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Study of Wearable Biosensor with Special Reference to Health Care Monitoring

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Abstract— Wearable Biosensors enables real time analysis of biochemical fluids such as sweat, saliva and tears and provides information about health conditions. As the name states, these sensors are worn on body, at wrist, in form of clothes, in mouth etc, thus termed as wearable and are used to sense various diseases, heart rate, pulse rate, body pressure, body temperature etc, thus termed as biosensor. The biological element detected by biosensors are antibodies, enzymes or nucleic acids. These biological elements interact with analyses to be tested and the response is then converted to electrical signals. The real time information is sent wirelessly to the monitors, laptops or smart phones. Wearable biosensors helps in early detection of health events and avoids hospitalization. These sensors are used to monitor a wide range of parameters as stated, for the health and fitness of individuals. Wearable biosensors have found advantage over other biosensors as these are easy to use, low cost, flexible, and sensitive. These wearable biosensors have found wide application in cardiac monitoring, diabetics monitoring, agriculture, bio-defense practices, environment, and drug delivery. In this research article, we discussed some of the research work done on wearable bio sensing technology and also some of the latest and modern wearable biosensors used in Health care monitoring.

Keywords: wearable biosensors, Health Care Monitoring, biochemical fluids, sweat, saliva, tears, heart rate, pulse rate, body pressure, body temperature.

I. INTRODUCTION

With the rapid advancement in science and technology in today`s world, especially in field of medicine. Different fields of medicine comprises micro/nanotechnology, wireless technology, wireless communication, information technology, and biomedical sciences during past 10 to 15 years. Various wide range of models and designs are built for a wide range of biosensors as well as for wearable biosensors [1]. Recently, these biosensors are used in health care monitoring to detect diseases such as diabetics, early detection of cancer and various other diseases biomarkers. This provides the way of improving the way of quality of care in health care system [2]. These biosensors provides monitoring of patients, athletes, premature infants, children, psychiatric patients, people who need long term care, they are also effective in prevention, timely diagnosis, control and treatment of diseases[3].

II.BIOSENSORS

A biosensor mainly comprises three parts theses are Bioreactor System, Transducer and an Output System [4].

Biosensors are designed to react only with a particular substance and result of this comes in form of a message that can be used by any electronic device. These are considered as receptor, communication systems based sensor can display, simulate, treat, or substitute human biophysics performance.

The use wearable devices changed this flow in recent years, and also branching from tracking physical exercise activities to focus on tackling major challenges in health care applications such as management of diabetics or remote monitoring of people. To achieve these goals/research has been done for the development of wearable biosensors that incorporate biological recognition element into sensor operation.

Also, wearable biosensors are recently increasing attention in the field of health care monitoring, to solve the health related issues fast, economic, accurately and precise for users , and also provides real time performance of athletes, or disease status of patient[5]. These devices are based on monitoring the different types of bio signals released by human beings through epidemic skin, perspiration, breath, urine, and saliva [6] as biophysical and biochemical signals. Other signals refers to physical health signals[7] such as body temperature[8], body movements[9], blood pressure[10], heart rate[11], or electrocardiogram[12], chemical health signals related to disease biomarkers includes various metabolites[13], functional proteins[14], oligonucleotides[15]. The important part in wearable biosensors are the transducers that selectively and sensitively, translate bio signals into detectable signals in detectable form. These wearable biosensors fulfills the requirement of healthcare system in terms of miniaturization, flexibility, conformability and starch ability [16]. There are several wireless biosensors proposed in past 10 to 15 years [17]-[23]. In this reference,

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In 2018[17], Ting Wang, Hui Yang, propose a " Mechno-Based Wearable Transducive Sensing for Wearable Healthcare". This Mechno-Based transduction converts biophysical and biochemical signals into mechanical signals, like pressure, strain, deflection and swelling, which are transferred into electrical or colorimetric signal. This simple design of material with micro/nanostructures enables mechno-based transducive sensing with wearability, strachability, high sensitivity and dynamic monitoring properties.

In 2017[18], Amir mehmood, Adnan Nadan proposed "A study of wearable Bio-sensor technologies and application in health care". In their study, they present technologies for two types of bio-sensors (ECG, EMG) and compare them with traditional ECG and EMG equipment. They uses SHIMMERTM wireless sensor as an example of wearable biosensor technology. This use of technology have found application for health monitoring of elderly people, chronic patients and fitness and fatigue observation.

Viewing the result of comparison between traditional and wireless sensor technology for ECG and EMG, the result shows that wireless sensor for ECG and EMG are flexible, small in size, wearable and they can be available anywhere. The power source for wireless biosensor are battery, whereas for traditional ECG and EMG are electrical wall sockets.

In 2016[19], Bargava Teja Nukala, Taro Nakano, proposed a low cost, tiny, light weight(wearable), ultra-low power, flexible Gait sensor for real time classification of patients having balance disorder vs. normal. In this study, a basic inertial measurement unit (IMU) is used to collect the gait data from 4 patients, diagnosed with balance disorders and three normal subjects, each performing dynamic gait index (DGI) test while wearing the custom Wireless Gait Analysis Sensor (WGAS). In order to perform successful classification of patients vs. normal subjects, several different algorithms are used, such as Back propagation Artificial Neural Network (BP-ANN), Support Vector Machine (SVM), K-nearest neighbors (KNN) and binary decision trees (BDT).

The result in above study shows that WGAS system with artificial neural network (ANN) can successfully detect patient with balance disorder with high accuracy and in no time. This study goals to provide physicians and with cost effective means to identify dynamic balance issue and risk fall of data collected in clinical examination.

In 2016[20], Wei gao, Hnin Y.Y.Nyein, presented "A Wearable Sweat Biosensor ". This wearable perspiration biosensor shows a real time analysis of sweat composition and provides knowledge about health information. The detection technique used in this study includes optical sensor for sweat rate and sweat pH analysis, impedance based sensor for sweat conductivity and sweat monitoring and stripping based sensor for heavy metal analysis.

In 2016[21], Fu-Kang wang, Mu-Cyuntang, develop "A wrist Pulse rate monitor using a self-injection locked radar technology "` this study detects the respiratory rates and heart rates at one meter distance using a self-injection-locked (SIL) radar and continuous wave(CW) radar to compare the sensitivity with power consumption. The pulse rate monitor construction is based on bistatic SIL radar architecture. This monitor is also used an antenna which is composed of SIL oscillator and a patch antenna, when this is attached to a band, which is worn on wrist, the antenna can monitor pulse on wrist by modulating the SILO with associated Doppler signal, further, SILO`s output signal is received and demodulated by remote frequency, discriminator to obtain pulse rate information. The study focus on using flexible electronics to provide more comfortable wearable radars for long term monitoring from vital signs and exercise tracking.

In 2017[22], Goivanni Diraco, Leone presents "A radar based smart sensor for unobtrusive elderly monitoring in ambient assisted living application". This study is done to detect both cardiorespiratory and body movements without causing discomfort. The system architecture in this study focus on micro Doppler processing, microenvironment signature and vital signs through empirical made decomposition (EMD). The result shows the radar smart sensor in multi-sensor and multi-target real life scenarios (e.g. community dwelling of older people) for detection of vital signs and clinical events.

In 2017[23], Pratibha Sharma, Newman, Carlin S. Long presented the use of wavelet transform to detect compensated and decompensated in congestive heart Failure (CHF) patient. This study provides improved health care , reduced cost and emergency hospitalization of patients with CHF by analyzing the heart and lungs sounds to distinguish between compensated and decompensated states signals from heart and lungs are analyzed using wavelet transforms to measure changes in CHF patients status from compressed and decompressed or vice-versa. The measurements are taken using a digital stethoscope and electrocardiogram (ECG) to monitor their progress in management of their disease.

Fourier, short time Fourier and wavelet transforms are examined in this study to obtain the best method to detect the shifts in status of CHF patient. Thus, the most precise result was obtain by using wavelet analysis. This wavelet transform provides better resolution, in time, for higher frequency and better resolution for lower frequency also.

III.WEARABLE DEVICES FOR PERSONAL HEALTH CARE MONITORING

In recent time, various types of wearable biosensor are in field. These have found a latest trends in the field of medicine, these are classified on basis of targets such as glucose, pH, metabolites , electrolytes from tears, saliva and sweat, another

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basis of classification is the monitoring of physiological parameters, such as temperature, stress etc.

Some recently used wireless wearable biosensors which are used for health care are shown.

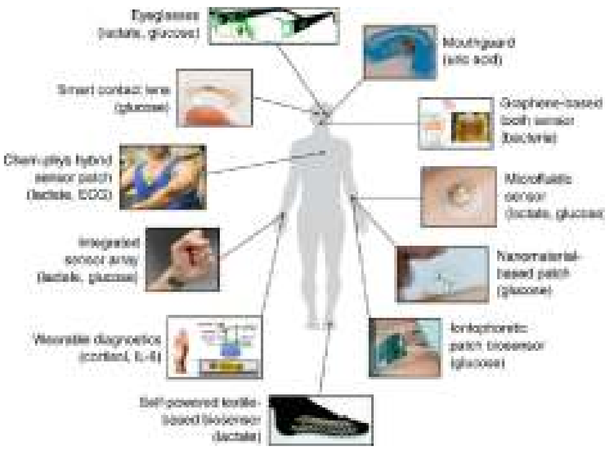

Fig 1: Types of wearable biosensors (source: https://www.google.com)

EYE GLASSES

These biosensors are capable of detecting sweat electrolytes and metabolites. This new class of biosensor consist of lactate sensor and a potentiometric potassium ion selective electrode with two nose bridge pads of glasses and interfaced them with wireless electronic device on glasses arm. The electrochemical sensor are screen printed on polyethylene terephthalate(PET) stickers on both side of glasses nose pads, in order to monitor the sweat electrolytes and metabolites.

The electronic backbone of glasses offers control of amperometric and potentiometric transducers and provides Bluetooth wireless transmission of data to host device. These glasses can also be used for sweat glucose monitoring, simply by replacing lactate bridge sensor to glucose one [24]

SMART CONTACT LENS

This type of wearable biosensor is used for measuring the amount of glucose in tears. It consist of small glucose sensor and wireless chip built into lens and two layers of lens material , the glucose sensor and wireless chip is embedded. This smart lens sensor has found main use for diabetics patients. A small pin size hole in lens allows the tear fluid to go into the sensor to measure the blood sugar level. The electronic equipment lie outside the pupil of eye and iris. Hence, there is no damage to eye [25].

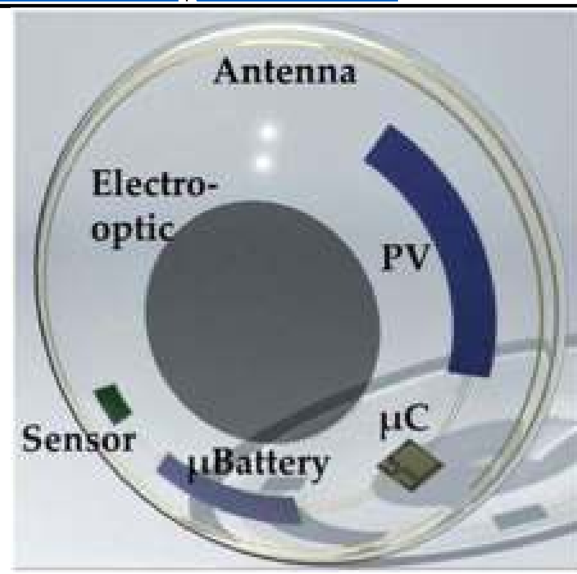

Fig 2: Smart Contact Lens Biosensor (source: https://www.google.com)

NANOMATERIAL BASED PATCH

This patch has made wireless wearable technology as one of the important route to mobile health. Patch as wearable biosensor has the ability to monitor chronic diseases. Biometric data and any disease sign is wirelessly sent and wirelessly monitored by doctors and patients via Bluetooth. This sensor is fitted to a disposable and adhesive patch and this patch is designed such that it is suitable to place on chest. This wearable sensor has the ability to gather biometric dates like Pulmonary(Sleep Duration, Respiratory rate, Sleep quality, Sleep actigraph,/ sub-posture), cardiovascular(Heart rate variability, heart rate , single lead ECG, contextual heart rate), Neurologic(Gait analysis, Fall detection, severity) and other such as step count, posture, temperature, energy expenditure, stress[26].

Fig 3: Nanomaterial Based patch biosensor (source: https://www.mepits.com/tutorial/180/biomedical/wearable-biosensors)

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MICROFLUDIC SENSOR

This type of wearable biosensor are soft, flexible and stretchable in nature, that uses wireless communication electronics, that immediately and robustly bonds to the surface of skin without chemical and mechanical irritation. The interaction of sensor with skin shows access points for small set of sweat glands. The embedded chemical analyses colorimetric markers such as chloride and hydronium ions, glucose and lactate. The results from above wearable biosensor provides the quantitative value of sweat rate, total sweat loss, pH and concentration of chloride and lactate both. One of the major advantage of this sensor is, as it can be mount at multiple locations on body, without chemical and physical interaction by making the use of biological adhesives and soft device mechanics and watertight interfaces [27].

Fig 4: Microfluidic Biosensor (source: https://google.com)

MOUTH GUARD

This mouth guard wearable biosensor offers high sensitivity, selectivity and stability towards uric acid detection in human saliva. The Salivary uric Acid (SUA) using this sensor is detected by Prussian blue/uricase/glutarldehyde/polyortrophenylendiamine platforms. The mouth guard enzyme electrode is applied for detection of uric acid (UA) which is the final product for purine metabolism. An abnormal concentration of UA is the biomarker for various diseases such as hyperuricemia, gout, leach-nyhan syndrome and renal syndrome [28].

Fig 5: Mouth Guard Wearable Biosensor (source: https://google.com)

TOOTH SENSOR

This wearable biosensor is attached with tooth enamel for the detection of bacteria in saliva. This sensor consist of graphene based electrodes and an inductive coil, antenna printed on silk thin film substrate. The dissolution of this thin-film allows attachment of biosensor to irregular surfaces of tooth enamel. The capture of bacteria by antimicrobial peptides on sensor surface results in change in conductivity of graphene film, which is monitored using radio frequencies. This sensor can successfully detect ~ 100 Helicobacter pylori in 1µl of human saliva. Wearable sensor offers sensitive, specific and detection of bacteria with wireless sensing capability [29].

Fig 6: Tooth Wearable Biosensor (Source: https://google.com)

SELF POWERED TEXTILE BASED SENSOR

These are highly stretchable, self-powered textile based sensor. The biological components such as glucose and lactate are detected using this textile based sensor. By providing the power signal proportional to sweat fuel concentration, these devices provide strechability and act as highly selective and stable self-powered textile based sensor. These skin worn "Scavenge sense display " devices contributes to skin worn systems, advance self-powered sensors and wearable electronics on a stretchable garments. The fabrication these biosensor is done by screen printing technology, which includes simple ink patterns over highly stretchable fabrics or other wearable surface accessories.

Using this process, printable electronics array on stretchable fabrics, such as socks, can be worn on human body comfortably example, in foot. As compared with other fabrication method this biosensor provides mechanical resistance, accommodates stress such as starching, scalable and free transferring steps, vacuum, clean room, high temperature and time consuming processes. This fabrication provides a wide range of soft commercial garments. This particular bioelectric socks can incorporate other sensors also, such as pressure sensor for monitoring the foot pressure for athletes or diabetics [30].

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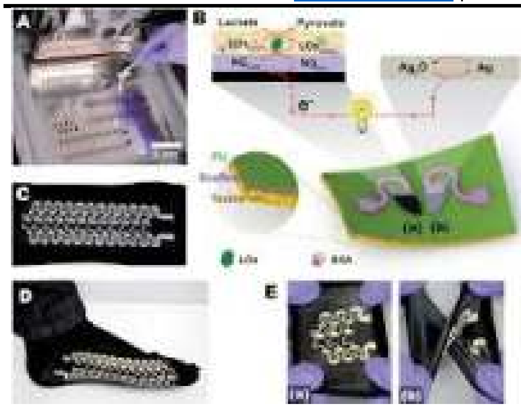

Fig 7: Self Powered textile Based Biosensor (Source: https://google.com)

WEARABLE DIAGNOSTICS

These flexible substrate based biosensor is developed to detect the level of cortisol in sweat. Cortisol is a hormone in controlling the metabolism, bone formation, immune system and its imbalance is related to psychological stress and other health related issues. This sensor consist of three electrodes on flexible polyamide substrate with porous structures. The semi conductive structures, when interacts with liquid electrolytes, formed an electrical double layer, which improves the charge storage capacity and thus sensitivity and range of electrical sensor. This sensor shows a range of 10 – 200 ng/ml and detection limit of 1ng/ml for detection of cortisol in human sweat [31].

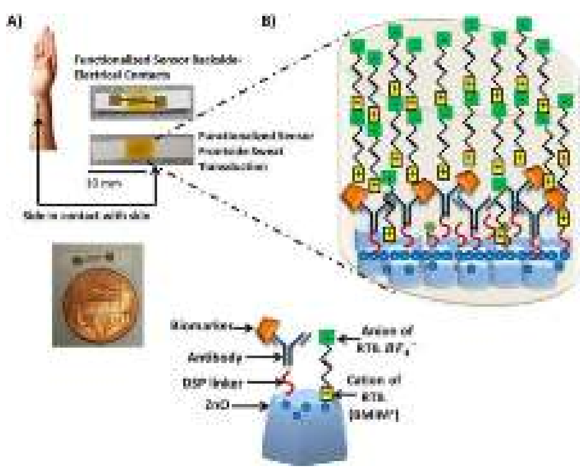

Fig 8: Wearable Diagnostic Biosensor (source: https://google.com)

INTEGRATED SENSOR ARRAY

This type of array biosensor are flexible and no external analysis is needed, hence integrated in from, which is multiplexed for perspiration analysis, which simultaneously measures sweat metabolites such as glucose and lactate and electrolytes(such as sodium and potassium ions) along with skin temperature. This wearable system measures the sweat profile of humans, engaged in long term indoor and outdoor activities and also provides real time assessments of physiological states of patients. Results from above sensor shows that excessive loss of sodium and potassium in sweat could result in hypometrimia, hypokalemia, muscle cramps or dehydration, sweat glucose is related to blood glucose, sweat lactate is marker of pressure ischaemia and skin temperature is informative for various diseases and skin injuries such as pressure ulcers[32].

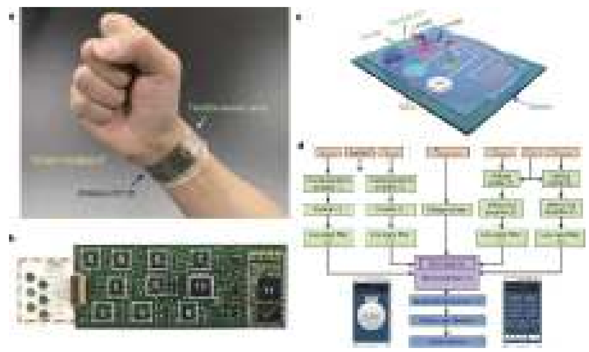

Fig 9: Integrated sensor array Biosensor (source: https://google.com)

IV. CONCLUSION

In this review, we have highlighted the importance of wearable biosensors in field of health care monitoring and some type's modern wearable biosensors. Theses sensors provide a wide range of applications, such as detection of metabolites (lactate or glucose), to the electrolytes monitoring (such as sodium, potassium or calcium) in sweat, tears, saliva. This recognition provides wearable great use for real- world applications. The process of sensing through these wearable sensors is benefited from the development of multiplexed sensing platform, improved sensing process and advancement in flexible material and wireless electronics. This increases the reliability of wearable biosensors, analyte monitoring and wearability.

We concluded that, the improved and flexible human device interface is one of the important property of these biosensors and is only possible because of the incorporation of mobile based acquisition, data analysis and result reporting without any specialized equipment. Furthermore, integration of flexible sensors into textiles with wireless communication data collection (e.g. Bluetooth technology) creates opportunity for real time, continuous on-body monitoring of physiological parameters during daily activities. Long term signal collection and data mining, is helpful for advance medical research such as diagnosis of cancer at early stage, Parkinson disease and other chronic diseases. Thus, we can say that next generation wearable biosensors will provide mobile health (mHealth) technologies and fast advancement in nanotechnologies to get

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early diagnosis and disease detection, which provides a better opportunity for humans at personal level.

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