

İTÜ



# Team Results Document

## Beeomarkers



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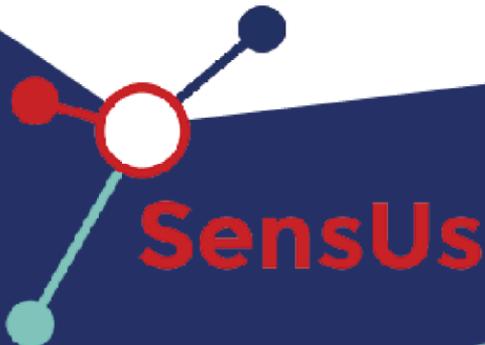
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SensUs 2023  
Traumatic Brain Injury

## 1. Abstract

Traumatic brain injury (TBI) is a disease that occurs by the damage to the neurons in the brain, and it is one of the biggest health problems in the 21st century. The most common cause of traumatic brain damage is a severe blow or jolt to the head or body. Today, TBI is diagnosed by using magnetic resonance imaging (MRI) and computed tomography (CT), however, these methods are time-consuming, very expensive and are not able to detect mild TBI. Here in this study, we offer a novel biosensor approach that uses the principle of gold nanoparticles' plasmonic properties to detect glial fibrillary acidic protein (GFAP), which is the biomarker of TBI. In addition, we offer a mechanism that simply, rapidly and cheaply detects 96 samples in a spectrophotometer at the same time. In comparison to conventional methods like CT and MRI, our biosensor is advantageous considering some limitations such as patient restrictions, radiation exposure, etc.

**Key Words:** Gold nanoparticles, traumatic brain injury (TBI), glial fibrillary acidic protein (GFAP), biosensor, plasmonic, immunoassay

## 2. Biosensor System and Assay

In this project, we decided to use the plasmonic features of the gold nanoparticles for GFAP detection. Since metallic nanoparticles have plasmonic features, it is very advantageous to use them for biosensors. Strong localized surface plasmon resonance (LSPR) is present in these metallic nanoparticles, which enhances light scattering and absorption at particular wavelengths (Yguerabide & Yguerabide, 1998; Jain, Lee, El-Sayed, & El-Sayed, 2006). Furthermore, changes in the nanoparticles' size, shape, and composition allow for easy tuning for maximal sensitivity as an optical label (Huang, Neretina, & El-Sayed, 2009). Unlike fluorescent dyes which are very common in cellular biomarker analysis, metallic nanoparticles are not affected by photobleaching. And they are highly water soluble and nontoxic in comparison with other nanoparticles such as quantum dots (Wax & Sokolov, 2009). Additionally, metallic nanoparticles offer a large surface area for conjugation with targeted molecules such as proteins, antibodies, and aptamers as well as small molecules to increase their biocompatibility in physiological settings (Rosi & Mirkin, 2005). Among all the nanoparticles, gold nanoparticles are the most preferred ones for biological samples due to their unique properties (Jans & Huo, 2012). AuNPs' LSPR is in the visible and near-infrared spectrum. The ability to identify AuNPs with the naked eye or with low-cost colour cameras is made possible by the significant visible light absorption and scattering, which enables colourimetric bioassays and bioimaging (Aldewachi et al., 2018; Chang et al., 2019). In addition to that since there are 96 wells in one plate, therefore, our system is able to detect 96 samples in one run which significantly decreases the time range. To increase the efficiency of our biosensor, the immobilization of gold nanoparticles was followed by PEG treatment on the surface. PEG linkers are found to discard the non-specific adsorption and absorption hence increasing the overall sensitivity of the biosensor system (Lakshmipriya et al., 2013). In our biosensor system, the incorporation of a PEG linker into the system was done for increased sensitivity.

## 2.1. Molecular Recognition and Assay Reagents

The biosensor incorporates a configuration employing gold nanoparticle immobilized Poly-L-lysine(PLL) coated polystyrene surfaces within a 96-well plate. The covalent attachment of the PEG linker (Thiol-PEG-NHS) on gold nanoparticles (AuNPs) further enhances the sensor's sensitivity.

**Polymers and Surface Treatment** For the substrate, PLL polymers were utilized to coat polystyrene surfaces. PLL was diluted in ultrapure water to create a stable coating for the polystyrene surface to further immobilize the gold nanoparticles on the surface.

**Gold Nanoparticles (AuNPs) and Immobilization** AuNPs, crucial to our biosensor design, were immobilized onto the PLL-treated surface. 60 nm-sized gold nanoparticles were employed. The electrostatic interactions between the positively charged PLL layer and negatively charged AuNP provided the layers of the biosensor system. The plasmonic properties of gold nanoparticles differed and resulted in shifts at absorbance values and red-shift of the spectrum peak.

**PEG Linker Attachment and Antibody Conjugation** Immobilized AuNPs were coupled with PEG-linkers to establish a robust and oriented immobilization of the antibodies. The linker facilitated efficient interaction between the antibodies and the AuNPs, enhancing the sensor's binding efficiency and response. PEG linker in dimethyl sulfoxide (DMSO) was used to covalently attach the antibodies to the gold nanoparticles. To recognize the target analyte (GFAP), antibodies in PBS were employed as the molecular recognition element. Due to the complications on the arrival (late delivery) of the GFAP antibodies, an alternative antibody which was present in our laboratory was used for the optimization steps prior to the anti-GFAP conjugation. The successful conjugation of antibodies was achieved through an NHS ester reaction chemistry. This ensured the stable binding of antibodies to the nanoparticles, preventing detachment during subsequent assay steps. The immobilization of antibodies on the PEG-linked AuNPs was finely tuned, guaranteeing maximal accessibility and specificity towards GFAP.

## 2.2. Physical Transduction

The biosensor is based on optical principles. Gold nanoparticles have specific wavelengths according to their morphological properties such as size and shape. By their localized surface plasmonic properties, AuNPs can be used with the detection methods (Ferrari, 2023). The analyte solutions are incubated with surface-functionalized AuNPs immobilized on PLL-coated well plates. After the recognition occurs between the antibody and the biomarker protein, there would be a measurable change in the peak wavelength of the spectrum, which is correlated with the analyte concentration. The shift at the peak wavelength of AuNPs is detected by a custom-made (Beomarker's) spectrophotometer system.

## **2.3. Cartridge Technology**

In our pursuit to create a disposable platform that effectively processes the sample fluid, we opted for the utilization of widely recognized well plates commonly employed in laboratory settings. The sample fluid containing the target analyte is introduced into the multiple individual wells. Sample pretreatment, dilution or preconditioning is not required as the PEG linkers attached to AuNPs prevent non-specific molecule adsorptions.

## **2.4. Reader Instrument and User Interaction**

This system is dedicated to the development of an advanced absorbance spectrophotometer system, augmented with a diffraction grating, for the comprehensive analysis of GFAP solution absorption properties. By subjecting GFAP samples to light and detecting absorbed light through the integration of a diffraction grating and CCD sensor, we aim to unravel intricate absorption behaviors.

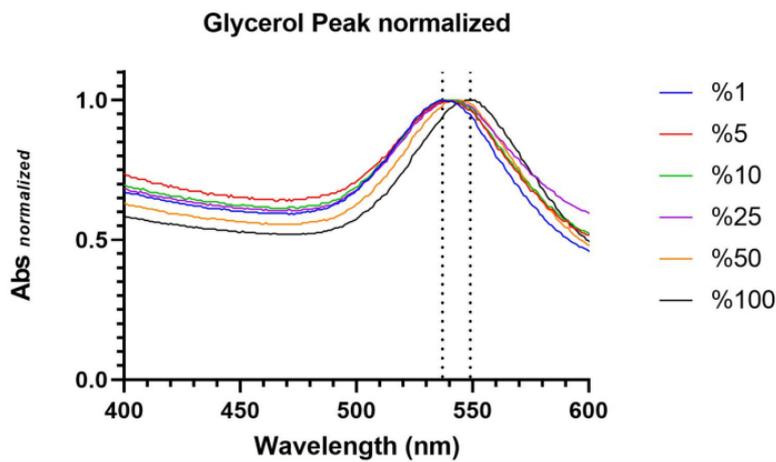
The system harmoniously combines a 540 nm LED light source, a precision mechanical assembly for well plate positioning, and the spectrophotometer, all managed through an intuitive interface for efficient data processing. This innovative approach promises deeper insights into the samples' absorption characteristics, offering valuable information for unraveling their biochemical traits and potential applications.

The device's cover is opened, and an empty well plate is inserted into the apparatus. Following the completion of the calibration process, the well plate containing previously prepared samples is placed into the device, and the device is initiated. Subsequently, the initial measurement is conducted using the software interface. The user can take measurements by selecting one well or multiple wells then calibration measurements are carried out for each selected well. After the user positioned the well plate, they click on the "Filled Measurement" option, thus obtaining measurements for each selected well. The results of the batch measurements are stored in an Excel file. If just one well is selected, the outcome is displayed on the "Result" screen. Measurements for both empty and filled wells are saved on the local disk for each well. This enables the user to access previous measurement results at their discretion (Appendix 9.3-9.5).

## **3. Technological Feasibility**

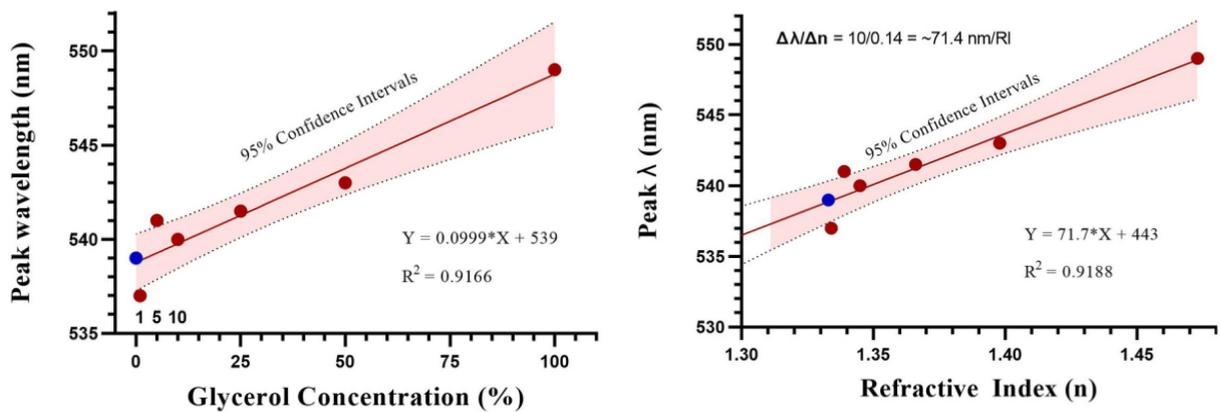
Due to the late delivery of the GFAP antibodies and GFAP protein, the optimization and the validation of the nanoplasmonic biosensor were performed with glycerol solutions at varying concentrations (i.e., %1, %5, %10, %25, %50 and % 100). Glycerol solutions are commonly used in the sensitivity tests and validation of nanoplasmonic biosensors. These experiments provide a comparison between different solutions with different refractive indexes.

The resulting graphs are demonstrated. The shifts at the peak wavelength of values were observed to be increasing from %1 to %100 glycerol concentrations as expected. Results are indicating a clear correlation between the increasing glycerol concentration and the redshifts at the



peak wavelength of the biosensor. The results were promising for the construction of the nanoplasmonic biosensor as they are indicating that the biosensor is sensitive to the presence of solutions with different refractive indexes and the altering concentrations of the solutions.

To calculate the refractive index (RI) sensitivity, the shifts in the peak wavelength values are divided by the shifts in RI. The sensor exhibited a sensitivity of approximately 71.4 nm/RI. Biofluids like serum and plasma possess refractive indices ranging from 1.334 to 1.339, which fit well with our detection limit (Weeth, Witton, & Speth, 1969).



**Figure 3.1.** The red shifts in the peak wavelength and corresponding refraction indices after intubation with glycerol solutions at varying concentrations on AuNP-immobilized PLL-coated surfaces.

The measurement system comprising an absorbance microplate reader, which includes a mechanical system for moving the microplates and a spectrometer with a diffraction grating and a CCD sensor, shows excellent technological feasibility. Precision stepper motor-driven mechanical mechanism ensures precise microplate positioning for repeatable readings. For accurate readings of absorbance, a consistent illumination source like the embedded LED is necessary. The CCD sensor, along with the diffraction grating in the spectrometer, captures and disperses light accurately. The technology obtains accurate wavelength and absorbance readings by painstaking calibration using well-known light sources and reference solutions. Leveraging Python's capabilities and its libraries, the reader's software controls the microplate movement, triggers CCD sensor readings, and processes the captured data. Proper optical design, noise reduction measures, and safety precautions are all made with careful planning. In conclusion, our absorbance microplate reader shows remarkable technological feasibility and has the potential to provide an economical solution for fundamental absorbance measurements.

#### 4. Originality

The utilization of 96 wells within a single plate provides the biosensor multiplexing capability. This design permits the detection of 96 samples in one run, significantly reducing the time required for analysis. Incorporation of PEG linkers onto the AuNPs prevents nonspecific adsorption and absorption, so enhancing the overall sensitivity of the biosensor. The most important aspect in the originality of the system is the unique configuration of the biosensor. The platform employs gold nanoparticle-immobilized surfaces within a 96-well plate, coupled with the covalent attachment of PEG linkers and antibodies. This integrated approach optimizes the binding efficiency and response of the sensor.

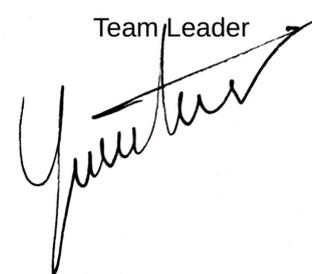
Conceptualization of the biosensor is done by the supervisor and division of sub-teams, each focusing on a distinct aspect (biology, materials, and physics) of the biosensor's development is done by the team captain. The supervisor Dr. Abdulhalim KILIÇ, the team leader Yaşar Yurtsever, Emir Çubukçuoğlu, Elif Deniz Çalı, and Zeynep Şahin worked in wet-lab studies as the lab team, and actively participated in conducting experiments, developed surface modification strategies, ensuring that the biosensor performance met the intended objectives.

In our team; Yaşar Yurtsever worked as team leader, Emir Çubukçuoğlu worked as vice-leader; Ömer Faruk Güleç, Yaren Özdemir and Kaan Yapıcı worked on spectrophotometer as a physics team; Sude Nur Sandıkçı, Hayriye Ceylin Ünal, Öykü Yanaz, and Gizem Şahin worked on entrepreneurship processes as (ES) team; Emir Çubukçuoğlu, Furkan Fıçıcı, Büşra Akdağ and Hande Ezgi Kepenek worked onto the feedback moments; Gizem Şahin and Hande Ezgi Kepenek worked on social media processes as a social media team. Those whose names are written here are the main ones responsible for the tasks. The entire team worked together in all categories.

Assist. Prof. Dr. Abdulhalim KILIÇ

Team Supervisor  


Yaşar YURTSEVER

Team Leader  


## **5. Translation Potential**

In the field of advanced medical diagnostics, the cutting-edge nanoplasmonic biosensor offers a novel solution customized to the requirements of current healthcare professionals, hospitals, healthcare companies, and medical centers. With the ability to detect GFAP, a vital biomarker of Traumatic Brain Injury (TBI), and designed with a special focus on accuracy, efficiency, and convenience, this biosensor has the potential to revolutionize the diagnosis of TBI. The detailed business canvas can be seen below.

### **5.1. Stakeholder Desirability**

Customers, which are healthcare professionals in the related field, are driven by the collective goal of accurate and reliable diagnosis of TBI; improving patient outcomes, enhancing diagnostic precision, and optimizing healthcare resources with a non-invasive and quick diagnostic tool for efficient patient management. Additionally, customers are in need of integration of the biosensor into existing clinical workflows, and healthcare organizations are willing to embrace modern technologies that improve the quality of their services and enable them to remain competitive while providing solutions that are value-driven. Our nanoplasmonic biosensor responds to these complicated needs by providing a solution to improve diagnostic performance, promote financial viability, and improve patient care in the diagnosis of TBI.

Beyond customers, it's essential to understand the stakeholders who play significant roles in the successful adoption and impact of biosensors. Stakeholders include a diverse range of individuals, organizations, and entities, each contributing to the reaching goal of advancing TBI diagnosis and patient care. At the center of the healthcare journey, patients and their families stand as the ultimate beneficiaries of accurate diagnosis. Their need for timely, reliable, and non-invasive diagnostic methods drives the adoption of technologies such as this biosensor, assuring them of quicker interventions. Additionally, academic and research institutes strongly look for revolutionary technology that advances the understanding of medicine. Collaboration with scientists who are willing to validate and improve the biosensor's effectiveness would increase its reliability and encourage further innovation.

Besides healthcare stakeholders, regulatory authorities and insurance providers would also contribute to the biosensor in several legal aspects. In terms of regulatory concerns, the Ministry of Health and relevant health organizations have a role as stakeholders, and technologies which comply with strict quality and safety standards are required. Their goal of protecting the well-being of patients is aligned with demonstrating compliance with regulatory obligations. Alongside these regulatory compliances, insurance companies have an interest in ensuring quality healthcare at an affordable price. They seek to provide insurance for cutting-edge medical technologies, which is consistent with the capability of the biosensor for precise and effective diagnosis.

Important gains of this biosensor contribute to its advantages. Its 96-well plate form enhances efficiency by processing multiple samples simultaneously. Moreover, label-free detection minimizes

errors, ensuring reliable results and real-time screening provides clinicians with dynamic insights, elevating diagnostic accuracy and fastening treatment decisions. In an extensive value proposition, our biosensor may stand out by drawing on detailed competitor analysis. It specializes in user-friendliness, compactness, speed, and data transfer. Our biosensor avoids disadvantages including patient limits, radiation exposure, size restrictions, and limited accessibility, in contrast to standard techniques like CT and MRI. Additionally, while other sensors are highly sensitive, our biosensor's special advantages include enhanced biomarker detection, portability, and simplicity of use, highlighting its strength for point-of-care testing.

## **5.2. Business Feasibility**

Research funds of the university were used in the implementation of the project. The laboratories, measuring devices, and production equipment used in the production and development of the sensor were carried out with the help of resources available within the university. For the production and scaling phases, resources such as potential investors, industry partners, and commercial loans were evaluated. During the project development process, the necessary expertise in the fields of engineering, biotechnology, and optics, as technical information of the university and team members was applied during the design, prototyping, and production stages of the sensor. Team members' project management, intra-team cooperation, resource allocation, and time management skills have enabled the project to progress effectively. The university supports and research funds are available to provide the necessary financing at the R&D stage. During the scaling phase, financial resources can be increased by cooperating with investors and industry partners. The laboratories and research infrastructure available at the university can be used during the prototyping and development stages of the sensor. The physical infrastructure required for production and scaling can be provided with appropriate resources. The areas of expertise of the team members are sufficient and accessible within the scope of the sensor's design, prototype production, and optimization processes. At the scaling stage, capacity can be increased by collaborating with experienced project managers and consultants.

Biosensors marketing and sales strategy aims to reach targeted customers effectively and highlight the value of our product. Planned strategies include social media and digital marketing, collaboration, industry events, training, and consulting processes. In order to successfully develop our biosensor and provide a competitive advantage in the market, it is planned to focus on core activities with the highest added value. These activities include Research and Development, B2B Sales, Manufacturing, Marketing, Business Development and Collaboration. Applications will be made to the relevant patent office to protect our innovative designs and technologies. By being involved in the patent process, our product's intellectual property will be protected, helping to maintain competitive advantage and support commercial success. It is planned to generate income by making license agreements or developing collaborations with other companies through our patent portfolio. Key partners in our business model are material suppliers, distributors, marketing and sales experts, hospitals and clinics, research institutions and universities, occupational health and safety specialists,

Istanbul Technical University - Technology Transfer Office, Law Office, Istanbul Technical University MOBGAM, bank and incubation center. In partnerships with universities and research institutions, cooperation will be made in the fields of R&D, and knowledge and expertise will be shared. The real-world performance of our product will be evaluated by conducting clinical studies of our biosensor in partnership with healthcare institutions and clinics. In partnerships with industry partners and investors, it will be possible to quickly introduce the product to the market, provide financial support and scale the product. These collaborations will form the basis of long-term success by meeting the needs and goals of both parties.

The entire life cycle of the sensor (raw material supply, production, use, waste management) was analyzed and environmental impacts such as energy consumption, carbon footprint, water use, and waste generation were evaluated as a result of this analysis. In the design phase of the product, it aimed to minimize negative environmental effects by adopting green design principles such as material selection, energy efficiency, and waste reduction. Studies are planned on the reuse and recycling of wastes arising from production processes. Suppliers that comply with sustainability standards are selected by communicating effectively with all stakeholders in the supply chain of the materials to be used in sensor construction. Innovative technologies and methods have been used in the production processes, taking into account the topics of energy efficiency and environmental sustainability. Due to the 96 wall-plate used in the designed sensor, sustainability awareness is also instilled in the consumers. The developed technology has been designed with a sustainable approach against the single-use principle.

Effective marketing and communication strategies have been developed that highlight the superior performance and benefits of our optical biosensor. It is planned to provide training and consultancy services to customers to ensure that our value proposition is understood correctly. Customers will be supported with guides on how to use the product, webinars, and individual consultations. Continuous improvements to the product will be made by taking into account customer feedback. Thanks to these strategies, the value of our product will be understood by the customers. At the same time, the biosensor will be delivered directly to the institutions and professionals where it will be used. In addition, promotion and distribution processes will be supported through online platforms. It is aimed to establish a valuable relationship with customers by providing personalized support, troubleshooting, and continuous communication channels. As a result of the feedback obtained from customers utilizing these communication resources, product development processes will continue.

The development process of the biosensor was supported by interviews with specialist doctors working in related fields and extensive literature research. In addition, support has been received from professors within the university.

### 5.3. Financial Viability

Precise and consistent estimates of expenses per usage of our biosensor are critical for proper financial strategy. This includes precise estimations of the components needed, such as gold nanoparticles, PLL, linker, and Anti-GFAP, as well as the cost of 96-well plates. Furthermore, we evaluate the expenses of research & development, manufacturing, assurance of quality, and compliance with regulations. Incorporating these costs into our calculations offers an accurate estimation of both the direct and indirect costs associated with the construction of the biosensor. We also include the optical device's operational and maintenance expenses, as well as the possible expenditures for user training.

Our team realizes the essential relevance of financial sustainability in the effort to develop a new biosensor for early traumatic brain injury (TBI) detection. To do this, we thoroughly assessed the cost projections for numerous components essential to the building of our biosensor. Gold nanoparticles, a critical component of our biosensor's plasmon-enhanced design, cost between \$100 and \$500 per gram. This critical component adds considerably to overall production costs, indicating the cutting-edge technology used in our biosensor. Poly-L-lysine(PLL), a substance that enhances interaction with gold nanoparticles, is another critical component of our biosensor. This layer is critical to the operation of our nanoplasmonic system. PLL provides a basis for the biosensor's functioning while being cost-effective, with an estimated cost per gram ranging between \$0.1 and \$0.5. The linker and Anti-GFAP, which are responsible for drawing GFAP molecules from blood samples, cost between \$5 and \$20 per unit. While these features are essential for biomolecular identification, they constitute only a little portion of the overall expenses. We use commonly used 96-well plates for our substrate, which cost between \$0.2 to \$2 per unit. These plates serve as the foundation of our biosensor configuration, ensuring interconnection with existing laboratory equipment. While material costs account for a large portion of our predictions, they are supplemented by massive research and development (R&D) expenses. R&D expenditures, which include wages, laboratory supplies, and equipment, are the foundation of innovation, allowing us to design a biosensor with exceptional precision. Furthermore, regulatory compliance is a significant expense. Testing, certification, and regulatory filing fees guarantee that our biosensor meets industry standards and regulations.

Our anticipated sales price considers the biosensor's unique features and benefits, ensuring that it is in line with the value it provides to our customers. We're concentrating on delivering a clear and realistic predicted sales price for a transparent pricing approach. The price quoted includes both our production expenses and a profit margin. To determine profitability, we compare the expected sales price to the overall production expenses, ensuring that our pricing strategy is sustainable while being competitive in the market.

We considered market dynamics and production costs while pricing our ground-breaking biosensor for early TBI diagnosis. Our biosensor, which employs nanoplasmonic gold nanoparticles and an optical system, has unit prices ranging from \$79,2 to \$79,2. In comparison to invasive TBI diagnostic procedures, we established a unit pricing of \$79,2. This is consistent with our competitor's strategies and provides accessibility while compensating for our costs. Our objective is to give

healthcare providers a low-cost, non-invasive diagnostic tool that will improve TBI diagnosis and patient outcomes.

A rising need for non-invasive and reliable diagnostic methods characterizes the overall potential market for early traumatic brain injury (TBI) diagnosis. The future market picture is positive as people become less ignorant of the impact of TBI on public health. The existing gold standard approaches for TBI diagnosis include intrusive procedures and time-consuming processes, demanding the non-invasive and quick detection capabilities of our biosensor. We compared our biosensor to other technology, emphasizing its improved features and benefits. Furthermore, we evaluated our market size to that of other successful biosensor products to ensure that our selected market is large enough to pay our development expenditures and create long-term income.

Our biosensor for traumatic brain injury (TBI) diagnosis outperforms conventional approaches such as CT scans and MRIs. Our biosensor's affordability, priced at \$79,2, addresses financial constraints associated with invasive treatments, which can vary from \$700 to \$3,500. It is a game changer due to its non-invasiveness, rapid outcomes, and reduced healthcare costs. Our biosensor has the potential to alter patient care and improve medical diagnostics by providing accurate and accessible TBI diagnosis at a fraction of the cost.

Our main source of revenue is the selling of our biosensor to healthcare professionals and medical facilities. In addition, we are looking into new strategic alliances with medical institutes. To guarantee financial sustainability, we conducted a clear and trustworthy comparison of our anticipated revenues and development and manufacturing expenses. The identification of the break-even point is crucial because it tells us how many biosensors we need to sell to pay all expenditures. Our company plan entails establishing a strong business intelligence system to collect and evaluate market trends, client preferences, and competition activity on a continual basis. This strategic strategy will allow us to make informed judgments and remain competitive.

Our statements are extensively confirmed by interviews, literature, and other trustworthy sources. We interviewed potential consumers, medical professionals, and stakeholders to validate the market need for our biosensor. In addition, we cited scientific literature and market studies to back up our market research and pricing plan. This thorough approach guarantees that our claims are grounded in real-world insights and industry expertise, enhancing the credibility and robustness of our business model.

For the emergency case diagnosis of Traumatic Brain Injury (TBI), a Gold Nanoparticle (AuNP) Plasmon Based Biosensor to detect Glial Fibril Acidic Protein (GFAP) is presented. The biosensor was produced as a kit on a 96-well plate, so the healthcare institutions that reach this kit must also have the necessary spectrophotometric instruments for measurement. The ability to operate with different instruments gives the biosensor an advantage since it is also possible to make single measurements on a 96-well plate, if necessary, but up to 96 measurements can be made simultaneously in case of multiple emergency patients. After the competition, there is the idea of entrepreneurial activity with this biosensor. During the competition, a lot of gains were made in this regard. And even several experts were interviewed to get information that such a biosensor is really necessary for TBI diagnosis in the emergency room. If the biosensor becomes widely used, one of the

future goals is to have all biosensors connected and create a database. The data generated in this way will lead to future research in terms of both diagnosis and treatment. On the other hand, the highly sensitive and specific biosensor technology used is also open to use for different protein-based detection methods. In this way, the idea of using this biosensor system for different diseases is among the future plans.

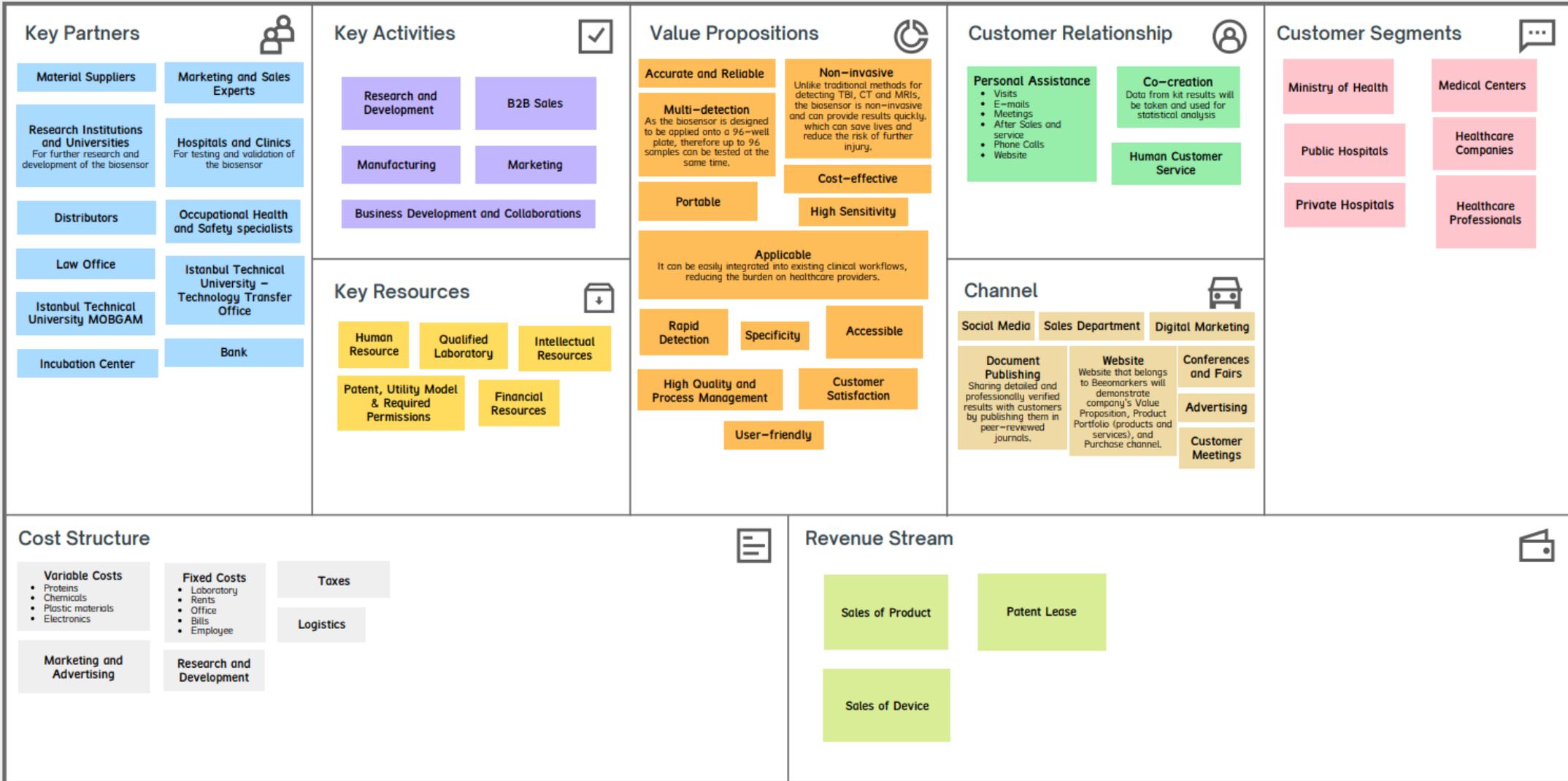
# Business Model Canvas

Designed For:  
Entrepreneurship Session 1 / SensUs

Designed by:  
Team Beemarkers

Date:  
23.03.2023

Version:  
V1



## 6. Team and Support

### 6.1. Contributions of the Team Members

Our team consists of 14 people whose names are Yaşar Yurtsever, Asım Emir Çubukcuoğlu, Büşra Akdağ, Hayriye Ceylin Ünal, Öykü Yanaz, Elif Deniz Çalı, Gizem Şahin, Furkan Fıçıcı, Hande Ezgi Kepenek, Kaan Yapıcı, Ömer Faruk Güleç, Yaren Özdemir, Sude Nur Sandıkçı and Zeynep Şahin. Our team is divided into 3 sub-teams which are the biology team, the materials team, and the physics team. The biology team focused on how the antigen could be captured and measured with the help of the antibody of GFAP via gold nanoparticles whereas the materials team are mostly focused on how the gold nanoparticles could be used in a biosensor and how the size of the gold nanoparticles could affect the biosensor that we were planning to design. In addition to that, the physics team mostly contributed to the building of the measuring device and how we can take the absorbance measurement from our biosensor design. Yaşar Yurtsever is our team's team captain and also he is a part of the biology team. In addition to that, he contributed to the experiments of our biosensor design. Asım Emir Çubukcuoğlu also took a role in the biology team and participated in the experiments for establishing the biosensor. He also contributed to the presentations that are shown in feedback moments and partner sessions. Hayriye Ceylin Ünal and Öykü Yanaz took a role in the materials team and also contributed to the requirements for entrepreneurship sessions. Kaan Yapıcı, Ömer Faruk Güleç, and Yaren Özdemir are the team members of the physics team and they built the whole measurement device and helped our team to understand the optical principle which is an important part of our system. Zeynep Şahin and Elif Deniz Çalı are part of the biology team and they mostly contributed to the experimental parts of the biosensor system. Sude Nur Sandıkçı is also part of the biology team and she contributed to the experiments and also to the requirements and presentations for the entrepreneurship sessions. She also helped to get sponsorship for our team. Gizem Şahin is a part of the biology team and she manages our LinkedIn account by creating all of the content for this platform. She also contributed to the requirements and presentations for the entrepreneurship sessions and helped to get sponsorship. One of the team members of the biology crew is Hande Ezgi Kepenek and she contributed to the requirements for partnership sessions. She managed our Instagram account by creating the content for this account. Büşra Akdağ and Furkan Fıçıcı also took roles in the biology team and mostly contributed to the requirements of partnership sessions. All of the team members established the business model and its canvas.

## **6.2. People Who Have Given Support**

Assist. Prof. Dr. Abdulhalim Kılıç is our advisor and had many contributions to our project, to the experiments, and to the team. He followed every step of the project and gave us feedback. At the same time, he taught us a lot of things by helping us at points we didn't understand and got stuck. He also contributed a lot in creating the experimental setup and performing the experiments. Also, we did interviews with 2 doctors, Dr. Serdar Çevik and Dr. Ömer Faruk Yıldız. These doctors are focused on neurology and traumatic brain injuries and gave a lot of advice for our biosensors based on their experiences as doctors. We also did an interview with Associated Professor Adnan Veysel Ertemel who is an entrepreneurship specialist. We receive advice and feedback on how we can sell our biosensor to our customer segment and how we can improve our business model.

## **6.3. Sponsors and Partners**

Our main sponsor is the AXA insurance company. With their sponsorship, we will be able to cover our main expenses such as flight tickets and so on. Also, Dr. Serdar Çevik provided financial support to our team. In addition to that, BOGA Medicals helped us with the distribution process of GFAP protein and anti-GFAP that is provided by Hytest. DEMCON also advised on the physical aspect of our biosensors such as optic systems and gave feedback that was very useful for us.

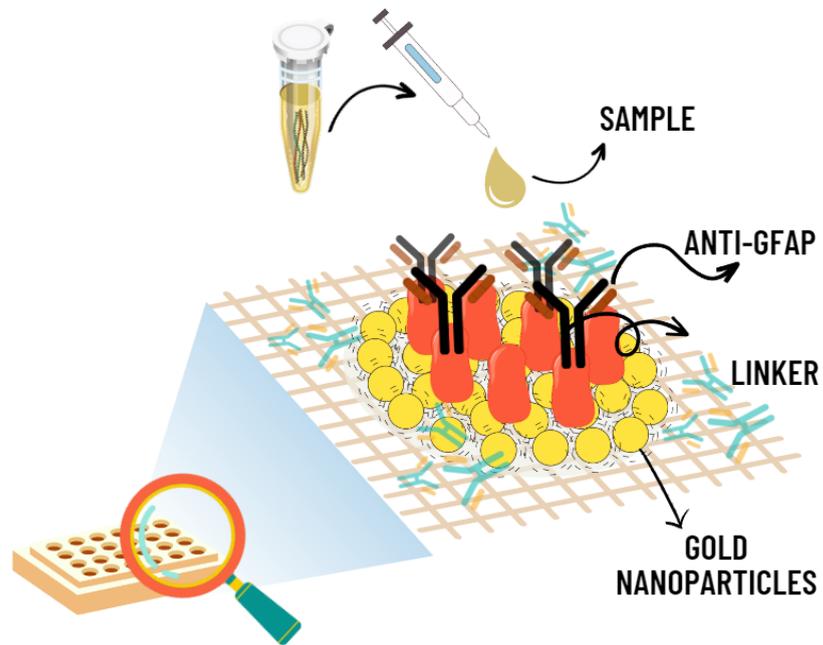
## **7. Final Remarks**

For the emergency case diagnosis of Traumatic Brain Injury (TBI), a Gold Nanoparticle (AuNP) Plasmon Based Biosensor to detect Glial Fibril Acidic Protein (GFAP) is presented. The biosensor was produced as a kit on a 96-well plate, so the healthcare institutions that reach this kit must also have the necessary spectrophotometric instruments for measurement. The ability to operate with different instruments gives the biosensor an advantage since it is also possible to make single measurements on a 96-well plate, if necessary, but up to 96 measurements can be made simultaneously in case of multiple emergency patients. After the competition, there is the idea of entrepreneurial activity with this biosensor. During the competition, a lot of gains were made in this regard. And even several experts were interviewed to get information that such a biosensor is really necessary for TBI diagnosis in the emergency room. If the biosensor becomes widely used, one of the future goals is to have all biosensors connected and create a database. The data generated in this way will lead to future research in terms of both diagnosis and treatment. On the other hand, the highly sensitive and specific biosensor technology used is also open to use for different protein-based detection methods. In this way, the idea of using this biosensor system for different diseases is among the future plans.

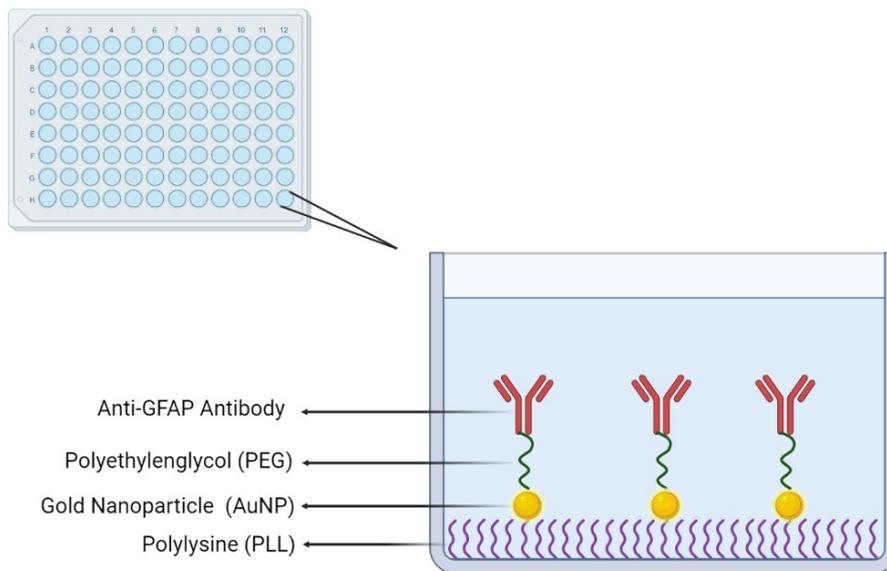
## 8. References

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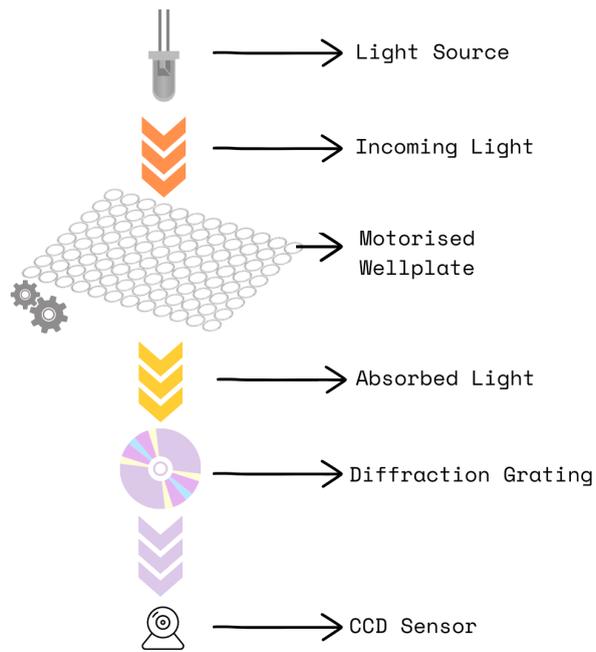
## 9. Appendix



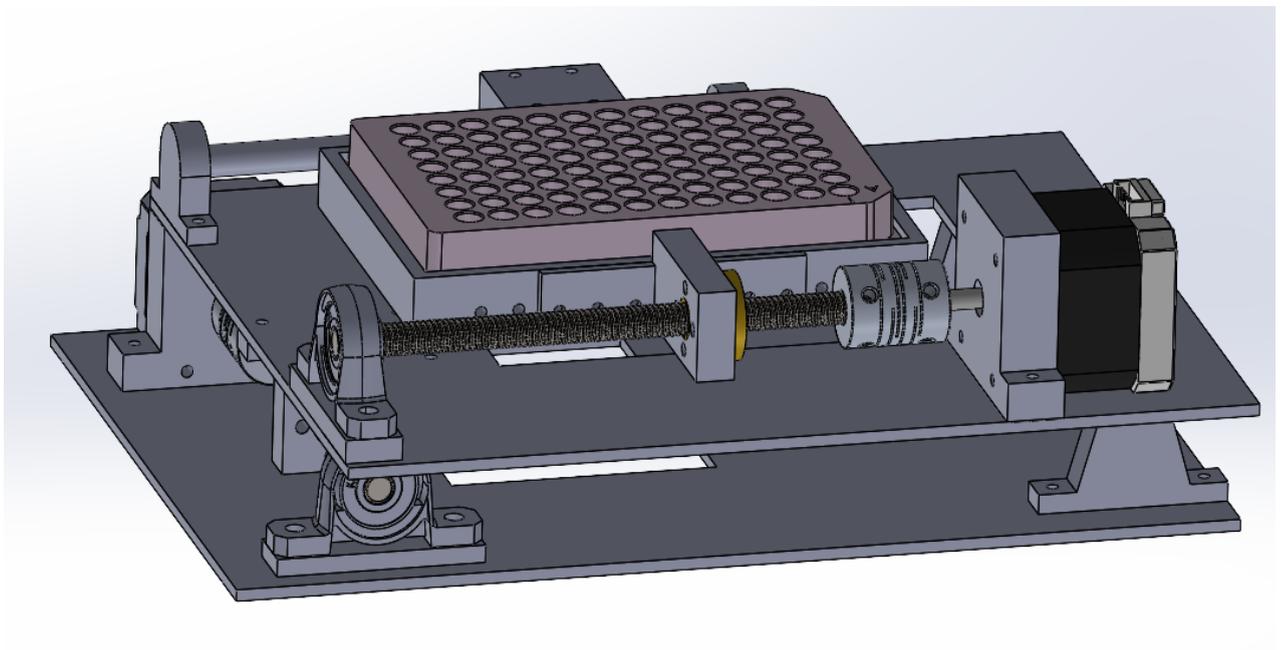
**Figure 9.1.** Illustration of Beeomarker's plasmon-based biosensor system.



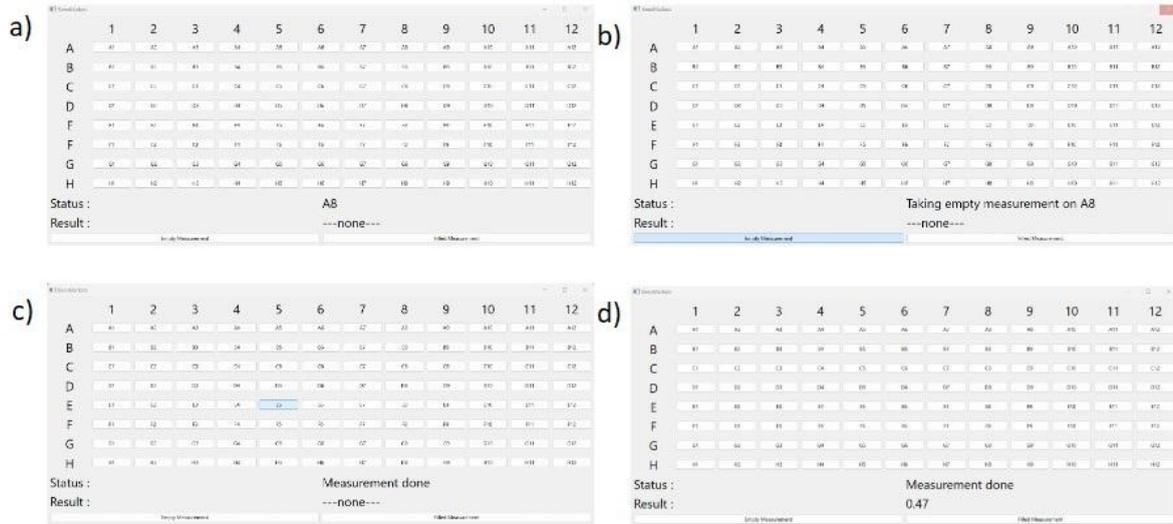
**Figure 9.2.** Illustration of wells of the 96-well plate of the Beeomarker's plasmon-based biosensor system.



**Figure 9.3.** The illustration of a custom-made Beemarker's spectrophotometer. The detection method of Beemarker's biosensor system.



**Figure 9.4.** The 3D design and production steps of custom-made Beemarker's spectrophotometer.



**Figure 9.5.** Device software. a) Before the measurement well is moved as selected. b) Getting calibration measurements before the actual result. c) When the measurement is completed, the interface gives a “measurement done” message. d) After the measurement, the interface gives the result.