimes occur because of this [88]. By implementing the capacitive ECG monitoring (cECG) technique, the measurement mode can be done by no contact to the passenger or driver. Figure 5 shows the co-driver's seat featuring the capacitive electrodes at the backrest.

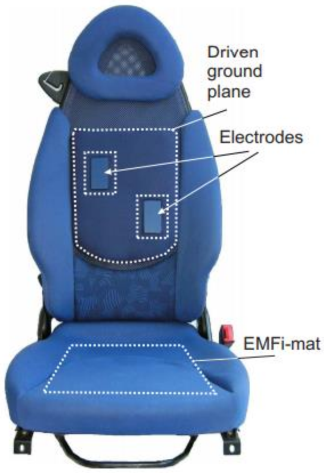

Figure 5. The co-driver seat featuring capacitive electrodes at the backrest and an additional acceleration sensor (EMFI-mat) in the seat [87].

3.4.2 Method and Apparatus for Monitoring Driver Alertness

Method and Alertness for Monitoring Driver Alertness is invented by [89]. The inventor has made a seat to monitor driver's seated posture by using pressure sensor array disposed in or on the seat to indicate pattern of pressure from the driver's body distributed over the seat surface [89]. The invention's objective is to determine if the driver may not be able to operate the vehicle safely by using a method and apparatus for monitoring driver alertness that utilizes seat-mounted pressure sensor and also provides the occupant status information to the occupant restraint system controller.

Drivers are not currently well-informed of their drowsiness or sleepiness, thus increasing the risk for them and others when they are driving while drowsy or sleepy [90]. When the driver is not drowsy, their alertness when driving will be better than when they are drowsy when the frequency of eye blinks increases, the braking response takes very long and causes increased lane deviation [91]. The invention will detect the driver's head tipping or nodding forward, it will detect the increased blink rate or eyes closing and detect the accuracy of tracking the vehicle within the lane while driving. The controller is able to distinguish between the patterns indicating a heavy occupant, calling for a relatively rapid and/or high-powered inflation of the airbag, a lighter occupant, calling for a slower and lower-powered inflation; and a child safety seat, calling for complete suppression of bag deployment [89].

3.4.3 Driver Health and Fatigue Monitoring System and Method

Drowsiness and distracted driving are common abnormal driving behaviors and both driving behaviors for different drivers vary [92]. [93] is another inventor who invented a driver health and fatigue monitoring system and method. This invention is to monitor the vehicle characteristic, condition, property and the state of the driver [93]. The invention is to give signals or notification to the driver's condition of their health or inattention that requires driver response to continue the operations of the vehicle.

Fatigued driving can cause the driver's inability to control the vehicle especially after a long drive, making the driver weak, owing to the mental state and poor physical condition [94]. Rash driving is also a major traffic violation which reflects on the mental state of the unwillingness for any regard to the road and traffic rules [95]. The current driving scenario is needed to help reduce the impact of impaired driving because not all driving scenarios are the same and, therefore, a combination of specific warnings and/or automated driving measures need to be developed [96]. The advantages of the invention of the driver health and fatigue monitoring systems and method are a combination of methods that can be applied through the systems. The combination uses heartbeat and respiration rates to determine drowsiness, for example, the eyelid motion observation and a behavioral diagnostic based on the observation of the vehicle lateral control behavior can be combined to improve the forecasting accuracy and reduce false alarm [93]. Variations in the eye will change according to the eye blink i.e. if the eyes are closed, it means high output, otherwise the output is low [97].

According to [98], there are four categories using the visual features techniques: eye state analysis, eye blinking analysis, mouth, and yawning analysis and facial expression analysis. From the information of the driver gaze direction, it can be detected if the driver is distracted [99]. The heartbeat and/or respiration of the driver and/or occupant of the vehicle can be analyzed to determine the state of drowsiness or health state by the new uses analyzer and the new uses of weight sensor e.g. bladders, strain gages, load sensors or displacement sensors, radar based-sensors or accelerometer [93]. According to [100], the use of various sensors can be uncomfortable for the driver and may impede the movement of the driver but there is a strong need for low-cost drowsiness sensors that can be used for early identification of drivers at risk of drowsiness.

4. CONCLUSION

Technological advances in driving safety have increased dramatically in recent times. This has resulted in most automobile industries competing to keep their vehicles safe and thus reducing road accidents resulting in losses to many, especially road users. To make driving safer, the driver monitoring system has been improved in many ways to detect driver health, driver fatigue, drowsiness, drunkenness, and driver negligence. Safety while driving is important to prevent accidents. Various reforms or improvements in terms of safety features have been made by vehicle manufacturers especially driver monitoring systems. The safety features of the driver's monitoring system is to monitor the driver's health. Driver's health plays a very important role especially in terms of fatigue or drowsiness while driving. Various inventions have been carried out over the years to monitor driver's health. Each of these inventions has its own advantages depending on local needs and circumstances. This is because the cost of manufacturing is high, and the automobile companies have to comply with the rules and regulations of a country.

The SCI sensors layout design can be used to prevent road accidents as a result of driver behavior and will make driving monitoring systems more effective with soft substrates technology that has the advantage of geometric deformation based on appropriate shapes. It also can reduce the cost of fabrication because of less complexity in production and increased creativity in product development. The breath movement of the human body will affect the seat sensor signals [101]. Even the SCI can interface with the human body and is compatible with human supple and sensitive nerve. One of the improvements in the advanced stretchable conductive ink technology is that it can also be used to mimic the function of human skin and it is further enhanced by converting human skin stimulation such as temperature, pressure, tension, humidity and many more to electrical signals [102]. This will be able to determine the efficiency of the SCI through the sensors used to detect fatigue or drowsy drivers. The results from that efficiency will be optimized to get the best model for the SCI sensors layout design for the driver's seat.

The main challenge in the driver monitoring system is to integrate many of the driver's health level tracking features at one time. This is because, in the driver's health monitoring system, most of the previous studies and inventions could only be detected by one sensor at a time. Sometimes the signal given by the sensor is in error in terms of the data received. The data received has errors in terms of the body size of the driver (child or adult), driver's posture (seating position), driver's use of sunglasses (eye-related sensors), driver's age, driver's disability etc. This shows the importance of a driver's monitoring system to detect more than one driver's health status at a time to determine the driver's actual condition.

Driver Health and Fatigue Monitoring System and Method is a system that can combine more than one method to detect the drowsiness and fatigue of the driver at one time. The system invented by [93], can improve forecasting accuracy and reduce false alarm or signal to monitoring and determining the health of the driver. The combination of the systems can also be used by combining the heartbeat sensor, respiration sensor and motion sensor with other occupant sensor systems. For example, the driver seat and weight sensors based on strain gages or bladders can only be used for health and fatigue monitoring systems, and to classify passenger and driver. The system can also be used by optical sensors, ultrasonic sensors, seat track, and seatback sensors, etc. [93].

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