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Fabrication of PMMA Borate Bioactive Thin Films for Wound Healing Applications

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In the realm of regenerative medicine and tissue engineering, PMMA borate bioactive thin films have become a potential composite material. PMMA borate bioactive thin films are created, described, and possibly used in this paper. In order to add bioactivity and controlled drug release capabilities, borate bioactive glass was incorporated into a PMMA matrix to create the films. Both components had been well integrated, as shown by Fourier Transform Infrared (FT-IR) spectroscopy, and Field Emission Scanning Electron Microscopy (FE-SEM), which showed a uniform distribution of bioactive glass within the PMMA matrix.The precise control over medication release made possible by the variable surface wettability of PMMA could be advantageous in applications for wound healing. The films displayed a steady release of bioactive ions, resulting in the ideal milieu for tissue regeneration and wound healing. PMMA and borate bioactive glass' biocompatibility and biodegradability greatly improved their applicability for biomedical applications.Although the study offered insightful information about the potential of PMMA borate bioactive thin films, more investigation is required to confirm their effectiveness and safety in clinical settings. PMMA borate bioactive thin films have the biomedical to advance tissue engineering and regenerative medicine by serving as a versatile and effective biomedical material that can be used to solve a variety of biomedical difficulties.

Keywords: Regeneration, Biocompatibility, Biomedical, PMMA.

1. Introduction

An increase in interest in creating sophisticated materials that can work well with live tissues and encourage tissue regeneration has been seen recently in the field of biomaterials. The combination of Polymethyl methacrylate (PMMA) and borate bioactive glass has stood out among these materials as a promising composite with outstanding promise in a range of biological applications(Sato et al. 2006). PMMA has long been a popular material in the medical and dentistry industries since it is transparent and biocompatible. Borate bioactive glass, on the other hand, demonstrates bioactivity, enabling it to bind with living tissues and promote tissue integration and regeneration(Abodunrin et al. 2023).By combining PMMA and borate bioactive glass, a novel opportunity is presented to take advantage of the benefits of both elements and produce a multifunctional material that solves problems in various biomedical situations. This composite is useful for specialized applications in wound healing, tissue engineering, drug delivery, and regenerative medicine because it has a variety of customized features, including controlled drug administration, improved mechanical strength, and surface functionalization(Ensoylu et al. 2022).Borate bioactive thin films are a specific kind of surface coating or layer made of borate-based bioactive glass that is put onto a substrate with a predetermined thickness(Zhao et al. 2022). Due to their bioactivity and propensity to encourage tissue integration and regeneration, these thin films are of tremendous interest in a variety of biomedical applications. Borate bioactive thin films have great promise for the creation of cutting-edge biomaterials and medical equipment(Negut and Ristoscu 2023). The benefits of PMMA (Polymethyl methacrylate) and borate bioactive glass are combined in PMMA borate bioactive thin films to provide a multifunctional material with potential medicinal uses(Liu et al. 2013). While borate bioactive glass offers bioactivity and the capacity to connect with living tissues, PMMA is a widely used biocompatible polymer with good transparency, mechanical qualities, and processing simplicity. Researchers want to utilize the advantages of both materials for various biomedical applications by integrating borate bioactive glass into a PMMA matrix as a thin film(Baino et al. 2016).However, it is crucial to note that issues like obtaining good interfacial adhesion and optimizing the dispersion of borate bioactive glass inside the PMMA matrix need to be dealt with in the fabrication process. To assure the thin films' acceptability and safety for in vivo applications, it is also important to carefully assess their bioactivity and degrading behavior(Tan et al. 2022).PMMA borate thin films have the potential to be very important in applications for wound healing. They are useful instruments for encouraging tissue regeneration, expediting wound healing, and avoiding problems in the wound healing process because of their bioactivity, controlled drug administration capabilities, improved mechanical qualities, and adaptable surface features. The creation of creative scaffolds and wound dressings that improve patient outcomes and wound healing techniques may result from more research and development in this field(Hum and Boccaccini 2012).An overview of PMMA borate bioactive glass, a flexible composite for biomedical purposes, is provided in this article. We will go through the special qualities of each component, the significance of their interaction, and the prospective applications that have drawn the attention of scientists and medical specialists(Lee et al. 2014).

2. Materials and Methods:

2.1 Materials

PMMA (Polymethyl Methacrylate): The polymer matrix for the thin film is selected to be of high quality PMMA (SRL). Borate bioactive glassby sol-gel synthesis is used to create the borate bioactive glass component, which contains the elements boron, silicon, calcium, and sodium. The composition of the bioactive glass should be chosen specifically to encourage bone repair and tissue integration.Depending on the method used to fabricate the film, the right solvents are employed to dissolve the PMMA and produce a homogeneous solution or dispersion.

2.2 Methods

PMMA pellets or powder are dissolved in a suitable solvent such as to create a PMMA solution.The PMMA solution is supplemented with the borate bioactive glass particles, and the mixture is agitated to ensure even dispersion.Using a spin coater, the PMMA borate bioactive glass solution is subsequently applied to a substrate (such as glass or silicon). To obtain the appropriate thin film thickness, rotation speed and deposition time are regulated.The PMMA borate bioactive thin layer is then left behind after heating the coated substrate to evaporate the solvent.t is significant to note that depending on the needs of the research or application, different materials and procedures may be employed. To create a PMMA borate bioactive thin film with the appropriate properties for its intended usage in biomedical applications, it is crucial to optimize the materials and fabrication method.

2.3 Characterization Techniques:

Synthesized Bioactive materials were characterized to further analyse the properties of the prepared materials. X-ray diffraction patterns used to study the crystalline phases with the wavelength of Cu Kα (Bruker D8 advance). Functional group properties were analyzed through Raman spectroscopy (WITEC ALPHA300 RA – Confocal Raman Microscope with AFM). To investigate the morphological and elemental analysis by FE-SEM and EDS [JEOL (JSM -IT 800) { FE-SEM }] and Oxford Instrumentations [EDS].

3. Results

3.1 Fourier Transform Infrared (FT-IR) Spectroscopy

C-O-C and C=O vibration was observed through FT-IR spectroscopy in pure PMMA. After reinforcement of borate, BO3 units were noted. Pure PMMA showed entirely plain morphology after addition of PMMA, porous features was observed. Any shifts or changes in the absorption peaks that can be indicative of interactions or chemical bonds between PMMA and the bioactive glass can be seen in the FT-IR spectra.

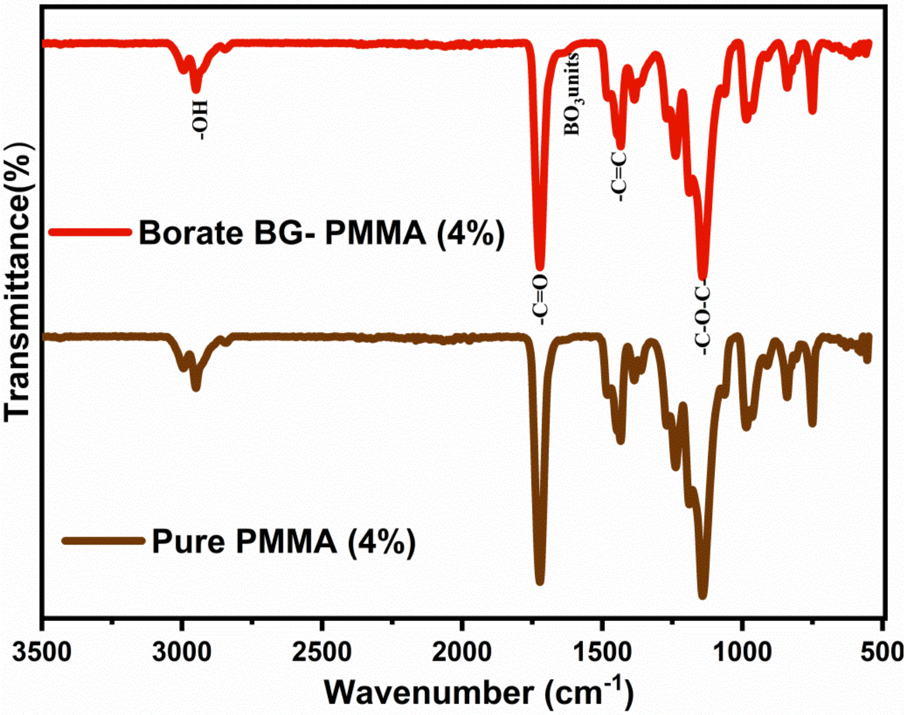

Figure 2: Fourier Transform Infrared (FT-IR) Spectroscopy of pure PMMA and PMMA borate bioglass

The film's composition, chemical structure, and probable interactions are taken into account while interpreting and discussing the FT-IR data. It aids in understanding how the composite's characteristics and bioactivity are affected by the combination of PMMA and borate bioactive glass as well as confirming their existence in the mixture.

3.2 Field emission scanning electron microscopy (FE-SEM)

High-resolution photos from the FE-SEM show the thin film's surface morphology. Particle distribution, porosity, and any surface abnormalities can all be seen by researchers. Borate bioactive glass particles can be found throughout the PMMA matrix and are dispersed there. For the best mechanical and biological effects, a uniform dispersion is preferred. Film Thickness: Using the acquired pictures or cross-sectional imaging, the FE-SEM can be utilized to measure the film thickness. Surface modifications: If any coatings or surface treatments have been applied to the thin film, FE-SEM can help visualize the ensuing changes in surface features. In order to verify the film's microstructural characteristics and determine whether it is suitable for particular biological applications, FE-SEM analysis is a crucial characterization approach.

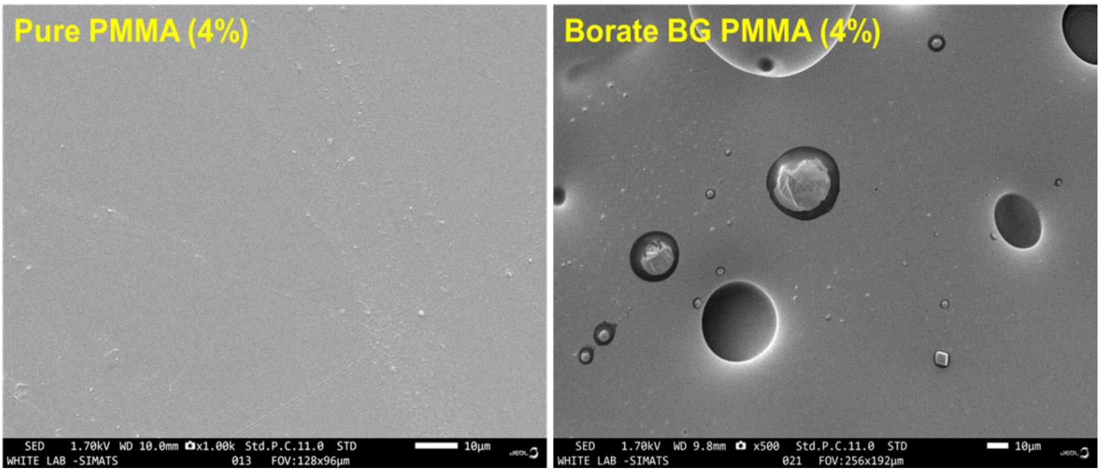

Figure 3: Field emission scanning electron microscopy (FE-SEM) of pure PMMA and PMMA borate bioglass

3.3 Contact angle goniometer

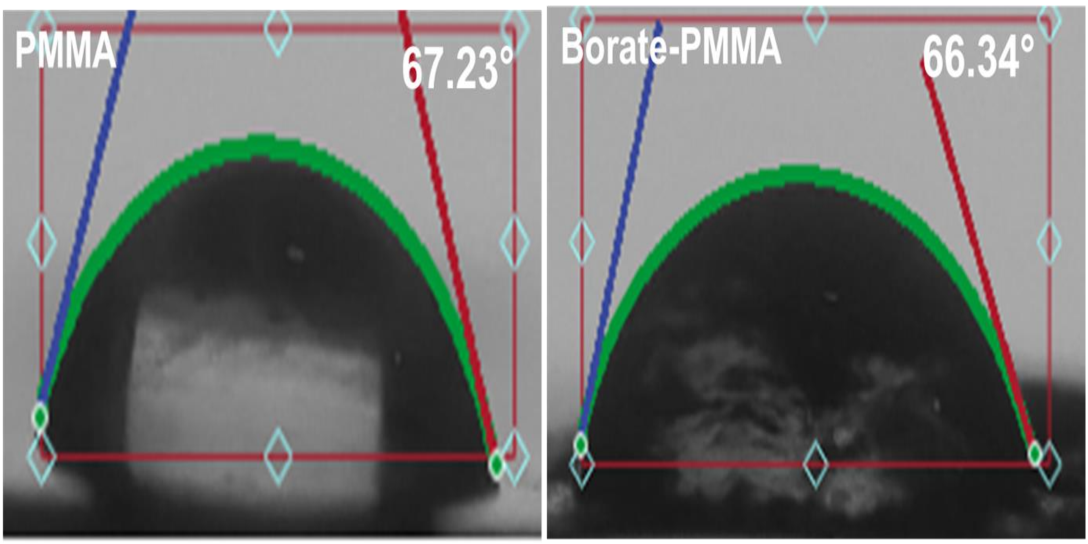

Figure 4: Contact angle of PMMA and PMMA borate bioglass

To measure the contact angle of borate bio glass PMMA, a droplet of liquid (typically water) is placed onto the surface of the composite, and the angle between the droplet and the surface is measured. This angle can provide information about the interaction between the liquid and the surface of the material, which in turn reflects the surface properties of the composite.Measuring the contact angle of borate bio glass PMMA composites can provide important information about their surface properties, which can have implications for applications, such as in tissue engineering, drug delivery, and surface coatings. It can help in understanding the interaction of the composite with biological fluids, adhesion of cells, and overall performance in specific environments.The chemical makeup, surface roughness, and surface treatments of a PMMA borate bioactive thin film are some of the variables that can affect its contact angle.Additionally, the contact angle measurement can shed light on how the composite film's overall performance and bioactivity are affected by the interaction between PMMA and the borate bioactive glass components.

3.4 Tensile strength:

Due to their fragility and tiny size, thin films can be difficult to determine in terms of tensile strength. Several techniques, such as nanoindentation, microtensile testing, and micromechanical testing, are frequently used to evaluate the tensile strength of thin films.The tensile strength of borate bio glass PMMA composites can be determined through tensile testing, which involves applying a controlled force to a specimen of the composite in the axial direction until it fractures. The force applied and the resulting deformation is measured, and the tensile strength is calculated as the maximum stress reached during the test, divided by the cross-sectional area of the specimen.The tensile strength of borate bio glass PMMA composites is an important parameter to consider for their structural applications, such as i dental materials, bone substitutes. Proper characterization and understanding of the tensile strength can help in designing and optimizing the composite material for specific functional requirements, taking into account the mechanical performance needed for the intended application (Ding et al. 2014).

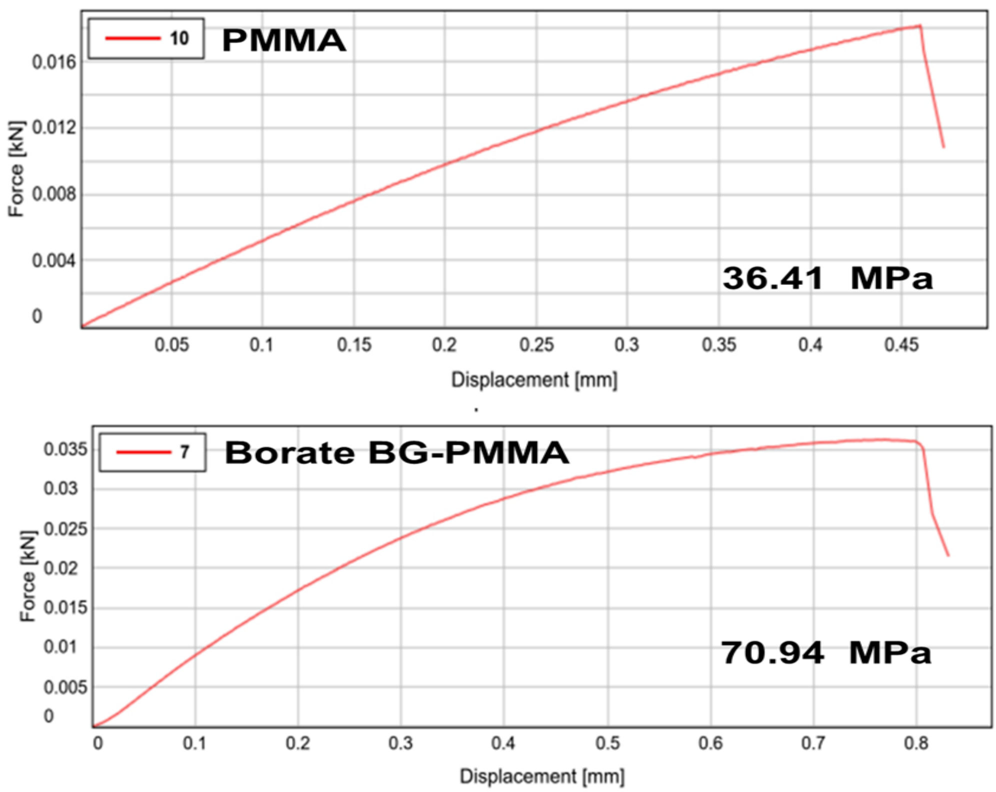

Figure 5: Tensile strength of PMMA and PMMA borate bioglass

4. Discussion

PMMA borate bioactive thin films' distinctive set of characteristics opens up a variety of biological application possibilities. The composite is a promising material for bone tissue engineering because, as shown by its bioactivity, it can support the development of hydroxyapatite. The thin films may be used to replace bone grafts by encouraging osteoconduction and aiding in the development of new bone(Serrano-Aroca et al. 2022).For applications involving drug distribution, the thin films' adjustable surface wettability can be used. A precise and localized therapeutic effect can be achieved by altering the surface characteristics, which controls the release kinetics of medicines or growth factors(Sergi et al. 2020). The efficacy of drug delivery systems in a variety of medical therapies may be improved by this feature.In wound healing, PMMA borate bioactive thin films can store bioactive ions like calcium, sodium, and boron before they are progressively released into the wound bed. These ions have been demonstrated to promote angiogenesis, collagen formation, and cellular responses, all of which are necessary for wound healing(Dorati et al. 2017). By acting as a physical barrier, the thin layer can shield the wound site from external pollutants, infections, and mechanical forces. The barrier function aids in establishing an environment that is ideal for the wound to heal in peace, lowering the danger of infection and accelerating the healing process.Cell adhesion, migration, and proliferation are made easier by the PMMA borate bioactive thin film's flat surface shape. Skin cells, fibroblasts, and endothelial cells, which are crucial for healing wounds and regenerating tissue, are especially benefited by this characteristic(Felgueiras and Amorim 2019). PMMA is a biodegradable material therefore the thin film might deteriorate gradually over time. The bioactive glass particles and ions included in the film are released as it deteriorates, offering prolonged support for tissue regeneration and wound healing. The ability to fabricate PMMA borate bioactive thin films into a variety of shapes and sizes makes them useful for wound dressing applications suited to certain wound types and sizes.In a variety of therapeutic settings, including chronic wounds, diabetic ulcers, burn injuries, and post-surgical wounds, PMMA borate bioactive thin films have the potential to enhance wound healing results. These thin films can be used as advanced wound dressings, patches, or skin substitutes or they can be directly applied to the wound site(Azadani et al. 2021).Due to their bioactivity, controlled release abilities, biocompatibility, and customizable surface features, PMMA borate bioactive thin films have a lot of potential for use in wound healing applications. They have the potential to greatly accelerate wound healing and boost patient outcomes as a flexible and efficient wound dressing material(Maximov et al. 2021).The controlled and slow release of medicinal substances or bioactive ions contained inside the film is referred to as the drug release of PMMA borate bioactive thin films. The thin films are ideal for numerous biomedical applications, including drug delivery systems, because of this controlled release property. To accomplish certain therapeutic objectives and increase the effectiveness of treatment, the medication release profile can be customized(Abodunrin et al. 2023).In bone tissue engineering, osteogenic chemicals can be added to thin films to encourage bone growth at the location of bone fractures or abnormalities. Drugs are released from thin films in a regulated manner, reducing the need for repeated administration and guaranteeing long-lasting therapeutic effects(Cui et al. 2017). PMMA borate bioactive thin films, in particular for drug delivery and tissue engineering, are a potential platform for a variety of biomedical applications due to their drug release characteristics. In a variety of clinical settings, their capacity to deliver therapeutic chemicals in a continuous and controlled manner increases their efficiency in encouraging tissue regeneration and wound healing(Rahaman et al. 2014).

5. Conclusion

A versatile and promising composite material with tremendous promise for different biomedical applications is PMMA borate bioactive thin films. PMMA, a biocompatible polymer, and borate bioactive glass, a bioactive substance, are combined to create a composite that has special and advantageous qualities.These thin films are effective wound dressings and scaffolds that encourage tissue integration, controlled drug release, and barrier function against infections. They show significant potential in wound healing applications. An ideal milieu for tissue regeneration and healing processes is created by the prolonged release of bioactive ions and medications, facilitating faster wound closure. Beyond wound healing, the tunable drug release capabilities and bioactivity of PMMA borate bioactive thin films open doors to various other biomedical applications. They can be explored as drug delivery carriers for targeted therapies, tissue engineering scaffolds for bone regeneration, and coatings for biomedical implants to improve their integration with surrounding tissues.Even though this study has shed light on the potential of PMMA borate bioactive thin films, more analysis and clinical trials are required to confirm their long-term performance in practical biomedical contexts. Undoubtedly, further investigation and improvement of these films will open the door to new treatment approaches and medical breakthroughs in the fields of tissue engineering and regenerative medicine.

Conflicts of interest

There are no conflicts to declare.

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