# OPTIMAL FABRICATION AND PHYSICO-MECHANICAL PERFORMANCE OF ELECTROSPUN NANOFIBER-BASED BIODEGRADABLE AND BIOCOMPATIBLE POLYMERIC CONSTRUCTS

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*by*

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*Submitted in fulfilment of the requirements of the degree of*

**Doctor of Philosophy**

*to the*

**INDIAN INSTITUTE OF TECHNOLOGY DELHI**

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# CERTIFICATE

This is to certify that the thesis entitled "**Optimal fabrication and physico-mechanical performance of electrospun nanofiber-based biodegradable and biocompatible polymeric constructs**" submitted to the Indian Institute of Technology Delhi by **Ms. Deepika Sharma**, for the award of the degree of **Doctor of Philosophy** in the Department of Materials Science and Engineering (formerly known as Centre for Polymer Science and Engineering), is a bonafide record of original research work carried out by the candidate. The results contained in this thesis have not been submitted, in part or full, to any other university or institute for the award of any degree.

I further certify that Ms. Sharma has fulfilled all the requirements for the submission of the thesis.

**Prof. Bhabani. K. Satapathy**
Professor
Department of Materials Science and Engineering
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# ABSTRACT

The effect of variation of applied voltages, orifice diameters, solvent mixtures, solvent ratios, PLA/PCL blending ratios, solution concentration of blends, and the flow rate was reported via morphological analysis of electrospun mats (EMs). Further, the set of optimal process parameters, i.e., the orifice diameter of ~0.5 mm, receiving distance ~5 cm, an applied voltage of ~20 kV, a solvent mixture of CF/DMF (80:20), solution concentration of ~10 wt. %, optimized for individual PLA and PCL-based EMs, was later adopted for the fabrication of EMs based on the PLA/PCL blends. Thus, the study established a hierarchical processing optimization route for designing blended EMs by following a set of variable electrospinning process parameters. In a subsequent study, the influence of the solvent systems on the fiber-diameters, morphology, crystallinity, thermal stability, hydrophobicity, quasi-static mechanical, and solid-state visco-elastic responses of the EMs was evaluated. PLA/PCL (70:30 w/w) blend-based EMs fabricated using DCM/DMF (80:20 v/v) solvent mixture exhibited comparatively lower crystallinity (~25%) but higher fiber diameter (1.03 ± 0.21 μm), strain-at-break (~155%), and hydrophobicity (~130º) compared to CF/DMF (80:20 v/v) system. Thus, the study demonstrated the systematic role of solvent characteristics in terms of their volatility, dielectric constant, and solvent-mixture composition on the electro-spinnability and fabrication of high-strength, deformable, hydrophobic, bead-free EMs with near monodisperse fibrous assemblies for biomedical applications. Similarly, a compositionally optimized operational pathway was established for designing and the estimation of the physico-mechanical performance of PLA (PLAF), PCL (PCLF), and different PLA/PCL blend-based EMs, fabricated at a constant set of electrospinning process parameters. The mechanical performance of PPF-80 (PLA/PCL 80:20 w/w) EM exhibited the highest tensile strength (~2 MPa) and strain-at-break (~94%) amongst fabricated mats. Further, PPF-70 (PLA/PCL 70:30 w/w) EMs also exhibited comparable, mechanical performance, crystallinity, and hydrophobicity. Thus, PPF-70 and PPF-80 blended systems can be used for the fabrication of engineered EMs. Moreover, the structural fabrication and optimization of PLA/PCL blend-based bead-free EMs were performed using Response Surface Methodology (RSM) and Taguchi design of experiments (DoE). From the three control parameters i.e., PCL content, *N*, *N*- dimethylformamide (DMF) content, and electrospinning solution concentration, the optimal parametric combinations for minimizing the bead defects amongst EMs were obtained. The parametric optimization outcomes remained identical, from both RSM and Taguchi approaches, irrespective of the difference in the number of experimental trials. The experimental validation of the predicted results from Taguchi-design showed an excellent agreement with >95% accuracy concerning minimization of bead defects and average fiber diameter. The optimally designed EM structures showed a correspondingly optimal level of suture resistance, where fine fibers offered higher resistance to suture failure due to the cooperative network effects unlike the relatively coarse fiber-based EMs undergoing collapse attributed to fiber buckling and fiber slippage in the labile structural network.

Integrated structures were also fabricated by compaction of PLA/PCL mixed films (~150 μm) over PLA/PCL-based entangled EMs (fiber diameter ~250- 850 nm) by adopting (a) solvent adhesion and (b) hot compression techniques. The morphological, thermal, microstructural, and quasi-mechanical properties of solvent-cast films and integrated composite patches were investigated. It was found that solvent-assisted consolidation efficiency remained inferior to the hot compression-assisted consolidation techniques. The tensile strength/modulus remained better in the composite patches obtained by hot compression while strain-at-break was superior in the patches obtained by solvent-assisted consolidation technique. The study established the conceptual feasibility of developing structurally engineered 3D composite patches with tunable physico-mechanical properties. In a subsequent study, curcumin (CUR)-loaded PLA/PCL EMs were fabricated as excellent carrier systems, exhibiting a diffusion-controlled mechanism release behavior confirming to Peppas- Korsmeyer, Higuchi, Kopcha model and the new generalized logarithmic model. The evaluation of structural and viscoelastic properties of the fabricated EMs showed an increase in modulus and strength, along with a subsequent decrease in elongation, with an increase in CUR content. Suture-induced cooperative collapse dynamics in the EMs have been found to be a three-stage process involving stable, stable-unstable, and fast-unstable structural failure corresponding to network realignment, lateral pullout/fracture of fibers, and divergent tearing along the crack path. The viscoelastic responses showed a prominent shift in glass transition temperature ($T_g$) of the PCL phase indicating the development of CUR-induced microstructural changes and are attributed to the presence of H-bonding interactions between the polymeric segments of PLA/PCL-based EMs. Thus, the study demonstrates, functionally efficient designing of PLA/PCL-based CUR-loaded biodegradable EMs with sustained retention of tunable mechanical properties and hydrophobicity, irrespective of the extent of (*in-vitro*) CUR release. Similarly, the influence of beta-cyclodextrin (β-CD) loading on the morphological, thermal, and microstructural properties was thoroughly investigated. The studies revealed an enhancement in modulus and strength was observed for ~2.5-5 phr of β-CD content, however, the mechanical properties were observed to deteriorate for β-CD content > 5 phr. Spectroscopic analysis elucidated the removal of CUR from ethanol-water solutions and its simultaneous encapsulation in β-CD hydrophobic cavities (released) of fabricated EMs. Thus, the study demonstrates the development of biodegradable-functional EMs with tunable physico-mechanical properties for biomedical applications, facilitating encapsulation and rapid removal of waste hydrophobic ultrafine molecules from the system.

Synthesis and characterization of CUR and β-CD based inclusion complexes (ICs) prepared using co-solvent (IC-1) and common solvent (IC-2) precipitation techniques, were evaluated. The thermal and microstructural characterization exhibited a complete encapsulation of CUR with β-CD from both sides for IC-2. Thus, the study demonstrates the possibility to fabricate optimally controlled nanoparticles (NPs) of CUR/ β-CD IC, exhibiting a significant potential to be electrosprayed on biomedical surfaces of implants and devices with enhanced efficacy and stability of CUR release. In a subsequent study, the

IC of CUR and β-CD was optimally incorporated in electrospun PVA nanofibers, to obtain uniform bead-free nanofibers with minimum average diameter and variation using Taguchi's experimental design. Analysis of variance (ANOVA) showed a major influence of IC loading on the average fiber diameter and the number of bead defects, for IC-loaded PVA-based EMs. This is attributed to the presence of significant interactions between IC and PVA matrix. The study conceptually demonstrated the optimal designing of structurally engineered hydrophilic IC-loaded PVA-based EMs as potential drug release substrates.

Further, PCL-*b*-PLLA diblock copolymer and its EMs were characterized for their microstructural, thermal, and physico-mechanical properties. The EMs of synthesized copolymer exhibiting the optimal level of average fiber diameter (Co-FD) and diameter variation (Co-SD) were obtained following Taguchi's experimental design. The physico-mechanical properties of the optimized EMs were evaluated vis-à-vis the influence of FD and SD on the mechanical properties. The swelling and weight loss showed marked improvement in PCL-*b*-PLLA based EMs reiterating the possibility of their enhanced compatibility as biomedical materials. Similarly, in a subsequent study, the poly(L-lactide-co-ε-caprolactone) (PLCL) concentration induced variation in thermal, microstructural, mechanical, and viscoelastic attributes of thermodynamically immiscible PLA/PCL (70:30 w/w) blend-based EMs, was evaluated. An increase in surface electronegative potential, specific surface area, pore-volume, strength, and modulus with a subsequent decrease in elongation was observed for EMs with low copolymer content (~2.5 to ~5 phr), indicating the presence of significant interactions between the respective polymeric chains of the block copolymer and blended matrix. Further, the surface responsiveness of engineered EMs exhibited significant potential for the adsorption of hydroxyapatites with a subsequent enhancement in cell viability. Thus, the study reports an efficient approach for designing surface-active, compatibilized, biodegradable, and structurally stable EMs of immiscible polymeric blends with tuneable properties using a similar polymer-based diblock copolymer for its potential use in the development of biomedical devices. Moreover, the physico-mechanical performance of IC-loaded PVA coated compatibilized PLA/PCL blend (~2.5 phr copolymer content) based hybrid EMs, was evaluated. Here, ~60 wt. % and ~80 wt. % IC loaded PVA-based EMs, exhibit excellent antimicrobial efficacy, with adherent bacteria < 10%. Moreover, an enhancement in cell attachment potential, i.e., ~135% was observed for H-bonded IC and PVA coated hybrid EMs. Thus, the study demonstrates the development of engineered structurally stable, pliable, biocompatible, and antimicrobial EMs, as potential wound dressing materials.

# सार

लागू वोल्टेज, छिद्र व्यास, विलायक मिश्रण, विलायक अनुपात, पीएलए / पीसीएल मिश्रण अनुपात, मिश्रणों की समाधान एकाग्रता, और प्रवाह दर की भिन्नता का प्रभाव इलेक्ट्रोसपुन मैट (ईएम) के रूपात्मक विश्लेषण के माध्यम से बताया गया था। इसके अलावा, इष्टतम प्रक्रिया मापदंडों का सेट, यानी, ~0.5 मिमी का छिद्र व्यास, प्राप्त दूरी ~5 सेमी, ~20 केवी का एक लागू वोल्टेज, सीएफ / डीएमएफ (80:20) का एक विलायक मिश्रण, समाधान एकाग्रता ~10 wt. %, व्यक्तिगत पीएलए और पीसीएल-आधारित ईएम के लिए अनुकूलित, बाद में पीएलए/पीसीएल मिश्रणों के आधार पर ईएम के निर्माण के लिए अपनाया गया था। इस प्रकार, अध्ययन ने चर इलेक्ट्रोसपिनिंग प्रक्रिया मापदंडों के एक सेट का पालन करके मिश्रित ईएम को डिजाइन करने के लिए एक पदानुक्रमित प्रसंस्करण अनुकूलन मार्ग की स्थापना की। बाद के एक अध्ययन में, ईएम के फाइबर-व्यास, आकारिकी, क्रिस्टलीयता, थर्मल स्थिरता, हाइड्रोफोबिसिटी, अर्ध-स्थैतिक यांत्रिक और ठोस-राज्य विस्को-लोचदार प्रतिक्रियाओं पर विलायक प्रणालियों के प्रभाव का मूल्यांकन किया गया था। DCM/DMF (80:20 v/v) विलायक मिश्रण का उपयोग करके निर्मित पीएलए / पीसीएल (70:30 w/w) मिश्रण-आधारित EMs तुलनात्मक रूप से कम क्रिस्टलीयता (~25%) लेकिन उच्च फाइबर व्यास (1.03 ± 0.21 μm) प्रदर्शित करते हैं। सीएफ/डीएमएफ (80:20 वी/वी) प्रणाली की तुलना में तनाव-पर-ब्रेक (~155%), और हाइड्रोफोबिसिटी (~130 )। इस प्रकार, अध्ययन ने इलेक्ट्रो-स्पिनेबिलिटी पर उनकी अस्थिरता, ढांकता हुआ निरंतर, और विलायक-मिश्रण संरचना के संदर्भ में विलायक विशेषताओं की व्यवस्थित भूमिका का प्रदर्शन किया और उच्च शक्ति, विकृत, हाइड्रोफोबिक, मनका मुक्त ईएम के पास मोनोडिस्पर्स रेशेदार असेंबली के साथ निर्माण किया। जैव चिकित्सा अनुप्रयोगों के लिए। इसी तरह, इलेक्ट्रोस्पिनिंग प्रक्रिया के एक निरंतर सेट पर निर्मित पीएलए (पीएलएएफ), पीसीएल (पीसीएलएफ), और विभिन्न पीएलए / पीसीएल मिश्रण-आधारित ईएम के डिजाइनिंग और भौतिक-यांत्रिक प्रदर्शन के आकलन के लिए एक संरचनात्मक रूप से अनुकूलित परिचालन मार्ग की स्थापना की गई थी। पैरामीटर। PPF-80 (पीएलए / पीसीएल 80:20 w/w) EM के यांत्रिक प्रदर्शन ने फैब्रिकेटेड मैट के बीच उच्चतम तन्यता ताकत (~2 MPa) और स्ट्रेन-एट-ब्रेक (~94%) प्रदर्शित किया। इसके अलावा, PPF-70 ( पीएलए / पीसीएल 70:30 w/w) EMs ने तुलनीय, यांत्रिक प्रदर्शन, क्रिस्टलीयता और हाइड्रोफोबिसिटी का भी प्रदर्शन किया। इस प्रकार, PPF-70 और PPF-80 मिश्रित प्रणालियों का उपयोग इंजीनियर EMs के निर्माण के लिए किया जा सकता है। इसके अलावा, पीएलए / पीसीएल मिश्रण-आधारित मनका-मुक्त ईएम के संरचनात्मक निर्माण और अनुकूलन को रिस्पांस सरफेस मेथोडोलॉजी (आरएसएम) और तागुची डिजाइन ऑफ एक्सपेरिमेंट्स (डीओई) का उपयोग करके किया गया था। तीन नियंत्रण मापदंडों यानी पीसीएल सामग्री, एन, एन-डाइमिथाइलफॉर्मामाइड (डीएमएफ) सामग्री, और इलेक्ट्रोसपिनिंग समाधान एकाग्रता से, ईएम के बीच मनका दोषों को कम करने के लिए इष्टतम पैरामीट्रिक संयोजन प्राप्त किए गए थे। प्रायोगिक परीक्षणों की संख्या में अंतर के बावजूद, आरएसएम और तागुची दोनों दृष्टिकोणों से पैरामीट्रिक अनुकूलन परिणाम समान रहे। तागुची-डिज़ाइन से अनुमानित परिणामों की प्रयोगात्मक मान्यता ने मनका दोषों और औसत फाइबर व्यास को कम करने से संबंधित > 95% सटीकता के साथ एक उत्कृष्ट समझौता दिखाया। इष्टतम रूप से डिज़ाइन की गई ईएम संरचनाओं ने सिवनी प्रतिरोध का एक समान रूप से इष्टतम स्तर दिखाया, जहां ठीक फाइबर ने सहकारी नेटवर्क प्रभावों के कारण सिवनी विफलता के लिए उच्च प्रतिरोध की पेशकश की, अपेक्षाकृत मोटे फाइबर-आधारित ईएम के विपरीत, जो फाइबर बकलिंग और लैबाइल स्ट्रक्चरल में फाइबर स्लिपेज के लिए जिम्मेदार थे। नेटवर्क।

(ए) विलायक आसंजन और (बी) गर्म संपीड़न तकनीकों को अपनाकर पीएलए / पीसीएल-आधारित उलझे हुए ईएम (फाइबर व्यास ~250- 850 एनएम) पर पीएलए / पीसीएल मिश्रित फिल्मों (~150 माइक्रोन) के संघनन द्वारा एकीकृत संरचनाएं भी गढ़ी

गई थीं। सॉल्वेंट-कास्ट फिल्मों और एकीकृत मिश्रित पैच के रूपात्मक, थर्मल, माइक्रोस्ट्रक्चरल और अर्ध-यांत्रिक गुणों की जांच की गई। यह पाया गया कि विलायक-सहायता प्राप्त समेकन दक्षता गर्म संपीड़न-सहायता प्राप्त समेकन तकनीकों से कमतर रही। गर्म संपीड़न द्वारा प्राप्त मिश्रित पैच में तन्य शक्ति/मापांक बेहतर रहा जबकि सॉल्वेंट-असिस्टेड कंसॉलिडेशन तकनीक द्वारा प्राप्त पैच में स्ट्रेन-एट-ब्रेक बेहतर था। अध्ययन ने ट्यून करने योग्य भौतिक-यांत्रिक गुणों के साथ संरचनात्मक रूप से इंजीनियर 3डी समग्र पैच विकसित करने की वैचारिक व्यवहार्यता स्थापित की। बाद के एक अध्ययन में, करक्यूमिन (CUR)-लोडेड पीएलए / पीसीएल EMs को उत्कृष्ट वाहक प्रणालियों के रूप में गढ़ा गया था, जो पेपास-कोर्समेयर, हिगुची, कोप्चा मॉडल और नए सामान्यीकृत लॉगरिदमिक मॉडल की पुष्टि करते हुए एक प्रसार-नियंत्रित तंत्र रिलीज व्यवहार प्रदर्शित करता है। गढ़े हुए ईएम के संरचनात्मक और विस्कोलेस्टिक गुणों के मूल्यांकन ने सीयूआर सामग्री में वृद्धि के साथ, बढ़ाव में बाद में कमी के साथ-साथ मापांक और ताकत में वृद्धि दिखाई। ईएम में सिवनी-प्रेरित सहकारी पतन की गतिशीलता को तीन-चरण की प्रक्रिया के रूप में पाया गया है, जिसमें स्थिर, स्थिर-अस्थिर, और तेज़-अस्थिर संरचनात्मक विफलता शामिल है, जो नेटवर्क पुनर्संरेखण, पार्श्व पुलआउट / तंतुओं के फ्रैक्चर और दरार के साथ अलग-अलग फाड़ के अनुरूप है। पथ। विस्कोलेस्टिक प्रतिक्रियाओं ने पीसीएल चरण के कांच संक्रमण तापमान (टीजी) में एक प्रमुख बदलाव दिखाया, जो कि सीयूआर-प्रेरित सूक्ष्म संरचनात्मक परिवर्तनों के विकास को दर्शाता है और पीएलए / पीसीएल-आधारित ईएम के बहुलक खंडों के बीच एच-बॉन्डिंग इंटरैक्शन की उपस्थिति के लिए जिम्मेदार है। इस प्रकार, अध्ययन दर्शाता है, पीएलए/पीसीएल-आधारित सीयूआर-लोडेड बायोडिग्रेडेबल ईएम की कार्यात्मक रूप से कुशल डिजाइनिंग, ट्यून करने योग्य यांत्रिक गुणों और हाइड्रोफोबिसिटी के निरंतर प्रतिधारण के साथ, (इन-विट्रो) सीयूआर रिलीज की सीमा के बावजूद। इसी तरह, बीटा-साइक्लोडेक्सट्रिन (β-CD) के रूपात्मक, थर्मल और माइक्रोस्ट्रक्चरल गुणों पर लोड होने के प्रभाव की पूरी तरह से जांच की गई। अध्ययनों से पता चला है कि मापांक में वृद्धि हुई है और β-CD सामग्री के ~2.5-5 phr के लिए ताकत देखी गई थी, हालांकि, यांत्रिक गुणों को β-CD सामग्री> 5 phr के लिए बिगड़ते हुए देखा गया था। स्पेक्ट्रोस्कोपिक विश्लेषण ने इथेनॉल-पानी के घोल से CUR को हटाने और गढ़े हुए EMs के β-CD हाइड्रोफोबिक गुहाओं (जारी) में इसके साथ-साथ एनकैप्सुलेशन को स्पष्ट किया। इस प्रकार, अध्ययन बायोमेडिकल अनुप्रयोगों के लिए ट्यून करने योग्य भौतिक-यांत्रिक गुणों के साथ बायोडिग्रेडेबल-कार्यात्मक ईएम के विकास को प्रदर्शित करता है, जिससे एनकैप्सुलेशन की सुविधा होती है और सिस्टम से अपशिष्ट हाइड्रोफोबिक अल्ट्राफाइन अणुओं को तेजी से हटाया जाता है।

सह-विलायक (IC-1) और सामान्य विलायक (IC-2) वर्षा तकनीकों का उपयोग करके तैयार CUR और β-CD आधारित समावेशन परिसरों (ICs) के संश्लेषण और लक्षण वर्णन का मूल्यांकन किया गया था। थर्मल और माइक्रोस्ट्रक्चरल लक्षण वर्णन ने IC-2 के लिए दोनों तरफ से β-CD के साथ CUR का पूरा एनकैप्सुलेशन प्रदर्शित किया। इस प्रकार, अध्ययन CUR / β-CD IC के बेहतर नियंत्रित नैनोकणों (NPs) को गढ़ने की संभावना को प्रदर्शित करता है, जो CUR रिलीज की बढ़ी हुई प्रभावकारिता और स्थिरता के साथ प्रत्यारोपण और उपकरणों की बायोमेडिकल सतहों पर इलेक्ट्रोस्प्रे होने की एक महत्वपूर्ण क्षमता प्रदर्शित करता है। बाद के एक अध्ययन में, तागुची के प्रयोगात्मक डिजाइन का उपयोग करके न्यूनतम औसत व्यास और भिन्नता के साथ एक समान मनका मुक्त नैनोफाइबर प्राप्त करने के लिए, CUR और β-CD के IC को इलेक्ट्रोसपुन PVA नैनोफाइबर में बेहतर रूप से शामिल किया गया था। विचरण के विश्लेषण (ANOVA) ने IC-लोडेड PVA-आधारित EMs के लिए औसत फाइबर व्यास और मनका दोषों की संख्या पर IC लोडिंग का एक बड़ा प्रभाव दिखाया। यह आईसी और पीवीए मैट्रिक्स के बीच महत्वपूर्ण बातचीत की उपस्थिति के लिए जिम्मेदार है। अध्ययन ने संभावित दवा रिलीज सबस्ट्रेट्स के रूप में

संरचनात्मक रूप से इंजीनियर हाइड्रोफिलिक आईसी-लोडेड पीवीए-आधारित ईएम के इष्टतम डिजाइनिंग को अवधारणात्मक रूप से प्रदर्शित किया।

इसके अलावा, पीसीएल-बी-पीएलएलए डिब्लॉक कॉपोलीमर और इसके ईएम को उनके सूक्ष्म संरचनात्मक, थर्मल और भौतिक-यांत्रिक गुणों के लिए विशेषता थी। औसत फाइबर व्यास (Co-FD) और व्यास भिन्नता (Co-SD) के इष्टतम स्तर को प्रदर्शित करने वाले संश्लेषित कॉपोलीमर के EMs को तागुची के प्रायोगिक डिजाइन के बाद प्राप्त किया गया था। अनुकूलित ईएम के भौतिक-यांत्रिक गुणों का मूल्यांकन यांत्रिक गुणों पर एफडी और एसडी के प्रभाव के साथ किया गया था। सूजन और वजन घटाने ने पीसीएल-बी-पीएलएलए आधारित ईएम में उल्लेखनीय सुधार दिखाया, जो जैव चिकित्सा सामग्री के रूप में उनकी बढ़ी हुई संगतता की संभावना को दोहराते हैं। इसी तरह, बाद के एक अध्ययन में, पॉली (एल-लैक्टाइड-को-ε-कैप्रोलैक्टोन) (पीएलसीएल) एकाग्रता ने थर्मोडायनामिक रूप से अमिश्रणीय पीएलए / पीसीएल (70:30 डब्ल्यू / डब्ल्यू) के थर्मल, माइक्रोस्ट्रक्चरल, मैकेनिकल और विस्कोलेस्टिक विशेषताओं में भिन्नता को प्रेरित किया। मिश्रण-आधारित ईएम, का मूल्यांकन किया गया था। सतह इलेक्ट्रोनगेटिव क्षमता, विशिष्ट सतह क्षेत्र, ताकना-मात्रा, ताकत और मापांक में वृद्धि के बाद बढ़ाव में कमी के साथ ईएम के लिए कम कोपोलिमर सामग्री (~2.5 से ~5 phr) के साथ महत्वपूर्ण बातचीत की उपस्थिति का संकेत दिया गया था। ब्लॉक कॉपोलीमर और मिश्रित मैट्रिक्स की संबंधित बहुलक श्रृंखलाएं। इसके अलावा, इंजीनियर ईएम की सतह की प्रतिक्रिया ने सेल व्यवहार्यता में बाद में वृद्धि के साथ हाइड्रॉक्सीपैटाइट्स के सोखने की महत्वपूर्ण क्षमता का प्रदर्शन किया। इस प्रकार, अध्ययन बायोमेडिकल उपकरणों के विकास में इसके संभावित उपयोग के लिए एक समान बहुलक-आधारित डिब्लॉक कॉपोलीमर का उपयोग करके ट्यून करने योग्य गुणों के साथ अमिश्रणीय बहुलक मिश्रणों के सतह-सक्रिय, संगत, बायोडिग्रेडेबल, और संरचनात्मक रूप से स्थिर ईएम को डिजाइन करने के लिए एक कुशल दृष्टिकोण की रिपोर्ट करता है। इसके अलावा, आईसी-लोडेड पीवीए कोटेड कॉम्पैटिबिलाइज्ड पीएलए/पीसीएल ब्लेंड (~2.5 phr कॉपोलीमर कंटेंट) आधारित हाइब्रिड ईएम के भौतिक-यांत्रिक प्रदर्शन का मूल्यांकन किया गया था। यहाँ, ~60 wt. % और ~80 wt. % आईसी लोडेड पीवीए-आधारित ईएम, उत्कृष्ट रोगाणुरोधी प्रभावकारिता प्रदर्शित करता है, आसन्न बैक्टीरिया <10% के साथ। इसके अलावा, एच-बंधुआ आईसी और पीवीए लेपित हाइब्रिड ईएम के लिए सेल अटैचमेंट क्षमता में वृद्धि, यानी ~135% देखी गई। इस प्रकार, अध्ययन संभावित घाव ड्रेसिंग सामग्री के रूप में इंजीनियर संरचनात्मक रूप से स्थिर, व्यवहार्य, जैव-संगत, और रोगाणुरोधी ईएम के विकास को प्रदर्शित करता है।

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# LIST OF ABBREVIATIONS

| Abbreviations | Full form |
|---|---|
| **EM** | Electrospun (nano-/micro-fibrous) mat |
| **NP** | Nanoparticle |
| **ECM** | Extracellular matrix |
| **PLA** | Poly (lactic acid) |
| **PCL** | Polycaprolactone |
| **PVA** | Polyvinyl alcohol |
| **PLCL** | Poly(L-lactide-co-ϵ-caprolactone) |
| **CUR** | Curcumin |
| **β-CD** | β-cyclodextrin |
| **IC** | Inclusion complex |
| **IC-1** | Inclusion complex prepared by co-solvent precipitation technique |
| **IC-2** | Inclusion complex prepared by Common solvent precipitation technique |
| **PM** | Physical mixture |
| **CF** | Chloroform |
| **DCM** | Dichloromethane |
| **DCE** | Dichloroethane |
| **AC** | Acetone |
| **EtOH** | Ethanol |
| **DMF** | *N*, *N*-dimethylformamide |
| **DMSO** | Dimethyl sulfoxide |
| **DMSO-d6** | Deuterated dimethyl sulfoxide |
| **PBS** | Phosphate Buffer Saline |
| **OA** | Orthogonal array |
| **RSM** | Response surface methodology |
| **ANN** | Artificial neural network |
| **ANOVA** | Analysis of variance |
| **DoE** | Taguchi design of experiments |
| **S/N** | Signal-to-noise ratio |
| **RED** | Relative Energy Difference |
| ***E. coli*** | Escherichia coli |
| ***S. aureus*** | Staphylococcus aureus |
| **LB** | Luria broth |
| **SEM** | Scanning Electron Microscopy |
| **FESEM** | Field Emission scanning Electron Microscopy |
| **AFM** | Atomic Force Microscopy |
| **DSC** | Differential Scanning Calorimetry |
| **TGA** | Thermogravimetric Analysis |
| **WAXD** | Wide Angle X-ray diffraction |
| **FTIR** | Fourier transform infrared spectroscopy |
| **$^1$H NMR** | Proton nuclear magnetic resonance spectroscopy |
| **WCA** | Water contact angle |
| **DMA** | Dynamic mechanical analysis |
| **EDX** | Energy Dispersive X-Ray Analysis |
| **BET** | Brunauer-Emmett-Teller |
| **BJH** | Barrett–Joyner–Halenda |
| **DMEM** | Dulbecco’s modified Eagle’s medium |
| **FBS** | Fetal Bovine Serum |
| **MTT** | 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl tetrazolium bromide |

# LIST OF SYMBOLS

| Symbol | Meaning |
|---|---|
| $C_e$ | Chain entanglement concentration |
| $\rho$ | Density |
| $\Delta H$ | Variation in enthalpy of endothermic peak |
| $\Delta H_{mo}$ | Variation in enthalpy of fusion for a completely crystalline polymer |
| $\Delta H_m$ | Variation in enthalpy of fusion |
| $\Delta H_c$ | Variation in crystallization enthalpy |
| $\Delta H_{cc}$ | Variation in cold-crystallization enthalpy |
| $T$ | Endothermic peak temperature |
| $T_m$ | Melting temperature |
| $T_g$ | Glass transition temperature |
| $T_c$ | Crystallization temperature |
| $T_{cc}$ | Cold-crystallization temperature |
| $T_d$ | Degradation temperature |
| $\chi_c$ | Relative crystallinity |
| $A_c$ | Crystalline area |
| $A_a$ | Amorphous area |
| $L$ | Crystallite size |
| $\lambda$ | Wavelength of radiation |
| $\beta$ | FWHM (fullwidth at half maximum) |
| $2\theta$ | Diffraction angle |
| $K$ | Proportionality constant (~0.9) |
| $M_i$ | Initial weight of samples |
| $M_s$ | Weight of swollen samples |
| $M_d$ | Weight of dried samples |
| $S_{max}$ | Maximum displacement |
| $F_{max}$ | Maximum load |
| $E'$ | Storage modulus (from DMA) |
| $E''$ | Loss modulus (from DMA) |
| $\tan\delta$ | Damping parameter/ loss tangent |
| $E$ | Elastic modulus |
| $\sigma_{max}$ | Tensile strength |
| $\varepsilon_b$ | Strain-at-break |
| $\chi$ | Flory-Huggins chi parameter |
| $\delta_p$ | Hildebrand solubility parameters of polymer |
| $\delta_s$ | Hildebrand solubility parameters of solvent |
| $\rho_s$ | Density of the solvent |
| $T$ | Absolute temperature (K) |
| $R$ | Universal gas constant |
| $\delta$ | Solubility parameter |
| $\delta_T$ | Total solubility parameter (HSP theory) |
| $\delta_P$ | Polar interactions |
| $\delta_D$ | Dispersive interactions |
| $\delta_H$ | Hydrogen bonding interactions |
| $R_A$ | Distance between the polymer and solvent molecules |
| $R_A$ | Solvent coordinate position from center of the polymer sphere |
| $R_{AO}$ | Interaction radius of the polymer sphere |
| $\varepsilon$ | Dielectric constant |

| | |
|---|---|
| $M_t$ | Cumulative amount of curcumin released at time t |
| $M_\infty$ | Initial curcumin loading |
| $n$ | Diffusion exponent |
| $K$ | Constant characteristic of a curcumin-polymer system (Peppas-Korsmeyer equation) |
| $K_o$ | Zero-order release constants |
| $K_1$ | First-order release constants |
| $K_H$ | Higuchi dissolution constant |
| $A$ | Diffusion rate constant |
| $B$ | Curcumin erosion rate constant |
| $S_o$ | Intrinsic solubility of pure curcumin |
| $K$ | IC stability constant |
| $\zeta$ | Zeta potential |
| $I_s$ | Streaming current |
| $\Delta p$ | Hydrodynamic pressure difference |
| $\eta$ | Viscosity |
| $\varepsilon_r$ | Dielectric permittivity of liquid |
| $\varepsilon_0$ | Dielectric permittivity of vacuum |
| $L$ | Length of cross-section of the streaming channel |
| $A$ | Area of cross-section of the streaming channel |