MEMS based sensor for Blood group Investigation

Sushmita Katti[1], Pooja Naragund[2],Vaibhavi Saradesai[3]
Pyati Vidhyashree[4], Kaushik M[5], Anilkumar V Nandi[6]
Vaishali B Mungurwadi[7]
[1][2][3][4][5] Department of Instrumentation Technology
[6] Professor, Department of Electronics and Communication
B.V.Bhoomaraddi College of Engineering and Technology, Hubli,Karnataka, India
[7] Principal, Sarvajanik college of Engineering, Surat, Gujarat,India
Sushmitakatti046@gmail.com,poojavn11@gmail.com,vaibhavisaradesai01@gmail.com,
pyatividhya@gmail.com, Kaushik@bvb.edu, anilnandy@bvb.edu, vaishalibm@yahoo.com

Abstract- This article describes the design of MEMS based cantilever structure intended for determination of blood group and compared with manual method. Cantilever structure design has a sensing layer(2,4-Dinitrophenol) and when a blood sample comes in contact with this layer, it results in coagulation . in turn surface tension occurs due to chemical and biological reactions of antigen and antibodies resulting in coagulation on the surface of the three cantilever beams of a structure. This surface tension(surface stress) leads to deflection of beam. In our simulation this stress is applied to the structure to study the sensor action. The deflection is inversly proportional to applied stress. The surface stress on cantilever makes it to bend and this deformation helps in determination of blood group along with the RH factor. The structure of this sensor is designed and simulated using COMSOL multiphysics 4.2 software.

Keywords: MEMS, COMSOL, Blood group determination, sensor

1. Introduction

Blood is specialized body fluid that has four main components namely Plasma, Red Blood Corpuscles (RBC), White Blood Corpuscles (WBC) and Platelets. The exterior portion of RBC consists of antigens and plasma consists of antibodies. Antigens play vital role in determining the blood group. The antigens and antibodies are combined specifically with each other. This interaction between them is called as Antigen-Antibody (Ag-Ab) interaction. These reactions form a basis for existence of different types of blood groups. The reaction between Ag-Ab occurs in three stages. The first stage reaction involves formation of Ag-Ab complex, the second stage leads to visible events like precipitation, agglutination while the third stage includes destruction of Ag or its neutralization.

Salient feature of Antigen-Antibody reaction is the specificity of Ag-Ab reaction. It refers to the ability of an individual antibody combining site to react with only one antigenic determinant for example the antibody produced against kidney antigen will react with only kidney antigen,like a specific lock can be opened by its own key. Similarly one antibody can react with its own antigen only.

An immune complex is formed from the integral binding of an antibody to a soluble antigen. The bound antigen acting as a specific epitope, bound to an antibody is referred to as a singular immune complex.

$$Ag + Ab \longrightarrow \text{Ag-Ab complex}$$

During Antigen-Antibody reaction, the antibody attaches with antigen. The part of antigen which combines with antibody is called epitope. An epitope, also known as antigenic determinant, is the part of an antigen that is recognized by the immune system.

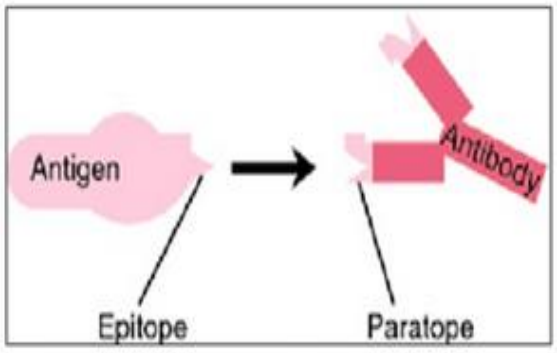

Figure 1. Binding site of Epitope and Paratope

The part of antibody that recognizes the epitope is called a paratope. The binding between antigens and antibody in Ag-Ab reaction is due to three factors namely closeness between antigen and antibody, non-covalent bonds or Intermolecular forces, affinity of antibody. Refer figure1.

Organization of the paper is as follows, Section 2 deals with the details of literature survey carried out, Section 3 discusses engineering design

process adopted during project execution, Section 4 provides detailed design followed with results and conclusion.

2. Literature survey

MEMS based sensors designed for detecting and sensing specific bio-molecules at low concentration depends upon analyte molecules. The work in [1] describes the design of a micrometer sized cantilever beam used as biochemical sensing in ambient temperature. The sensitivity was due to its properties of low flexural resistance, mechanical response to change in surface stress.

A bio-molecular reaction takes place on the surface of the cantilever beam and can be monitored by its deformation as an effect of changes in the surface stress. For bio-molecule recognition, cantilever structure was prepared by depositing a sensitive layer that senses bio-molecules usually proteins, antigen or antibodies.

Most of cantilevers designed for the applications of disease detection depend on optical readout which is a bit complex and difficult to fabricate. However authors in [1] proposed a simpler design that gives electrical signal that can be measured easily. This same new readout method is utilized in our project for blood group determination

Authors in paper [2] present a new approach for blood group testing. The paper describes development of prototype which is capable of performing the tests necessary for a safe blood transfusion automatically. The determination of 'ABO' and 'Rh' blood type was performed in tube, plate, micro-plates or gel centrifugation.

A methodology was developed regarding the pre-transfusion tests for determining the 'ABO' and 'Rh' type, based on the plate test and image processing techniques. This device automates the reading, centrifugation and interpretation of results of all the pre-transfusion tests. It is of 30cm height and 10-5 cm of diameter, it also has 6 plates and AC motor for mixture and centrifugation. The proposed system shows to perform the centrifugation in a simple approach. After separating the blood and obtaining the plasma, six slides were considered to test each of the phenotypes. On each slide the respective reagents and the blood of a patient were added. An image of the sample was acquired and sent to the computer for further processing. The presence or absence of agglutination in each sample was determined through image processing technique which is done by comparing the original images using image processing, and hence blood group determination was done [2].

The authors in [3] discussed about determination of blood glucose concentration, monitoring a valuable diabetes self management tool, which enables to check the blood glucose level as often as we need. Self monitoring blood glucose testing systems are essential in control of diabetes. The test system is used at home to measure the amount of glucose in the blood. This paper describes the design of a blood glucose sensor using COMSOL software [3].

3. Methodology

The objective of the work is to determine the blood group of a person instantaneously using the kit which should be portable, relatively inexpensive, environmentally benign and durable in addition to the attributes of safety, eco friendly, quick result, flexibility, economy, invitro, portable and durable by considering the size of cantilever beam, type of needle, cost and layer sensitivity as constraints. The functions of this design include antigen antibody reaction, after the serum is added to the blood, coagulation taking place due to chemical reactions, deflection of the cantilever due to surface stress and as there are three sensing layers present, depending on the surface strains and deflection, blood groups A,B,AB,O can be determined.

The graphical representation of objectives of a design can be expressed in the form of objective tree. It helps us to get the clear idea of all objectives which are important and also to know the relationship between them. Refer figure 2

Pair wise comparison generally refers to any process of comparing entities in pairs to judge which of each entity is preferred, or has a greater amount of quantitative property. The method of pairwise comparison is used in the scientific study of preferences This is often used as part of process of assigning weights to the objectives in design concept development as shown in table 1.

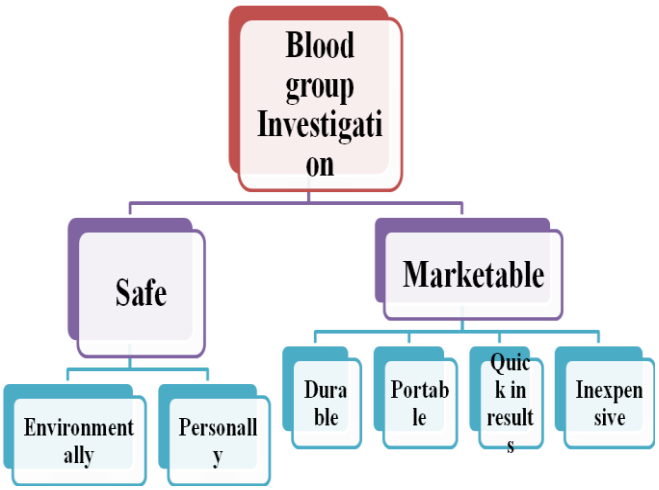

Figure 2. Objective tree

Table 1. Pair-wise Comparison Chart

Obj.	1	2	3	4	5	6	Score
1	--	1	1	0	1	1	4
2	1	--	1	1	0	1	4
3	0	0	--	1	1	0	2
4	0	1	1	--	0	1	3
5	0	1	1	1	--	1	4
6	1	0	1	1	0	--	3

The simplest form of a functional structure of a product is represented as the overall function diagram. This is commonly referred to as a "black box" and presents the overall function of the product along with inputs and outputs to the system, which can include flow of energy, materials, and information from/to the system surroundings. The sub- functions will not appear in this diagram. Refer fig3

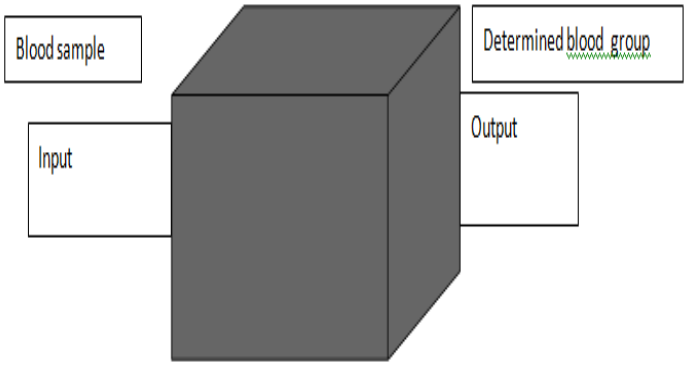

Figure 3.Black box model

White-box testing is a method of testing product that tests internal structures or workings of an application, as opposed to its functionality (i.e. black-box testing). In white-box testing an internal perspective of the system is used to design test cases. The tester chooses inputs to exercise paths through modules and determine the appropriate outputs.

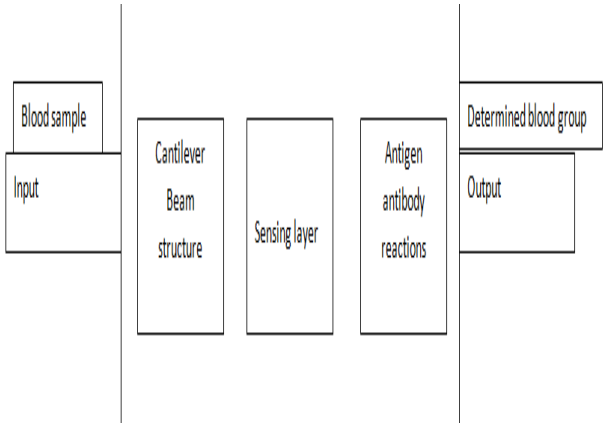

Figure 4. Transparent model

4. Detailed design

COMSOL Multiphysics 4.2 is an element analysis, solver and simulation software package for various physics and engineering applications. MEMS systems are designed mostly for detecting and sensing specific bimolecular at very low concentration. The sensing principle varies according to the device, the nature of the molecules and the precision required. Micrometer sized cantilever devices can be used as very sensitive and simple sensors in ambient environment.

The structure of blood group determining sensor is designed and simulated using COMSOL 4.2 software. The results are based on deflection of the cantilever. The deflection occurs because of the surface tension on cantilever, the surface tension in turn occurs due to chemical and biological reactions of antigen and antibodies resulting in coagulation on the surface of the three cantilevers. The structure of the blood group detection sensor and its dimensions are shown in fig.5.

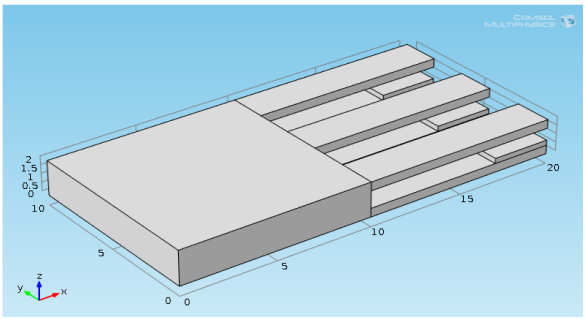

Figure 5. Structure of blood group detection sensor

The steps carried out in designing structure for blood group detection sensor in COMSOL 4.2 are as follows:

Step 1: Selecting physics: It includes Selecting 3 dimensional models, Solid mechanics, and Structural mechanics.
Step 2: Defining geometry: In model builder, right click on geometry and select blocks, cantilever blocks.
Step 3: Defining materials: Right click on material browser and select materials for all the blocks. After fixed constraint, right click on solid mechanics and apply boundary load on the three cantilevers. Apply total pressure of 0.001N/m^2

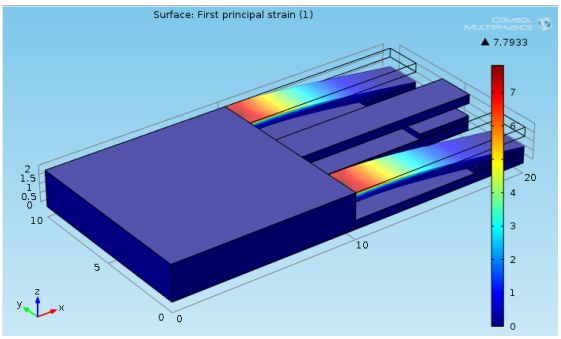

Figure 6. A+ blood group

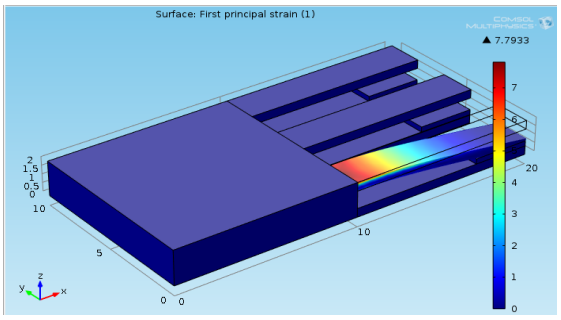

Figure 7. A- blood group

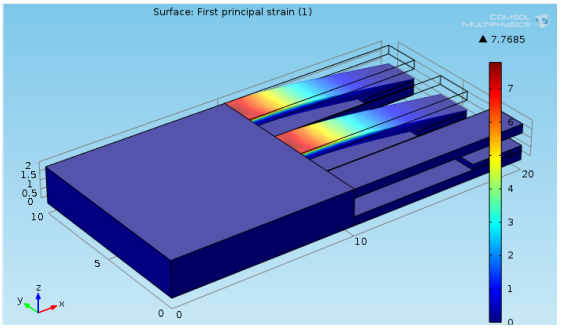

Figure 8. B+ blood group

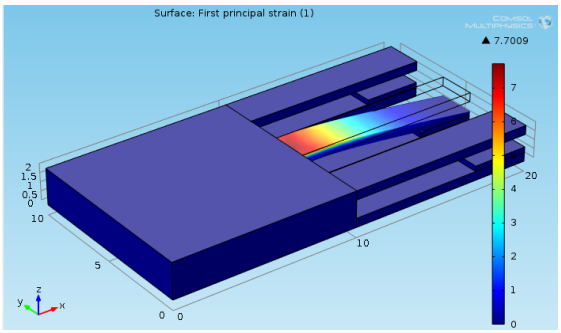

Figure 9. B- blood group

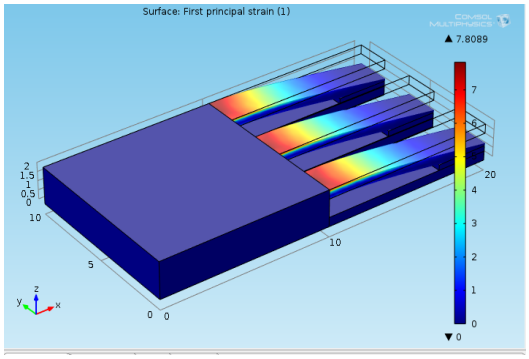

Figure 10. AB+ blood group

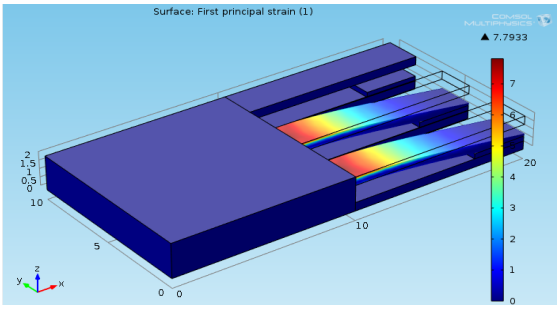

Figure 11. AB- blood group

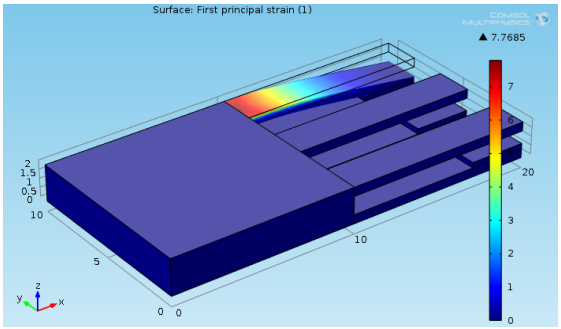

Figure 12. O+ blood group

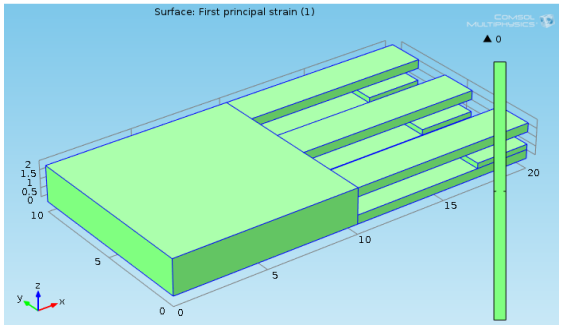

Figure 13. O- blood group

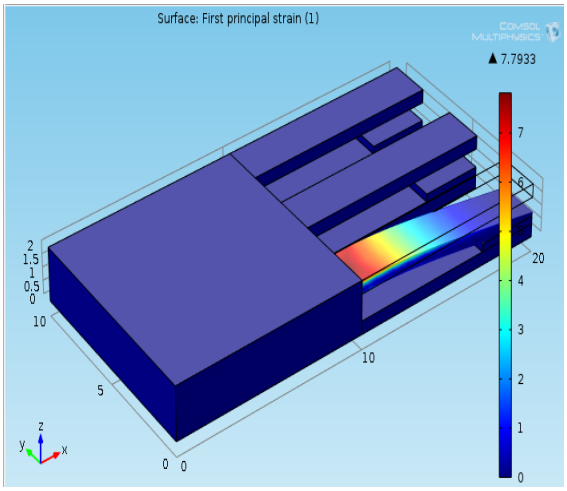

Figure 14.Deflection of A(-Ve) blood group

5. Results and conclusion

Table 2. Table showing stress variation against deflection in A(-Ve) blood group

Stress	Deflection
0.01	0.7
0.02	0.5
0.03	0.4
0.04	0.3
0.05	0.2
0.06	0.1
0.07	0

For applied stress in 3-D model of cantilever beam the corresponding variation in the deflection can be seen in the table 2. The deflection is inversely proportional to the applied stress. As the deflection changes the cantilever beam acts as variable capacitor. The change in the distance (deflection) is responsible for change in the capacitance. To measure this capacitance there need to be Kelvin's bridge which has one variable capacitor and three fixed capacitors. Using this Kelvin's bridge we can measure the voltage. The output is indicated through LED's which gives the digital output from which particular blood group is determined.

Table 3.The digital outputs to indicate the type of blood group

Blood group	First cantilever	Second cantilever	Third cantilever
A positive	1	0	1
A negative	1	0	0
B positive	0	1	1
B negative	0	1	0
AB positive	1	1	1
AB negative	1	1	0
O positive	0	0	1
O negative	0	0	0

The project describes automatic method of blood group detection and this model is designed using COMSOL multiphysics 4.2.The type of blood group is determined in the form of digital output.

References

[1] Jayu.P.Kalambe and Rajender M Patrikar,"Design of micro cantilever based bio-sensor with digital feedback control circuit", by Department of Electronics Engineering,Visveswaraya National Institute of Technology,Nagpur, Maharashtra ,India..

[2] Ana Ferraz, Filomena soares, "A prototype for blood typing based on image processing", R & D centre, Algoritmi, University of Minho, Portugal.

[3] Stephen A, Mackintosh, James I, Rodgers, Stephen P, Blythe, "Modeling an Enzyme Based Electrochemical Blood Glucose Sensor", Lifescan Scotland Ltd, Inverness, IV2 3ED, Scotland.

[4]. Priyadarshini, Ramya, kalayvarasi, kalpana, suthathira,"A Novel approach in identification of blood group using laser technology", Tamilnadu India.

[5]. Danial.L.Harp, "Current technology of chlorine analysis for water and waste water"