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A Review of Materials and Components for Developing a Smart Fall Detecting System

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Abstract

Fall of patients, aged people at home when alone and also at hospitals is a critical issue. If unnoticed in time falls can be a serious issue. It causes physical injuries and psychological effects. Falls at times can be fatal than the disease that causes fall. Hence there is a requirement of development of a system which can locate, identify fall. This can be achieved by using Flexible electronics. Flexible electronics constitutes mounting of circuits on flexible substrates and their biocompatible nature is of great interest in the biomedical field. Mounting electronic components on a flexible substrate makes a smart fall detection system which is flexible, potable and cost-effective. This makes the device a wearable gadget. A detailed literature review was conducted to identify the technical specifications of a fall detector; various substrates used to make flexible equipment .The review consisted of components and materials that can be used to develop a fall detector. The review shows the components which are used to design fall detectors such as Tri-axial accelerometers, Microcontrollers, various types of Transmitting modalities, receivers and various polymers used to make biomedical devices. The various manufacturers of accelerometers were noted. The various microcontrollers used were studied in detail and noted. The various polymers on which biomedical devices can be embedded were studied and their properties such as effects of corrosion, fatigue, instability, and irritability to tissues, and also mechanical characteristics were studied. Different circuits used and Anatomical positions for mounting the device were also studied.The various manufacturers of Fall detection were noted.

Keywords: *Flexible electronics, biocompatible, wearable, polymers, Anatomical positions.*

1. Introduction

Falls are common among elderly people. Fall is an event that has occurred ever since life on Earth began. This event which is a common occurrence among humans and is a part of everyday life is known to affect the aged people more. The percentage of aged people who suffer fall because of aging is 35% for 70 year olds and 50% for 80 year olds [1]. Effect of fall varies from moderate injury to grave injuries depending upon the impact to ground or floor irrespective of the age. This leads to serious complications such as physical harm, functional disorder and fracture [2]. Number of falls is on the rise day by day in India which can be attributed to socio-economic changes. A survey carried out by Centres for Disease Control and Prevention (CDC),says that one in three adults is prone to falls each year [1*] [6]. The risk of falling is more in females than males [6]. There has been a gradual inclination in nursing costs due to falls. From a study carried out in 2000, estimated annual costs of $16 billion to $19 billion was spent annually on injuries due to fall which were nonfatal [2]. In United States alone there was an increase in the number of deaths due to fall from 29 to 41 per 100,000 populations between 1999 and 2004[2]. Effects of fall are not just physical but also psychological. Individuals who have a history of fall have higher risk of fall in future than individuals who do not have fall history. The falls result in sustained psychological effects (fear, increasing dependence) [6]. Falls which go unnoticed in hospitals are more when the person goes to toilet. Device which can solve this complexity is in need and hospitals can purchase such devices when they are of low cost.

Developing a low cost fall detection system that is wearable and less intrusive for the patient is the need of the hour. The system should have the capability to not only detect fall but also send a signal to the concerned at the time of eventuality. Various public and private institutes and research bodies have been investing considerable amount of time and money on a system that will be able to find out the characteristics of fall and how best to avoid them. This system is also known a Personal Emergency Response System (PERS).

Fall detection systems can be classified into three types [4] [5][27]

a. By using wearable sensors.
b. By using ambient sensors.
c. By image processing technique.

1.1 Flexible Electronics, Fabrication Technologies of Flexible Circuits And Application

Flexible electronics is a combination of flexible plastic substrates and electronic circuits. Polymers such as PDMS, PMMS or other polyester films are embedded with electronic circuits. These circuits can are often mounted on the flexible plastic substrates.

1.1.1 Flexible, Transparent Electronics for Biomedical Applications [7]

The fabrication and integration of flexible biocompatible electronics is of great interest in the biomedical field. Electronic and fluidic based monitoring and therapeutic platforms can be mould into comfortable, low profile devices suitable for implanting in the body or for wearing on the body or in clothing. Truly integrated bioflexible devices would incorporate electronics, optics, photonics, wireless, fluidics, mechanical components, and power systems on a single flexible biocompatible substrate. Continued development of applications of this technology requires further development of biocompatible, flexible films with integrated electronics which can be mass produced at low cost. Basically, flexible electronics deals with circuits developed using Thin Film Transistors (TFT) [8].

1.1.2 TFT technologies

Different TFT technologies are available today to develop circuits. A. Amorphous Silicon Technology B. Polysilicon Technology C. Organic Thin Film Transistors D. Single Crystal Silicon on Flexible Substrates E. Mixed Oxide Thin Film Transistors. F. Hybrid (CMOS) Technology.

2. Introduction to Polymers

A polymer is a large molecule, or macromolecule, composed of many repeated subunits.Polymers are present all around us — from the basic building blocks of life constituting of proteins, nucleic acids, to the commercial products obtained.

2.1 Polymers in Biomedical Applications

The advent of medical-grade silicone rubber in 1952 prompted emphasis on the search for improved polymeric materials for use within the body [11]. Scientists around the world have performed numerous experiments to investigate these compounds. A completely adequate compound in one particular situation may be useless or harmful in another. In spite of varying drawbacks, a number of polymers have been employed with remarkable success in biomedicine.

A definite criterion for the selection of a particular polymer to be used in a biomedical electronic device is not generally available. Critical aspects, such as corrosion, fatigue, instability, and irritability to tissues, force the designer to draw primarily upon empirical in vivo experience [11]. The selection of polymers, with regard to properties and optimum methods of handling, is crucial to satisfactory performance at or within the boundaries of the living organism.

A review of at the different polymers used in biomedical applications is necessary to determine the merits of a particular polymer that may be used . Few of the polymers used are listed in Table 1

Table 1 Medical Uses of Polymers, In Vivo [11]

Polymers	(Numbers refer to key below.)
Adhesives for tissue repair	10, 11, 17
Augmentation (mammaplasty, rhinoplasty)	3, 7, 8,16, 17
Cranioplasty and dural substitutes	5, 6, 8, 11, 14, 16
Encapsulation of electronic devices	3, 4, 11, 13, 17
Ocular prostheses	7, 8, 11, 17
Orthopedic prostheses	3, 5, 8, 11, 13, 14
Prosthetic heart valves	4, 7, 8, 9, 12, 14, 17
Tissue replacement	5, 7,8, 14, 16, 17
Tracheoplasty and duct replacement	5, 7, 9, 12, 14
Vascular prostheses	1, 2, 4, 5, 6, 11, 12,14, 15, 16

Key: 1. Acrylic rubber; 2. Chlorosulfonated polyethylene;3. Epoxy; 4. Natural rubber ;5. Polyamide; 6. Polycarbonate;7. Polyester; 8. Polyethylene ;9. Polyimide ;10 Polymethyl 2-cyanoacrylate; 11. Polymethylmethacrylate(PMMA)12. Polypropylene 13. Polystyrene 14. Polytetrafluoroethylene 15. Polyurethane 16.Polyvinyl alcohol 17. Silicone rubber.

Apart from the above polymers Polydimethylsiloxane (PDMS) and Polyvinylidene fluoride (PVDF) are also used in biomedical devices. Applications of few polymers have been reviewed.

Polymethylmethacrylate (PMMA)

Application : Polymer-based Fabrication Techniques for Enclosed Microchannels in Biomedical Applications [12]. Analysis of body fluids like whole blood or serum are necessary in biomedical research to understand and determine the diseases, to perform pharmacological tests or to culture cells. Therefore, microfluidic systems is a favorable tool for processing body fluid samples. They allow using very small volume of fluids for analysis. Therefore, simple fabrication techniques have been engineered for systems with microchannel.

Table 2 Overview of Polymethylmethacrylate(PMMA**)** [13]

Trade names , acronym	Plexiglas, Lucite ,PMMA,
Class	Vinylidene polymers; acrylics
Properties	In visible wavelength PMMA is optically clear; ultraviolet absorption is minimal up to 260 nm. Desirable mechanical properties. Sensitivity is very high to electron radiation.
Applications	Used as substitute for glass. Used as resists in the fabrication of microelectronics chips

Poly(pyromellitimide-1,4-diphenyl ether)

Implantable Biomedical Microsystems for Neural Prostheses[14].German scientists have introduced a new concept for biomedical microsystems as neural prostheses. Polyimide is the chosen material. It has been proven to be a nontoxic material in biomedical applications and has already been used for neural implants.

Table 3 Overview of Poly(pyromellitimide-1,4-diphenyl ether) [13]

Trade names, acronym	Kapton, Vespel, Apical ,ODA-PMDA, PMDA-ODA
Class	Polyimides; high-performance polymers
Properties	Kapton Films have exceptional thermal stability, at variable temperature range it displays useful mechanical properties, excellent electrical properties and stability at varying humidity, not sensitive towards solvents, outstanding radiation resistance.
Major applications	Kapton films are used as cable wrap and wire, ,liners in motor-slot , substrates for flexible printed circuit boards, as insulators in thermal and electrical applications.

Polydimethylsiloxane

PolyDimethylsiloxane (PDMS) .PDMS is a Si based organic polymer that has found wide applications in MEMS and microfluidic device fabrication, soft lithography, contact lens manufacturing and device encapsulation [15]. PDMS is optically transparent, viscoelastic, chemically and thermally stable, highly flexible, hydrophobic and can easily be modelled with high resolution and aspect ratio. These unique properties of PDMS allow for high resolution moulds to be prepared from photolithographically defined substrate.

Table 4 Overview of PolyDimethylsiloxane (PDMS) [13]

Trade names, acronym	Dow Corning® 200fluid; PDMS;poly[oxy(dimethylsilylene)];
Class	Polysiloxanes; di-methyl silicones and siloxanes.
Properties	Physiological inertness and Hydrophobic. Thermal stability and Shear stability. Minimally affected by temperature. High resistance to UV radiation. Excellent release properties and surface activity.
Major applications	Biomedical devices, rubber molds, surfactants, water repellents, adhesives.

3. Components Required

3.1 Triaxial accelerometer

Accelerometer-Single and multi-axis models of accelerometer are are utilized to determine direction and magnitude . The direction of the acceleration is measured as vector quantity . They provide information regarding shock, vibration and falling [20]

ADXL335

The ADXL335 is a low powered accelerometer compassing 3 axis. The device is provides analog output which is proportional to acceleration. ADXL335 can measure dynamic as well as static tilt-sensing acceleration due to gravity [17].

LIS331EB

LIS331EB is a smart sensor system which consists a tri-axial accelerometer. This system is integrated with Cortex-M0 core which includes 64 KB Flash, 128 KB SRAM and 8 dual timers. Additional to sensing, the system acts as a sensor hub. For example, inputs from the gyroscopes, accelerometer, pressure compasses, and various sensors is communicated through the master I2C and elaborates/fuses together 9 or 10 axes (iNemo Engine software) to provide quaternions to the main application processor[24].

MPU-60X0

The MPU-60X0 Motion Processing Unit provides motion processing solution. It is integrated with a 9-Axis sensor fusion. This sensor can be used in game controllers,

Table 5 Comparison of the ADXL335, LIS331EB and MPU-6000/MPU 6050

Parameter Name	ADXL335	LIS331EB	MPU-6000/MPU-6050
Make	Analog Devices	ST Microelectronics	Inven Sense Inc
Operating Voltage	1.8V to 3.6V	1.8 - 3.3,	2.375 to 3.46
Max acceleration-	10000g	10000 *g*	10,000 g
Temperature Range	(Powered) −55°C to +125°C	-40 to +85	-40 to +85
Additional features	Excellent temperature stability	Single chip consisting of accelerometer and Signal processor	Single chip consisting of accelerometer and gyroscope

Table 6 Comparison of the ATmega32 and PIC16F87XA

Parameter Name	ATmega32	PIC16F87XA
Architecture	Harvard architecture	Harvard architecture
Pins	40	40
Pipelines	2-stage, single-level pipeline design	2-stage pipeline
Operating Voltage	4.5V - 5.5V	5V
Clock Speed	16MHz	20MHz

handset and tablet applications, motion pointer remote controls, and other consumer devices. The MPU-60X0 consists embedded 3-axis MEMS gyroscope, 3-axis MEMS accelerometer, and a Digital Motion Processor™ (DMP™) [25].

3.2 Microcontroller

PIC16F877A by Microchip is a 8 bit microcontroller [18]. It has a inbuilt analog to digital converter.

ATmega32 [26] is a 8-bit microcontroller. The Atmel ® AVR® AVR core combines a rich instruction set with 32 general purpose working registers.

Table 6 gives the Comparison of the ATmega32 and PIC16F87XA.

3.3 GPS Receiver

The Global Positioning System (GPS) is a navigation system depends on a satellite which is in outer space. It provides information regarding time and location irrespective of different weather conditions. anywhere on or near the Earth where there is an unobstructed line of sight to four or more. GPS satellites require a clear visual path to provide the data of areas in and near the earth.

3.4 GSM Modem

SIM300 V_7.03 is GSM modem used.

- Operates at 5V , the board on which it is mounted is designed for 7-12V supply.
- Current – 2A
- Through RS232 serial port it is interfaced with microcontroller.

3.5 Wireless Protocols

Under this section we review the different wireless protocols namely Bluetooth, UWB, ZigBee, and Wi-Fi .

3.5.1 Bluetooth[21]

Bluetooth, also known as the IEEE 802.15.1 standard. This wireless technology is a standard for communicating data from one to device to another. Exchange of information occurs between fixed devices and mobile devices and also computer peripherals.

3.5.2 UWB [21][22]

Ultra-wideband protocol is used in case of indoor short-range high-speed wireless communication. Its bandwidth is over 110 Mbps (up to 480 Mbps) which has the capability to satisfy audio and video delivery in home networking. Ultra-wideband characteristics are well-suited to short-distance applications, such as PC peripherals. UWB is used for real-time location systems; its precision capabilities and low power make it well-suited for radio-frequency-sensitive environments, such as hospitals.

ZigBee Transceivers [21][22]

3.5.3 ZigBee

This communication protocol is used for low power wireless communication over long distances. ZigBee is based on an IEEE 802 standard. ZigBee is a specification for various high-level communication protocols used to create personal area networks built from small, low-power digital radios. Typical application areas include[23]:. In case of domestic purpose they are used in smart lightning, temperature control and for purpose of entertainment.

Table 7 Comparison of the Bluetooth, UWB, Zigbee, And Wi-Fi Protocols [21]

Wireless Protocols	IEEE standards	Frequency band
Bluetooth	IEEE 802.15.1,	2.4GHz
UWB	IEEE 802.15.3 a	3.1-10.6 GHz
ZigBee	IEEE 802.15.4 a	868/915MHz; 2.4 GHz
Wi-Fi	IEEE 802.11 a/b/g	2.4 GHz; 5GHz

Table 8 Performance Comparison of Detection Test [28]

	False Negative(%)		False Positive (%)	
Anatomical Position	Forward Falls	Lateral Falls	Backward Falls	Other Activities
Chest	1.2	2.3	5.0	11.2
Waist	2.6	3.3	2.1	8.7
Thigh	1.0	10.0	2.2	11.0

3.5.4 Wi-Fi[21][22]

Wireless fidelity (Wi-Fi) includes IEEE 802.11a/b/g standards for wireless local areanetworks (WLAN). It allows users to surf the Internet at broadband speeds whenconnected to an access point (AP) or in ad hoc mode [21]. Wi-Fi allows cheaper deployment of local area networks (LANs).Wi-Fi Protected Access encryption (WPA2) is considered secure, provided a strong passphrase is used.

4. Anatomical Position

Group of researchers have performed the fall detection test using mobile phones[28]. The data collection involved 15 participants. The collection has a set of 450 falls covering all the possible directions and environment. Chest, waist and thigh are the anatomical positions selected for measurement of the fall detection performance. For the purpose of analysis terms false positive (FP) and false negative (FN) are used. When there is a fall but the device does not indicate fall then it is false negative. If the device indicates a fall when in reality fall has not occurred then it is false positive.

In general, the lower the both FN and FP are, the better the performance is. When phone was placed on waist the average FN value was 2.67% and the FP value was 8.7% thus it is the best position to place the phone. From these tests it is clear that system when placed around the waist provides a more accurate fall reading than any other anatomical position.

Conclusion

There are various fall detection systems which perform well for the detection . Among the various kinds of fall detection systems few of them are wearable type , but these systems are cumbersome to the user and are not flexible. In order to develop a flexible and wearable fall detection systems authors propose polymer based system. A detailed review of various polymers used in biomedical devices was undertaken. The review also consisted of components that can be used to develop a fall detector. A comparison between different Triaxial accelerometers, Microcontrollers, various types of Transmitting modalities, receivers , wireless protocols various polymers used to make biomedical devices is put forth. The various manufacturers of accelerometers were noted. The various polymers on which biomedical devices can be embedded were studied and their properties such as effects of corrosion, fatigue, instability, and irritability to tissues, and also mechanical characteristics of suitable were studied. Anatomical positions for mounting the device were also studied in detail .

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