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Bio-based resins for 3D-printing of sustainable polymers

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Stereolithography 3D-printing has gained attention due to its versatility to produce polymeric structures with high resolution and precision. This technique relies on the photopolymerization of liquid resins that are typically derived from fossil sources, which poses environmental challenges. In response, sustainable bio-based photoresins offer a promising route to reduce the carbon footprint. Several studies have explored formulations that include monomers derived from vegetables oils provided of acrylated functionality compatible with 3D-printing systems [1].

In this work, three resin formulations based on epoxidized soybean oil acrylate (ESOA) as monomer and ethanol as solvent were assessed. In addition, a fixed amount of photoinitiator (phenylbis(2,4,6-trimethylbenzoyl) phosphineoxide) and photoabsorber (β-carotene) were added to initiate and control the polymerization. The ESOA:ethanol weight ratios studied were 50:50 (R1), 75:25 (R2) and 90:10 (R3). Photoresins were placed in silicone molds and subjected to UV light to evaluate their behavior prior to 3D-printing. R1 resin exhibited low viscosity, due to the high ethanol content, and generated a brittle polymer with significant shrinkage. In contrast, the decrease of ethanol in R2 provided an intermediate viscosity resin that favored the formation of a solid polymer with good structural integrity. However, the drastic reduction of ethanol in R3 led to a high viscosity resin which, although it polymerizes in a solid structure, can limit its processability by stereolithography 3D-printing. These results suggest that R2 represents an optimal balance between low-viscosity resin and mechanical performance to develop sustainable and functional porous carbon materials with complex architectures through carbonization of the photopolymer.

Keywords: bio-based monomer; photopolymerization; soybean oil; stereolithograph; porogen.

Acknowledgments:
The authors acknowledge the financial support through the research grants 2022-T1/AMB-23946 and CNS2024-154264.

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La emisión de microfibras sintéticas textiles como amenaza sistémica a los límites planetarios.

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La industria textil es la principal responsable de la emisión de microfibras sintéticas al medio ambiente. Se estima que un tercio de los microplásticos oceánicos procede directamente de este sector, lo que representa una amenaza creciente para la salud de los ecosistemas y la biosfera [1]. Estas microfibras, que se desprenden principalmente durante el lavado y el fin de vida útil de las prendas, forman parte de una contaminación difusa presente ya en todos los compartimentos ambientales, incluidos los más íntimos de nuestro organismo, como placenta, cerebro u órganos reproductivos [2]. A pesar de la acumulación creciente de evidencia científica que nos advierte sobre su persistencia, bioacumulación y toxicidad potencial en organismos vivos, la respuesta del sector textil y normativas de ecodiseño sigue siendo prácticamente inexistente. La complejidad de su comportamiento ambiental y sus posibles efectos combinados con otras sustancias dificulta establecer umbrales de seguridad claros, lo que contribuye a que este impacto siga siendo ignorado [3].

Este estudio propone un análisis del impacto de los microplásticos desde el marco de los límites planetarios, una perspectiva que permite adoptar una visión global sobre los umbrales que condicionan la estabilidad del Holoceno, la base de la existencia del ser humano4. Así, se amplía el foco más allá de indicadores tradicionales —como el uso de agua o las emisiones de gases de efecto invernadero— para incorporar límites críticos como la contaminación química o la integridad de la biosfera. Se analizará cómo esta contaminación no solo incide en el límite de “nuevos contaminantes”, ya transgredido, sino también en otros como la acidificación oceánica o el cambio climático5. Este enfoque busca concienciar sobre la importancia de este problema y ponerlo en el centro del debate sobre sostenibilidad en el textil.

Palabras Clave: microfibras sintéticas; contaminación por microplásticos; límites planetarios; ecodiseño textil; contaminación química.

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Reciclado y reutilización de materiales compuestos de una pequeña pala eólica

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La industria eólica se ha marcado el objetivo de que en año 2030 el 100% de los componentes de los aerogeneradores sean reciclables. Actualmente se recicla entre el 85-90%, y el cuello de botella se encuentra en los materiales compuestos. Las palas eólicas, son el componente más difícil de reciclar. Están fabricadas principalmente por materiales compuestos, mediante fibras de vidrio y resinas termoestables, que cuando llegan al final de su vida útil no es posible una fácil separación de estos materiales [1]. Existen varias tecnologías de reciclado de los materiales compuestos en diferentes fases de desarrollo, y falta por ver cuál será la que aporte mayor viabilidad en todos los aspectos, tanto técnica, ambiental como económicamente. Este estudio presenta el reciclado de una pequeña pala eólica fabricada con resina termoplástica y la reutilización de las fibras obtenidas durante el reciclado para la fabricación de una nueva pala eólica. La sustitución de la resina termoestable por resina termoplástica, ayuda al reciclado de los materiales compuestos y a la recuperación de los materiales al final de su vida útil. El proceso de reciclado químico ha sido realizado mediante la disolución de la pala usando acetona como solvente. Posteriormente se han reutilizado las fibras recicladas para volver a fabricar otra pala mediante el proceso de infusión de resina asistido por vacío (VARI).

Palabras Clave: reciclado; composites; aerogenerador; pala.

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Recycling and reusing composites of a small wind turbine blade

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The wind industry has set a goal of 100% recyclable wind turbine components by 2030. Currently, between 85% and 90% are recycled, with the blades, made of composite materials, the most difficult component to recycle. Blades are primarily made of composite materials, using glass fibers and thermosetting resins, which cannot be easily separated at the end of life [1]. Several composite recycling technologies are in different stages of development, and it is pending to know which will be the most viable in all aspects: technical, environmental, and economically. This study presents the recycling of a small wind turbine blade made of thermoplastic resin and the reuse of the fibers obtained during recycling to manufacture a new wind turbine blade. Replacing thermoset resin by thermoplastic resin helps the recycling of composite materials and the recovery of materials at the end of life. The chemical recycling process was carried out by dissolving the blade using acetone as a solvent. The recycled fibers were then reused to manufacture another blade using the vacuum-assisted resin infusion (VARI) process.

Keywords: recycling; composites; wind turbine; blade.

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Emerging pollutant degradation processed by a novel 3D printed monolith: Performance evaluation and mechanisms

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A novel Cu@PLA monolith was prepared by 3D printing technology to activate persulfate (PS) for ciprofloxacin (CIP) removal from wastewater. This study focused on the development of a 3D catalyst from a commercial filament with a 73 wt.% Cu composition and a polymeric matrix of polylactic acid (PLA). The monolith design was a cylinder with an internal mesh, adopted to improve the fluid dynamics. Continuous-flow reactor experiments were conducted to investigate the effects of different operating parameters on CIP removal. Our findings indicated that the immersion of Cu@PLA monolith in an alkaline solution for 15 min activated the surface of the catalyst owing to the increase in Cu at%. After this process, the PS dose was optimised to 0.5 mM to achieve 90% of CIP degradation. The other parameters were pH_0 = 5, flow rate = 0.22 mL/min, T^a = 25°C and CIP = 1.3 ppm. The performance in long-term experiments (7 days) was excellent, with a slight efficiency decrease from the first hours (90%) to 84% at the end of the experiment. Moreover, the degradation mechanisms and transformation pathways were elucidated by scavenging tests and liquid chromatography/mass spectrometry, respectively. Finally, the feasibility of the system was demonstrated in real water matrices [1,2].

Keywords: heterogeneous catalyst, 3D printing technology, ciprofloxacin, advanced oxidation processes, zero-valent copper, PLA based composite.

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Green chemistry towards fluorescent polymeric VOCs sensors

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Water and air quality control is crucial in our society, and developing user-friendly sensing devices for specific molecules can greatly enhance air and water management.

In this work we present the development of two fluorescent polymeric sensors with high sensitivity and selectivity towards two highly toxic volatile organic compounds (VOCs) that threaten human health and the environment: formaldehyde and hydrogen sulphide.

Guided by the principles of green chemistry and circular economy [1], this work has been designed to maximize the environmental sustainability throughout the whole process of the sensor's preparation: the use of biobased polymers, green solvents and green techniques, and the minimization of synthetic and purification steps.

The sensors consist of a solid film made from naphthalimide-functionalized cellulose (NAP-Cell), which exhibits a rapid and highly sensitive fluorescence response upon contact with specific volatile organic compounds (VOCs). The solvents employed have been ionic liquids (ILs), water and ethanol, and most of the reactions proceed through microwave-assisted and UV-Vis irradiations, which are known as two of the most eco-friendly techniques.

Finally, the synthesis of the sensor devices has been repeated using regenerated cellulose obtained from agricultural waste as starting material to obtain the sensors, and then, one more sustainable step has been added to the whole strategy.

Keywords: green chemistry, VOC sensors, fluorescent sensing

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Renewable hydrogen from reinforced plastic waste of the recreational nautical sector

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The use of fibre-reinforced plastics (FRP) in the energy and transport sectors contributes to sustainability due to their low weight, which helps to reduce fuel consumption and CO_2 emissions. However, there is an unresolved issue for them to be considered completely sustainable: the lack of an industrially established recycling process. Pyrolysis is presented as the best alternative for this waste, using heat in the absence of oxygen to decompose the plastic matrix into gases and vapours, and recovering reusable fibres.

The objective of this work is to study the thermo-catalytic treatment of the volatiles (gases+vapours) generated in the pyrolysis of an epoxy-based pre-preg waste from recreational boats in order to transform them into valuable feedstock as renewable hydrogen. This would mean closing the loop of thermoset plastics and provide a solution to improve the profitability of the pyrolysis-based recycling plants for FRP.

The experiments have been performed in a lab-scale installation composed of two reactors. In the first one, pyrolysis and oxidation of the pyrolysis solid occurred, while in the second one, the volatiles emerging from the pyrolysis process were thermocatalytically treated. Based on the experience of the research team [1,2] three catalysts have been selected and their influence on the gaseous yield and composition has been studied. These are: a by-product of the alumina production, mainly composed of Fe_2O_3, and two nickel commercial catalysts. As conclusion, volatiles thermal-catalytic treatments enhance the production of interesting products such as hydrogen, reducing significantly the yields of pyrolysis liquids generated.

Keywords: fibre-reinforced thermoset plastics waste; recycling; pyrolysis; volatiles thermal/catalytic treatment; renewable hydrogen.

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Bio-Based Epoxy Adhesives with Sensing and On-Demand Debonding Capabilities for Marine and Aerospace Applications

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The increasing depletion of petroleum resources and environmental concerns are driving the development of polymers from renewable feedstocks. Thermosetting resins, known for their chemical resistance, dimensional stability, and strong adhesion, are widely used in adhesives, coatings, and composites [1], [2]. Among them, epoxy resins stand out, however, over 85% of commercial formulations still rely on bisphenol A [3].

This work presents fully bio-based multifunctional epoxy adhesives synthesized from epoxidized soybean/linseed oils (ESO/ELO) and tannic acid (TA) [4]–[6], doped with carbon nanotubes (CNTs) to enable piezo- and thermo-resistive properties. These adhesives address emerging needs in the aerospace and marine sectors, where structural adhesives with sensing and on-demand de-bonding capabilities offer significant advantages over conventional systems.

Formulations with epoxy-to-hydroxyl molar ratios of 1:1 and 1:1.5, incorporating up to 5 wt. % CNTs, were prepared and tested. Mechanical characterization showed adhesive strengths of 10–20 MPa on steel substrates. Electrical conductivity reached ~0.1 $S \cdot m^{-1}$. Sensing functionality was demonstrated via piezo-resistive (GF = 0.4 – 0.8) and thermo-resistive ($S = 0.06\% \cdot °C^{-1}$) responses. Thermal and water-assisted debonding tests confirmed reliable disassembly, with performance comparable to oil-derived thermosetting adhesives.

These results demonstrate the potential of sustainable, multifunctional adhesives for intelligent structural applications and underline their relevance for next-generation material systems.

Keywords: Bio-based epoxy resins, Multifunctional adhesives, Piezoresistivity, Thermoresistivity, On-demand debonding

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Novel Self-Healing Systems for Electroactive Smart Coatings Based on Recycled Carbon Fibers

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A novel thermoplastic-based self-healing strategy aimed at extending the functional lifespan of coating materials and facilitating sustainable end-of-life management of carbon fiber-reinforced polymer (CFRP) composites. Polyethylene adipate (PEA) and polyethylene glycol (PEG), selected for their potential biodegradability and bio-based origin, were employed as self-healing agents within coatings reinforced with 15 wt.% recycled carbon fibers (rCFs). Formulations with varying thermoplastic contents were prepared and characterized.

The performance of these systems was benchmarked against the commonly used polycaprolactone (PCL). Results demonstrated excellent electrical conductivity (up to 17.09 S/m with 10% PEA) and efficient Joule heating (up to 173 °C at 20 V with 5% PEG). Scanning electron microscopy (SEM) was used to characterize the thermoplastics' morphologies, while profilometry quantified self-healing efficiency, reaching (89.98 ± 5.36) % for the 10% PEG formulation.

Dynamic mechanical analysis (DMTA) revealed retention of the storage modulus for PEG-containing coatings and a moderate reduction in PEA-based systems.

Additionally, all formulations exhibited a progressive decrease in glass transition temperature (Tg) with increasing thermoplastic content.

These findings underscore the viability of underutilized thermoplastics as dispersed self-healing agents in recycled CFRP coatings, enabling the development of advanced, upcycled materials that maintain high mechanical and electrical performance while promoting circular material strategies.

Keywords: Recycled carbon fibers; carbon fiber-reinforced polymer composites, smartcoatings

TiO_2 and RGO based electrodes for dye-sensitized solar cell application.

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TiO_2 films are characterized by excellent light scattering, UV absorption, photocatalytic activity, chemical stability, and biocompatibility. Therefore, it is considered a versatile material with a wide range of applications, most notably its use as a photoanode in DSSC technology [1, 2]. Thanks to its low-cost, its large surface area and its suitable bandgap energy of 3.2 eV, TiO_2, commonly deposited on conductive substrates, plays an essential role in the electron transport. To enhance the electron transport, prevent recombination processes and improve the efficiency of that photovoltaic technology, many studies are focused on the search for an effective method to modify the TiO_2 surface [3]. It has recently [4] been determined that the incorporation of 2D graphene materials into a TiO_2-based photoanode allows a strong interaction between the TiO_2 particles with this material, which accelerates the transport of electrons and prevents their loss between the TiO_2 particles. This work investigates the influence of the deposition of titanium dioxide (TiO_2) films, both as a blocking layer and as a conductive layer, on rigid and flexible substrates coated with a conductive film, specifically indium tin oxide (ITO). Reduced graphene oxide was incorporated into these electrodes to increase electron flow and solar energy absorption.

Palabras Clave: TiO_2; graphenic materials; photoanode; DSCC solar cells.

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Impresión 3D de resinas sostenibles fotocurables para estructuras de carbono poroso con arquitecturas complejas

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La fabricación de materiales de carbono poroso con arquitecturas complejas, dimensiones precisas y un rendimiento adaptado a entornos específicos representa un desafío creciente en la ciencia de materiales. Esto es especialmente relevante al utilizar técnicas de manufactura aditiva eficientes en energía, como la estereolitografía láser (SLA), que dependen de la fotorreactividad de resinas líquidas [1]. En este estudio, se investiga el uso de resinas fotocurables a base de taninos para producir estructuras de carbono poroso con geometrías complejas, en particular una superficie mínima periódica triplemente (gyroide) con un diámetro interno de 13 mm y una longitud de 70 mm. El proceso de impresión 3D se ha llevado a cabo con éxito, y los materiales resultantes han sido caracterizados en profundidad mediante análisis termogravimétrico y análisis elemental CHNS para evaluar tanto el fotopolímero como las estructuras carbonizadas, proporcionando información sobre su estabilidad térmica y composición elemental.

Palabras Clave: Estereolitografía: Monómeros de origen biológico; Tanino; Gyroide.

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3D printing of photocurable sustainable resins for porous carbon structures with complex architecture

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The on-demand fabrication of porous carbon materials with intricate architectures, precise dimensions, and tailored performance in specific environments represents a growing challenge in materials science. This is particularly relevant when employing energy-efficient additive manufacturing techniques such as laser stereolithography (SLA), which depend on the photoreactivity of liquid resins [1]. In this study, the use of tannin-based photocurable resin was investigated to synthesize porous carbon structures with complex geometries, specifically a triply periodic minimal surface (gyroid) with an internal diameter of 13 mm and a length of 70 mm. The 3D printing process was successfully carried out, and the resulting materials were thoroughly characterized. Thermogravimetric analysis and CHNS elemental analysis were employed to evaluate both the photopolymer and the carbonized structures, providing insights into their thermal stability and elemental composition.

Keywords: Stereolithography: Biobased Monomers; Tannin; Gyroid.

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Tailorable piezoelectric response directly from melt-based 3D printing of biocompatible PLLA

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Biobased and biodegradable poly-L-lactide (PLLA) stands out among piezoelectric polymers for its biocompatibility and environmental sustainability. Its piezoelectric response is closely related to crystallinity and polymer chains alignment, which is conventionally achieved by drawing techniques. The material technology implementation would strongly benefit from the demonstration of a single-step process capable of directly achieve tailored piezoelectric morphology in PLLA biopolymer from polymer melt. Fused deposition modelling (FDM) 3D printing can play this role, directly achieving tailored piezoelectric morphology in PLLA biopolymer by microscale control of molecular chain orientation through preparation parameters, such as 3D printing speed or bed temperature. The printing-crystal phase content and texture-piezoelectric properties relationships are comprehensively presented, and the key 3D printing parameters to obtain optimized piezoelectric chain morphologies are defined. Results reveal melt-based 3D printing to be a suitable technique for manufacturing biocompatible PLLA piezoelectric platforms that are also biodegradable. Commercial PLLA has been used, with which large shear piezoelectric coefficients d14 approaching 10 pC/N has been attained under optimized printing conditions. Additionally, the effects of molecular weight and printing pattern on the piezoelectric response are evaluated, offering insights into material performance enhancement.

Keywords: Biopolymer; 3D printing; Fused Deposition Modelling; Piezoelectricity: Tissue Engineering.

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Fluorine-doped TiO_2@BODIPY hybrids: combined effects for enhanced visible-light photocatalytic activity and improved ROS generation

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Titanium dioxide (TiO_2) is among the most extensively studied photocatalysts due to its high chemical stability, low cost, and effectiveness in the degradation of organic compounds. However, its limited absorption in the visible region of the electromagnetic spectrum, coupled with the rapid recombination of photogenerated electron-hole pairs, constrains its overall performance under solar irradiation.

In this context, a functionalization strategy has been developed involving fluorine-doped TiO_2 modified with organic fluorophores such as BODIPY (4,4-difluoro-4-bora-3a,4a-diaza-*s*-indacene) family, with the aim of enhancing visible light absorption and promoting the generation of reactive oxygen species (ROS).[1] Fluorine doping favors the preferential exposure of the highly reactive {001} crystal facets,[2] while BODIPY derivatives offer tunable photophysical properties through structural functionalization. BODIPY compounds were synthesized bearing carboxylic acid groups at *meso* to enable covalent anchoring to the TiO_2 surface, heavy atoms (e.g., iodine) to facilitate intersystem crossing promoting singlet oxygen production. The resulting hybrid materials were characterized by spectroscopic techniques and exhibited a marked enhancement in visible light absorption and photocatalytic efficiency, as evidenced by increased radical generation. These findings highlight the potential of TiO_2-BODIPY systems as versatile and efficient platforms for advanced photocatalytic applications under visible light irradiation.

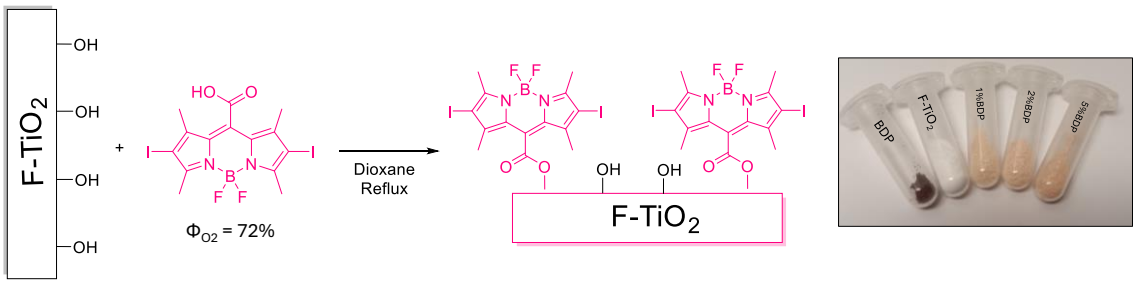

Figure 1. Functionalization scheme of fluorine-doped titanium oxides with BODIPY.

Keywords: Titanium dioxide; fluorine doping; BODIPY functionalization; visible-light photocatalysis; reactive oxygen species; photocatalytic activity

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Estudio de la sinergia entre nanofibras de lignina y estructuras metal-orgánicas (MOF) obtenidas por electrospinning para aplicaciones del medio ambiente

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Las estructuras metal-orgánicas (MOFs) destacan por su ajustabilidad estructural y química, aislamiento eléctrico y porosidad controlable, lo que permite interacciones específicas con iones. Estos materiales son estables en medios acuosos y han sido utilizados en la captura de agua en ambientes agresivos o tóxicos. Además, su producción puede ser rentable al emplear precursores metálicos y bloques orgánicos de bajo costo [1]. Entre ellos, el ZIF-8 (Zn(2-metilimidazolato)) resalta por su elevada estabilidad térmica y química, siendo uno de los MOFs más estudiados.

Dado que los MOFs suelen ser frágiles, es común integrarlos sobre sustratos poliméricos para mejorar su flexibilidad. El electrohilado ha sido recientemente reportado como una técnica eficiente para incorporar MOFs en fibras híbridas, combinando porosidad, alta área superficial y funcionalidad, lo que amplía su aplicabilidad en sectores como la energía y el medio ambiente [2].

Ante la necesidad creciente de materiales sostenibles para aplicaciones avanzadas, la lignina —un biopolímero abundante derivado de la biomasa— surge como alternativa viable a los polímeros fósiles. Las fibras de lignina presentan propiedades adecuadas para almacenamiento de energía (baterías, supercapacitores, celdas solares) y procesos catalíticos y ambientales (como soporte de catalizadores, fotocatalizadores, o adsorbentes para purificación de agua o captura de compuestos orgánicos volátiles) [3].

Las nanofibras híbridas de ZIF-8/lignina, tras tratamiento térmico, fueron caracterizadas mediante SEM y TEM para evaluar la incorporación de nanopartículas. Además, se analizaron sus propiedades texturales (BET, distribución de poro) y su capacidad de sorción y co-sorción de CO_2 (DVS y BTA).

Palabras Clave: MOF, nanofibras de lignina, electrospinning.

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Design, manufacturing and development of piezoelectric PLLA-ZnO nanocomposites by 3D printing.

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The main objective of this research is the synthesis of nanoparticles for coordination with bio-based polymers for developing composite materials with improved piezoelectric properties that are flexible, more sustainable and efficient for new applications in potentially disruptive technologies, such as wireless sensor networks and bio-implanted medical devices. For this purpose, two materials with piezoelectric properties are used, which, through their combination in a bionanocomposite, achieve a higher electrical response. These materials are poly-L-lactic acid with medical grade purity (PLLA) and zinc oxide nanorods. From 2D WAXS, DSC and electron microscopy analysis of 3D printed bionanocomposites, we could deduce that the piezoelectric morphology of PLLA is both influenced by the filler and the processing parameters [1,2,3,4]. This observation allows us to address one of the main challenges in the fabrication of piezoelectric materials and devices, which is to achieve a structure and arrangement that favors the piezoelectric response of the produced devices. This challenge has been overcome by 3D printing, through which it has been possible to orient both the polymeric chains of the matrix and the nanoparticles inside it, achieving a high electrical response. Both the elongation and the orientation of the printed material are key to increase the final piezoelectric response of the device (4.7 pC/N), for which the 3D printing conditions have been optimized to achieve thin and flexible films that are adaptable to different structures using specialized 3D printing equipment [5].

Keywords: bionanocomposites; poly-L-lactic acid; 3D printing; piezoelectricity

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Study of biopolymer-lignin composites for piezoelectric energy harvesting

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Biopolymers such as poly(β-hydroxybutyrate) (PHB) display interesting properties such as piezoelectricity, biodegradability, biocompatibility and flexibility in the context of finding novel energy harvesting strategies [1]. However, they are costly to produce and may suffer from limited processability. Adding lignin, an industrial waste product available in large quantities, offers a potential solution to these limitations and contributes to its valorization [2,3]. This study investigates whether the addition of lignin as a plasticizer enhances the piezoelectric response of PHB. A series of PHB-based composites with lignin contents from 5 to 30 wt% were prepared and processed via 3D-printing. In parallel, PHB reference films were prepared by solvent casting to study the properties of the neat polymer and the influence of 3D-printing. The different resulting materials were characterized using Scanning Electron Microscopy (SEM), Attenuated Total Reflectance Infra-Red (ATR-IR), Differential Scanning Calorimetry (DSC), X-Ray Diffraction (XRD) and scattering (WAXS/SAXS), and Potentiometry in order to study the influence of lignin and of 3D-printing on the textural and functional properties of PHB. Our preliminary results show that both the addition of lignin and 3D-printing increased the crystallinity of the samples, while a low piezoelectric response of 3D-printed PHB hints at insufficient PHB chain alignment, which leaves room for further optimization of the printing process.

Keywords: Poly(3-hydroxybutyrate), 3D-printing, Piezoelectricity, Lignin

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Crosslinked macromolecule achieves toughening and superior char-formation flame retardant effect in polypropylene

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In this work, a novel dendritic copolymer PNSi-co-MP as an intumescent flame retardant was fabricated using a silicon-, phosphorus- and nitrogen-containing monomer (PNSi) and melamine phosphate (MP) [1,2]. Random copolymerization way disrupted the regularity of monomer arrangement, resulting in the thermal deformation behavior of PNSi-co-MP being different from the self-polymerized macromolecule (MPNSi) / melamine polyphosphate (MPP) system. Consequently, PNSi-co-MP was distributed reasonably evenly in the polypropylene (PP) matrix, and some of the PNSi-co-MP particles deformed to 200-300 nm from 5~10 μm. More importantly, the toughness of PNSi-co-MP/PP was dramatically increased compared with MPNSi/MPP/PP. Specifically, 16PNSi-co-4MP/PP exhibited a 278% higher elongation at break and a 33.3% higher unnotched impact strength compared to 16MPNSi/4MPP/PP. Furthermore, PNSi-co-MP exhibited a rapid charring effect in PP. In a cone calorimeter test, the maximum combustion intensity of the composite was inhibited in only 17 seconds by the PNSi-co-MP molecule. Compared with the pure PP, the composite with 20 wt.% 12PNSi-co-8MP showed a 93.6% lower peak heat release rate and an 87.2% lower smoke production rate, indicating its excellent flame retardancy. The composites containing copolymer molecules also performed much higher flame retardancy than MPNSi/MPP/PP sample, although their chemical composition was almost the same except for the linking form of flame-retardant monomers. PNSi-co-MP simultaneously endowed PP with a higher limited oxygen index, glow wire flammability index, glow wire ignition temperature, residue yield, and fire

safety performance than MPNSi/MPP. The reason for this was that the copolymerization strategy aggregated the flame-retardant monomers into one molecule, thus effectively promoting the charring reaction. Accordingly, this work provided a new method for preparing flame-retardant molecules with comprehensive performance through molecular composition and structural design.

Keywords: intumescent flame retardant; rapid charring effect; copolymerization; toughening; polypropylene

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Obtención de películas bioactivas a partir de nanofibras de celulosa y nanopartículas de lignina polimerizada enzimáticamente

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La obtención de productos de alto valor añadido bajo el contexto de la bioeconomía circular se perfila como una de las soluciones para luchar contra el cambio climático y el agotamiento de los recursos fósiles. Por ello, en este trabajo se obtuvieron películas bioactivas a partir de biomasa de eucalipto combinando nanofibras de celulosa (NFC) y nanopartículas de lignina (NPL). Previamente, se llevó a cabo un pretratamiento enzimático respetuoso con el medio ambiente utilizando lacasas, con el fin de polimerizar la lignina y así modificar las propiedades de las películas obtenidas. El tratamiento con lacasas consiguió polimerizar con éxito la lignina, como así indica el aumento de su peso molecular promedio (de 3621 a 5681 Da) y la reducción de su contenido fenólico (de 552 a 324 mg GAE/g lignina). Además, esta polimerización provocó una reducción significativa del tamaño de las NPL resultantes (6,8 ± 2,4 nm) en comparación con las obtenidas a partir de la lignina sin tratamiento de polimerización (62 ± 22 nm).

La incorporación de NPL, tanto sin tratar como tratadas, confirió propiedades antioxidantes, antibacterianas y de protección UV a las películas obtenidas a partir de NFC-NPL. Se observaron mayores valores en las propiedades antioxidantes y de protección UV con las NPL polimerizadas, probablemente debido a su pequeño tamaño y a los grupos funcionales conjugados, respectivamente. Además, las películas con un 5% de NPL mostraron, en comparación con las películas control de NFC, mejor estabilidad térmica, alargamiento de rotura, permeabilidad al vapor de agua y transparencia.

Palabras Clave: Nanocelulosa; Nanopartículas de lignina, Películas bioactivas

Obtaining bioactive films from cellulose nanofibers and enzymatically polymerized lignin nanoparticles

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Obtaining high-value-added products within the context of the circular bioeconomy is emerging as one of the solutions to combat climate change and the depletion of fossil resources. Therefore, in this study, bioactive films were obtained from eucalyptus biomass by combining cellulose nanofibers (CNFs) and lignin nanoparticles (LNPs). An environmentally friendly enzymatic pretreatment using laccases was previously carried out to polymerize the lignin and thus modify the properties of the obtained films. The laccase treatment successfully polymerized the lignin, as indicated by an increase in its weight average molecular weight (from 3621 to 5681 Da) and a reduction in its phenolic content (from 552 to 324 mg GAE/g lignin). Furthermore, this polymerization caused a significant reduction in the size of the resulting LNPs (6.8 ± 2.4 nm) compared to those obtained from lignin without polymerization treatment (62 ± 22 nm).

The incorporation of both untreated and treated LNPs conferred antioxidant, antibacterial, and UV protection properties to the films obtained from CNF-LNPs. Higher antioxidant and UV protection values were observed with the polymerized LNPs, likely due to their tiny size and conjugated functional groups, respectively. Furthermore, films containing 5% LNPs showed improved thermal stability, elongation at break, water vapor permeability, and transparency compared to the CNF control films.

Keywords: Nanocellulose; Lignin nanoparticles; Bioactive films

Influencia de parámetros de fabricación aditiva en el comportamiento en agua de piezas poliméricas para aplicaciones sostenibles

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La sustitución de componentes metálicos por polímeros en entornos exigentes representa una estrategia clave para avanzar hacia soluciones más sostenibles y ligeras [1], [2], [3] . En este contexto, se presenta una investigación desarrollada por la Universidad Nacional de Educación a Distancia (UNED) en colaboración con la Universidad Rey Juan Carlos (URJC), centrada en el análisis del comportamiento en agua de piezas fabricadas mediante tecnología de fabricación por filamento fundido (FFF) con ácido poliláctico (PLA) y tereftalato de polietileno (PET).

El estudio evalúa la influencia de dos parámetros críticos de impresión —altura de capa y espesor de pared— sobre la absorción de agua, siguiendo la norma UNE-EN ISO 62:2008.

Se fabricaron probetas con geometría constante y configuraciones variables, que fueron sometidas a inmersión en agua destilada durante periodos controlados hasta alcanzar la saturación. Además, se analizó el efecto de recubrimientos protectores sobre la resistencia a la penetración de agua.

Los resultados permiten comprender cómo las condiciones de fabricación afectan al rendimiento de los materiales en medios húmedos, aportando información valiosa para el diseño de componentes poliméricos destinados a sustituir piezas metálicas en aplicaciones donde la interacción con el agua es un factor determinante.

Palabras Clave: ácido poliláctico (PLA); tereftalato de polietileno (PET); parámetros de fabricación; altura de capa; espesor de pared; fabricación filamento fundido (FFF)

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Aeso-based polymer composites containing biochar obtained by vat-photopolymerization technology

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Additive manufacturing (AM) technologies have been emerging as greener alternatives to production technologies for polymeric and polymer composite materials. Among the different AM technologies, vat-photopolymerization (VP), represents an easy method for obtaining well-defined objects by 3D printing. It is a light-based technology, which allows to obtain high printing resolution and a good level of shape complexity of the printed parts. During the process, the build platform is completely immersed within the photocurable resin and, thanks to the UV light, the liquid resin into the vat can be photocured and transformed into a uniform layer of solid material. The process goes on until the desired component is complete, according to the selected CAD model.

The present work aims to develop sustainable bio-based composites containing biochar (BC) as biofiller by using the Liquid Crystal Display (LCD) as 3D printing technology.

Acrylate epoxidized soybean oil (AESO) resin was used as photocurable polymer matrix, isorbornyl methacrylate (IBOMA) was used as reactive diluent, and phenyl bis (2,4,6-trimethylbenzoyl) phosphine oxide (BAPO) was employed as radical photo-initiator. Biochar coming from cellulose pyrolysis was used to prepare the composites by dispersing different amounts of filler within the AESO-based matrix. The printed specimens were fully characterized from thermal, morphological, and mechanical point of view. Several 3D printed parts were successfully realized showing very complex structures, high level of accuracy, and improved final properties in terms of elastic modulus, ultimate tensile strength, and glass transition temperature due to the reinforcing effect induced to the presence of the filler's particles, without significant effects on the thermal stability. Cell viability and cytocompatibility tests were also carried out to study their possible applications into the biomedical sector as for forearm splints.

Figure 1. 3D printed AESO-based objects filled with BC.

Keywords: Polymer composites; 3D printing technology; biochar

3D-printed acrylate epoxidized soybean oil (aeso)-based composites with agro-waste bio-fillers

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Additive manufacturing (AM) technologies are emerging as environmentally friendly production methods, offering simplified processes, compliance with performance standards, and advantages such as high precision, minimal raw material consumption, and reduced waste. Vat photopolymerization (VPP) is a technology that uses UV light to polymerize liquid photopolymers layer-by-layer and is an efficient, rapid prototyping tool. In recent years, polymer composites reinforced with bio-fillers have shown promise for AM, and the demand for sustainable production has brought bio-based polymers, derived from renewable resources to the forefront as viable alternatives to petroleum-based plastics.

At the same time, VPP technologies enable the creation of complex geometries with excellent dimensional stability, making them valuable in sectors such as automotive, packaging, and biomedical applications. However, a major obstacle to the wider application of VPP technology remains the scarcity of sustainable photocurable resins.

In response to this limitation, novel bio-based composites incorporating bio-fillers derived from agricultural wastes were successfully developed and designed using LCD-based VPP 3D printing.

The composites were prepared by integrating equal amounts (5 phr) of two agricultural by-product powders, one derived from corn agro-industrial processing (GTF) and the other from wine (WPL-CF). These bio-fillers were dispersed in a photopolymerizable resin matrix based on acrylate epoxidized soybean oil (AESO). Two reactive diluents, tetrahydrofurfuryl acrylate (THFA) and isobornyl methacrylate (IBOMA), were incorporated to adjust the resin properties, maintaining an AESO/diluent ratio of 60:40 by weight, with 2 phr of the radical photoinitiator BAPO (phenyl bis(2,4,6-trimethylbenzoyl)phosphine oxide).

Various characterizations were performed on powders, liquid formulations, and photocured specimens to evaluate rheological, morphological, mechanical, thermal, and viscoelastic properties.

The choice of reactive diluent significantly influenced the final properties of the composites: IBOMA resulted in stiffer and more structurally robust samples, while THFA produced more flexible and deformable samples. The inclusion of different biofillers also

resulted in different properties. The printed components showed high-resolution details and precise geometric definition.

In conclusion, the developed AESO-based composites successfully demonstrated distinct mechanical and structural behaviors, highlighting the possibility of tuning material properties through the selection of reactive diluents and the inclusion of bio-fillers derived from agricultural and industrial wastes.

Keywords: Polymer composites; Additive manufacturing; Biofillers

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Highly Efficient Electromagnetic Induction Heating for Recycling Plastics

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A circular economy is crucial to address plastic pollution's environmental and human impact. Thermal pyrolysis recycles plastics, but high energy use limits its economic viability because this demand of energy can be costly. Compared to conventional heating, induction heating in HDPE pyrolysis is more energy-efficient due to its ability to rapidly and precisely heat the material, resulting in faster reaction times, increased throughput, and reduced energy consumption., according to various studies [1,2].

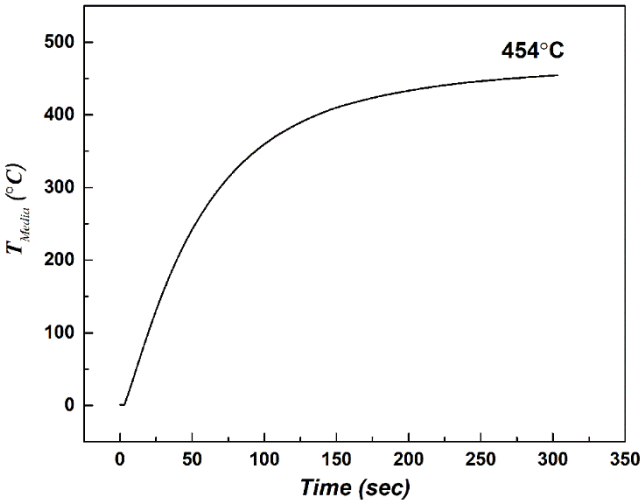

Figure 1. Media value of temperature achieved during heating of Metallic Lattice Structure at current intensity of 100A.

This study investigates the thermal pyrolysis of HDPE with 3D-fabricated metallic lattice structures (MLS) using induction heating. Complex and precise MLS were fabricated by Laser Powder Bed Fusion (LPBF) and additively manufacturing technology which selectively fuses the stainless-steel metal powder particles layer by layer. An alternating magnetic field is generated by a Helmholtz 4-turn copper coil that is connected to an induction heater (Easyheat system, Ambrell, UK) with a fixed current frequency of 230 kHz and an output power of 0.18 kW. All rights for this technology are reserved by the registered patent [3]. The results indicate that the temperature of the 3D-printed MLS reached a maximum of 454°C achieving a conversion of plastic feedstock within 10 min during the thermal pyrolysis. The polymer cracking process of HDPE was greatly enhanced by induction heating pyrolysis, resulting in new valuable products. This study

proved that a quick, energy-efficient, and adaptable plastic valorization method, based on the use of induction heating, was feasible.

Keywords: Induction Heating; Chemical Reactors; 3D-Priniting; Metallic Lattice Structures (MLS); Plastic Pyrolysis

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Potencial del Silicio Amorfo Hidrogenado para su aplicación en dispositivos energéticos sostenibles

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En el contexto energético actual, marcado por la urgente necesidad de transitar hacia un modelo sostenible y seguro, resulta imprescindible investigar materiales multifuncionales que sean abundantes, no críticos y de bajo impacto ambiental, pero que además presenten excelentes prestaciones tanto para la generación de energía renovable como para su almacenamiento [1]. Este enfoque es clave para reducir la dependencia de materiales estratégicos y garantizar la viabilidad tecnológica a largo plazo.

En este sentido, el silicio amorfo hidrogenado en lámina delgada, se posiciona como un material semiconductor no cristalino muy prometedor por su versatilidad y propiedades funcionales. En el ámbito de la energía fotovoltaica, gracias a su capacidad de pasivación superficial, resulta imprescindible su empleo para células de alta eficiencia. Además, es perfectamente compatible con tecnologías que requieren sustratos flexibles. Paralelamente, en almacenamiento electroquímico, ha despertado un notable interés como material alternativo al grafito en ánodos de baterías de ion-litio [2], contribuyendo a reducir el uso de este material, considerado crítico por la Comisión Europea debido a su limitada disponibilidad y creciente demanda.

Adicionalmente, el silicio amorfo puede ser fácilmente dopado, lo que mejora significativamente su conductividad eléctrica. También permite ser sometido a tratamientos térmicos para inducir su transformación en polisilicio, expandiendo así su campo de aplicación en dispositivos energéticos, como por ejemplo para las células fotovoltaicas TOPCOn dominantes actualmente en el mercado [3]. Estas características sitúan al silicio amorfo en un material de gran interés energético [4, 5], con un amplio potencial de aplicaciones en el desarrollo de tecnologías limpias y sostenibles.

Palabras Clave: silicio amorfo hidrogenado; lámina delgada; fotovoltaica; células solares; baterías de ion-litio; ánodos.

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Uso de nanocelulosa como refuerzo para mejorar las propiedades mecánicas de una matriz de vitrímero

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En la búsqueda de materiales ambientalmente sostenibles, este estudio investiga el desarrollo de nanocompuestos de vitrímeros reciclables y de origen biológico, reforzados con nanofibras de celulosa (CNF) de origen biológico [1]. Como alternativa a los polímeros termoestables, los vitrímeros son redes poliméricas permanentemente reticuladas que presentan enlaces covalentes dinámicos, lo que permite reacciones reversibles de intercambio de enlaces dentro de la estructura de la red [2]. Además, las nanofibras de celulosa (CNF) son nanomateriales de origen biológico de alta relación de aspecto, derivados de fuentes naturales de celulosa, que suelen presentar diámetros de entre 5 y 20 nm y longitudes de hasta varios micrómetros [3]. Las CNF se utilizan cada vez más como agentes de refuerzo sostenibles en sistemas de compuestos poliméricos avanzados.

En este trabajo, se incorporaron CNF a una matriz de vitrímero con porcentajes que oscilaban entre el 0,2 % y el 1,2 % en peso. Se evaluaron las propiedades mecánicas mediante ensayos de tracción y flexión en tres puntos, mientras que se empleó microscopía electrónica de barrido (MEB) para analizar las superficies de fractura. El análisis SEM confirmó la dispersión exitosa de las nanofibras y reveló un cambio en la iniciación de la fractura desde los bordes de la probeta en los vitrímeros no reforzados hasta la superficie de contacto con el refuerzo en los nanocompuestos. La caracterización mecánica demostró un aumento notable (de hasta un 20 %) en la resistencia a la tracción máxima con el contenido más bajo de CNF (0,2 % en peso), aunque la mayor fragilidad de los nanocompuestos contribuyó a una mayor variabilidad en los resultados de los ensayos de flexión.

Este estudio establece una metodología eficaz para la dispersión uniforme de nanorefuerzos de origen biológico en matrices de vitrímero y destaca el prometedor desempeño mecánico y la reciclabilidad de estos materiales compuestos sostenibles.

Palabras Clave: vitrímero; nanocompuesto; ensayos mecánicos.

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Effect of nanocellulose reinforcement on the mechanical properties of vitrimer matrix

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In pursuit of environmentally sustainable materials, this study investigates the development of bio-based, recyclable vitrimer nanocomposites reinforced with bio-based carboxy-methylated cellulose nanofibers (CNFs) [1]. As an alternative to thermosets, vitrimers are permanently crosslinked polymer networks featuring dynamic covalent bonds, enabling reversible bond exchange reactions within the network structure [2]. Furthermore, cellulose nanofibres (CNFs) are high-aspect-ratio, bio-based nanomaterials derived from natural cellulose sources, typically exhibiting diameters in the range of 5–20 nm and lengths up to several micrometers [3]. CNFs are increasingly utilized as sustainable reinforcement agents in advanced polymer composite systems.

In this work, CNFs were incorporated into an epoxy-imine vitrimer matrix at loadings ranging from 0.2 to 1.2 wt%. Mechanical properties were evaluated using tensile and three-point bending tests, while scanning electron microscopy (SEM) was employed to analyze fracture surfaces. SEM analysis confirmed successful nanofiber dispersion and revealed a shift in fracture initiation from specimen edges in unreinforced vitrimers to reinforcement sites in the nanocomposites. Mechanical characterization demonstrated a notable increase—up to 20%—in ultimate tensile strength at the lowest CNF content (0.2 wt%), although increased brittleness of the nanocomposites contributed to greater variability in bending test results.

This study establishes an effective methodology for the uniform dispersion of bio-based nanoreinforcements in vitrimer matrices and highlights the promising mechanical performance and recyclability of these sustainable composites.

Keywords: vitrimer; nanocomposites; mechanical tests.

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Investigation of New Bio-Based Hybrid Composite Materials Using Basalt and Recycled Carbon Fibers as Reinforcements

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The transition to sustainable engineering demands the development of materials that reduce environmental impact while maintaining performance. Biopolymers and their composites represent a key pathway toward this goal, offering biodegradability, reduced toxicity, and the potential to valorize waste resources. In this work, we investigate epoxidized resveratrol (RESEP), a bio-based resin derived from renewable feedstocks, reinforced with continuous basalt fibers as a sustainable composite solution for railway applications.

Three laminate systems were prepared via the hand lay-up method: a reference laminate (RESEP + basalt), a laminate modified with 5 wt% DOPO (a flame-retardant), and a laminate incorporating 7.5 wt% mechanically recycled carbon fiber (RCF), enabling circularity through the reuse of high-value waste. Comprehensive characterization included density, mechanical and thermomechanical testing, and fire performance assessments. The RCF-reinforced laminate was further examined for multifunctional capabilities, including structural health monitoring (SHM) and energy-efficient de-icing via Joule heating.

The results highlight the sustainability potential of integrating recycled fibers into bio-based composites. The laminate with 7.5 % recycled carbon fiber showed only a 6 % decrease in strength but a 14 % increase in stiffness and a 7 % improvement in interlaminar shear strength, while also providing electrical conductivity for real-time structural health monitoring and thermal functionality (ice removal in one minute at 8 V). In contrast, the addition of 5 % DOPO reduced mechanical strength by 30 % and halved interlaminar resistance, despite its intended fire-retardant role. Overall, RESEP-based laminates—particularly those reinforced with RCF—combine mechanical performance, fire safety, and multifunctionality, positioning them as promising candidates for exterior train fairings, whereas the reference laminate remains more suitable for interior panels where fire safety dominates. This research therefore supports the development of environmentally responsible composites aligned with circular economy and decarbonization goals in the transportation sector.

Keywords: composites; sustainability; basalt; recycled carbon fiber

Electrónica impresa en materiales compuestos sostenibles para aplicaciones en automoción

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A medida que las industrias se esfuerzan por encontrar soluciones de fabricación sostenibles e inteligentes, la integración de la electrónica impresa en materiales compuestos sostenibles representa un enfoque innovador.

La industria automotriz busca cada vez más materiales sostenibles y ligeros para mejorar la eficiencia del combustible y reducir el impacto medioambiental. En este contexto, la integración de la electrónica impresa en compuestos ecológicos representa un enfoque novedoso para desarrollar componentes automotrices inteligentes y sostenibles.

Mediante el uso de matrices poliméricas reciclables, recicladas o de origen biológico reforzadas con fibras naturales, reducimos la dependencia de los compuestos convencionales derivados del petróleo. Por otra parte, la electrónica impresa permite el desarrollo de nuevas funcionalidades ligeras, flexibles y de bajo coste, lo que hace que estos materiales sean adecuados para diversas aplicaciones en la automoción y la monitorización del estado estructural.

Este estudio destaca los últimos avances en la selección de materiales, las técnicas de procesamiento y la evaluación del rendimiento. Analizamos los retos relacionados con la compatibilidad de los materiales, la durabilidad y la fabricación, así como las posibles soluciones mediante métodos de impresión avanzados y formulaciones de tintas sostenibles. En última instancia, esta investigación tiene como objetivo allanar el camino para una nueva clase de materiales inteligentes y ecológicos en línea con los principios de la economía circular y la tecnología verde.

Palabras Clave: Material compuesto; Sostenible; Electrónica impresa; Fibras naturales.

Hydrogen Bonds in Blends of smart polymers and Carboxymethyl Cellulose.

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Thermoresponsive polymers can introduce unique properties into natural biopolymers, such as improved degradability and temperature-sensitive thickening behavior. In this work, we explore blends of two synthetic polymers, poly(N-isopropylacrylamide) and poly(N-ethylacrylamide), with the biopolymer carboxymethyl cellulose in water and mixed water/methanol systems. We examine how molecular composition and solvent environment influence the thermal response and gel formation of the materials. The results show that changing the ratio between the synthetic polymers alters the balance of hydrogen bonding and interactions within the blends, which in turn affects their gelation and responsiveness. These findings highlight the potential of combining synthetic and natural components to design new smart materials with tunable properties for applications in areas such as biomedicine, food technology, and sustainable materials.

Keywords: Smart polymers; blends; physical crosslinking

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Easy-scalable, Washable, and Healable Nanocomposite-infused Cotton for Electrically Active Wearable Technology

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The future of wearable technologies and electronics lies in smart textiles that are not just flexible and functional, but also scalable, robust, washable, and sustainable. Herein, we present a method compatible with the polymer and textile industries to fabricate highly conductive, hydrophobic, and healable cotton fabrics by using thermoplastic polyurethane (TPU) matrices doped with carbon nanotubes (CNTs). Through a simple two-step extrusion and hot-pressing process, cotton is impregnated with TPU-CNTs nanocomposites, achieving conductivities up to ~40 S/m, remarkable strain sensitivity at very low strain levels ($\Delta R/R_0 \approx 4$ for strains up to 5%), and water contact angles exceeding 100°. The fabrics show exceptional durability under mechanical, thermal, and washing cycles, with electrical performance maintained across 20 washing cycles and post-damage healing via hot pressing. These functionalized cotton textiles demonstrate high-fidelity sensing of human motion, making them ideal candidates for next-generation wearable technologies that are scalable, reliable, resilient, and suitable for real-world deployment.

Keywords: Multifunctional Composites; Strain Sensing; Thermistors; Carbon Nanotubes; Textiles

Comparative Study of Crosslinking Agents for More Environmentally Sustainable Rubber

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The widespread use of rubber in various industries, from automotive to consumer goods, has led to significant environmental concerns. Conventional rubber materials are typically derived from non-renewable petroleum-based sources and are vulcanized through irreversible chemical processes, making them difficult to recycle or degrade. As a result, end-of-life rubber products often accumulate in landfills or are incinerated, contributing to pollution and greenhouse gas emissions. This work explores a novel approach to develop sustainable self-healing elastomers based on epoxidized natural rubber (ENR) as the polymer matrix, using itaconic acid (IA) as a bio-based vulcanizing agent and a transesterification reaction promoter for self-healing. The focus is to achieve self-repairing properties to enhance environmental sustainability.

Traditional vulcanization methods using sulfur and radical crosslinking using dicumyl peroxide (DCP) are compared with an alternative strategy based on bio-derived compounds. Sulfur, the industry standard, is used as a benchmark, while DCP is included for its fast-curing kinetics. Itaconic acid, a bio-derived diacid, offers a sustainable alternative for vulcanization while introducing the potential for self-healing through transesterification reactions using zinc acetate. The study details the synthesis process for the itaconic acid-based elastomers and investigates the impact of this approach on the material's mechanical properties, self-healing efficiency, and environmental footprint. A comparative analysis is presented, evaluating stress-strain behavior, healing response under mechanical damage, and other characterization techniques. This research aims to demonstrate the feasibility of using itaconic acid for both vulcanization and self-healing in elastomers. The findings hold promise for the advancement of green materials science and the creation of high-performance, self-healing elastomers for various applications.

Keywords: Rubber, Itaconic acid, Self-Healing

Construction of novel MoS_2/BiOX (X = Cl, Br, I) heterojunctions with an enhanced photocatalytic activity for pollutants degradation

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For decades, global environmental pollution and energy shortage are major concerns of mankind and have attracted extensive attention. To tackle these issues, a lot of efforts have been made to develop efficient semiconductor photocatalysts. So far, it has been revealed that semiconductor materials, such as MoS_2, exhibit high photocatalytic activities, especially in H_2 production. However, MoS_2 shows poor photocatalytic efficiency for the utilization of visible light due to its high recombination rate of photo-generated electrons and holes. Being highly stable and active, the low-cost and non-toxic BiOX has attracted widespread attention recently. The layered BiOX semiconductors belong to the PbFCl-type tetragonal crystal system bearing a P4/nmm space group, which is built by $[Bi_2O_2]$ slabs and slabs of double halogen atoms along the z-axis direction. Several strategies have been developed to enhance the photocatalytic behaviour and promote the separation of photogenerated electrons-holes in bismuth-based photocatalysts, including ion doping, assembling heterojunctions, controlling morphology with modifiers or creating oxygen vacancies. Especially, the formation of heterojunctions by coupling semiconductors has demonstrated to be a successful strategy for enhancing the photocatalytic performance of individual semiconductors. This strategy promotes electron-hole separation while intensifying the internal electrostatic field. Thus, the photocatalytic ability of a heterojunction depends on factors such as the intimate contact of the semiconductors and their energy band positions [1,2].

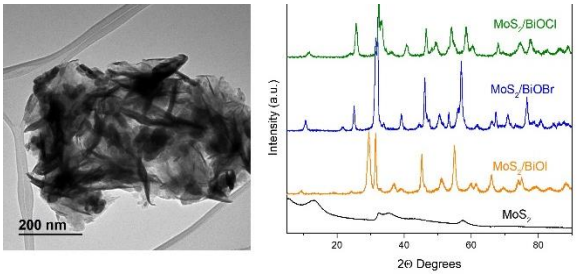

Figure 1. TEM image and XRD patterns of MoS_2/BiOX composites.

Here, we fabricated MoS2/BiOX (X = Cl, Br, I) composites (Fig. 1) by a facile one-step hydrothermal approach, and the products showed the improved efficiency of electron-hole separation across the MoS2/BiOX heterojunction for the photocatalytic degradation of several pollutants, such us dyes (Rhodamine B) and herbicides (Acetamiprid).

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Circular Economy: Transforming agrifood waste into composite polymers for energy applications

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The circular economy is a global need to transition from the linear "take-make-dispose" model to one that minimises waste, maximises resource reuse, and creates new energy devices to tackle climate change and pollution [1]. In this work we report the synthesis of polymer composites derived from agrifood residues [2], using pyrolysis and hydrothermal carbonisation to obtain carbon-rich materials such as activated carbon, hydrochar, biochar, graphene, graphite, quantum dots, and different monomers and polymers [3]. These materials are used in the design of innovative polymer composites and hybrid materials for application in energy storage systems, including EDLC supercapacitors, pseudocapacitors, rechargeable batteries, thermal energy storage systems, and photocatalytic H2 production [4,5].

The sustainable composites exhibited enhanced energy and power density, together with excellent cycling stability compared to conventional composites, highlighting their potential as low-cost and eco-friendly alternatives. Our results demonstrate how waste valorisation through advanced composite design can contribute to the circular economy by reducing environmental impact, extending material life cycles, and enabling technological advances in sustainable energy devices.

Keywords: Polymer composite; biowaste; biowaste polymer; carbonaceous materials; circular economy

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Caracterización de material compuesto de plástico reciclado y fibra natural del raquis de platanera después de serie de ciclos de reciclado

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Una de las mayores limitaciones del proceso de reciclado mecánico de los materiales compuestos es la presencia de dos materiales de diferente naturaleza (matriz y fibra), si a eso le añadimos que la matriz polimérica esté formada por al menos dos familias de polímeros mezclados y procedentes de residuos urbanos, el problema es todavía más complejo. En este trabajo se ha estudiado cómo evoluciona el material a partir de ser sometido a una serie de ciclos sucesivos de procesado mediante moldeo por compresión, triturado y reciclado [1]. Como matriz polimérica se ha utilizado una mezcla de residuos de polipropileno y polietileno de alta densidad, procedentes de tapones de botellas, cuya proporción media ha sido de 40% PP y 60% HDPE. Como fibra natural se ha utilizado la fibra extraída a partir del raquis de la platanera, considerado un residuo. El raquis es el núcleo central donde se sujetan las manillas de plátanos. La fibra de raquis ha sido obtenida a partir de combinar un proceso de enriado y de extracción mecánica. Partiendo de una placa con 2 capas de tejido unidireccional de fibra (a 90º) y 3 de polímero, procesada mediante moldeo por compresión, se obtienen probetas para su caracterización físico-química, que son posteriormente trituradas para repetir hasta 10 ciclos de reciclado. Los resultados muestran una clara influencia del ciclo de reciclado, donde las propiedades mecánicas tienen cierta tendencia a mejorar debido principalmente a que la fibra queda mejor distribuida en la matriz y con área total de contacto mayor.

Palabras Clave: Moldeo por compresión; fibra natural de raquis; material compuesto con fibra natural; reciclabilidad

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Characterisation of composite material made from recycled plastic and natural fibre from banana tree rachis after a series of recycling cycles

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One of the greatest limitations of the mechanical recycling process for composite materials is the presence of two different types of material (matrix and fibre). If we add to this the fact that the polymer matrix is made up of at least two families of mixed polymers from urban waste, the problem becomes even more complex. This study examined how the composite evolves after being subjected to a series of successive processing cycles involving compression moulding, crushing and recycling [1]. A mixture of polypropylene and polyethylene waste from bottle caps was used as the polymer matrix, with an average proportion of 40% PP and 60% PE. The natural fibre used was extracted from the rachis of the banana plant, which is considered waste. The rachis is the central core where the bunches of bananas are attached. The rachis fibre has been obtained by combining a retting process with mechanical extraction. Starting with a plate with two layers of unidirectional fibre fabric (at 90º) and three layers of polymer, processed by compression moulding, test specimens are obtained for physical-chemical characterisation, which are then crushed to repeat up to 10 recycling cycles. The results show a clear influence of the recycling cycle, where the mechanical properties tend to improve, mainly because the fibre is better distributed in the matrix and has a larger total contact area.

Keywords: Compression moulding; rachis natural fibre; natural fibre composite; recyclability

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[1] Zhao X et al, 2022 Recycling of natural fiber composites: Challenges and opportunities Resour Conserv Recycl 177 105962

Formulación y determinación de parámetros de proceso de PLA con fibra natural del raquis de la platanera, mediante fabricación aditiva

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Este trabajo presenta la formulación, comportamiento durante el procesado y el resultado posterior de un material compuesto formado por un polímero biobasado como el PLA y reforzado con fibra natural [1], obtenida desde los residuos resultantes del cultivo agrícola de la platanera, concretamente del llamado raquis. El raquis es el núcleo central donde se sujetan las manillas de plátanos y que son cortados normalmente en las plantas de proceso de las cooperativas del sector. La fibra de raquis ha sido obtenida a partir de combinar un proceso de enriado y de extracción mecánica. En este trabajo se han estudiado dos procedimientos de fabricación de granza de material compuesto (triturado de fibra en molino y sistema termomecánico) , con diferentes porcentajes de fibra, para alimentar un equipo de fabricación aditiva, de tecnología de extrusión de material (MEX) [2] y alimentador de husillo. Por otro lado, se ha analizado el comportamiento durante el proceso de fabricación aditiva, a partir de modificar parámetros de proceso MEX, con vistas a obtener los mejores resultados de calidad. Se han fabricado probetas con diferentes formulaciones y estrategias para realizar su caracterización morfológica, dimensional y mecánica. A pesar de la dificultad que supone el flujo a través de la boquilla de extrusión MEX del material durante la deposición, debido al riesgo de atascos de la misma, se ha comprobado la viabilidad del proceso y la calidad aceptable de las piezas obtenidas bajo determinadas condiciones.

Palabras Clave: fabricación aditiva; fibra natural de raquis; material compuesto con fibra natural

Agradecimientos: Este trabajo es parte del proyecto TED2021-131039B-C31 financiado por MCIN/AEI/10.13039/501100011033 y la Unión Europea "NextGenerationEU"/PRTR

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Formulation and determination of process parameters of PLA with natural fibre from the banana rachis, using additive manufacturing

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This paper presents the formulation, behaviour during processing and subsequent result of a composite material formed by a bio-based polymer such as PLA and reinforced with natural fibre [1], obtained from the waste resulting from banana cultivation, specifically from the rachis. The rachis is the central core where the banana hands are attached and is normally cut in the processing plants of the cooperatives in the sector. The rachis fibre has been obtained by combining a retting and mechanical extraction process. In this work, two composite material pellet manufacturing processes (fibre grinding in a mill and thermomechanical system) have been studied, with different fibre percentages, to feed additive manufacturing equipment, material extrusion technology (MEX) [2], with a screw feeder. Furthermore, the behaviour during the additive manufacturing process was analysed by modifying the MEX process parameters in order to obtain the best quality results. Test specimens were manufactured with different formulations and strategies to perform their morphological, dimensional and mechanical characterisation. Despite the difficulty involved in the flow of material through the MEX extrusion nozzle during deposition, due to the risk of clogging, the viability of the process and the acceptable quality of the parts obtained under certain conditions have been verified.

Keywords: additive manufacturing; rachis natural fibre; natural fibre composite

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Nanopartículas de sílice mesoporosa funcionalizadas con organoestaño y ácido fólico: influencia del PEG en su formulación y actividad antitumoral

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Actualmente, el cáncer constituye la segunda causa de muerte a nivel mundial. Entre sus tipos, el de mama es el más común en mujeres, con una elevada incidencia y una mortalidad cercana a 685.000 muertes anuales [1]. En respuesta a este escenario crítico, el grupo COMET-NANO desarrolla nanomateriales innovadores con aplicaciones en biomedicina.

En este trabajo se presentan nanopartículas de sílice mesoporosa (MSN) funcionalizadas con un compuesto de organoestaño(IV) con actividad antitumoral y, con ácido fólico para favorecer la internalización en células tumorales que sobreexpresan su receptor. Asimismo, se incorporaron diferentes proporciones de polietilenglicol (PEG) covalentemente unido, con el fin de mejorar la dispersión de los materiales en medios acuosos y en condiciones biológicas simuladas [2].

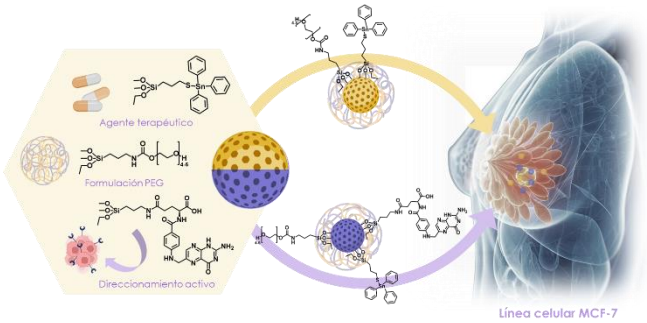

Figura 1. Nanomateriales sintetizados y su aplicación biológica.

Los nanomateriales se caracterizaron exhaustivamente y se evaluaron frente a células MCF-7 (cáncer de mama) y Hek 293T (sanas). Los resultados evidenciaron que la presencia de ácido fólico mejora la selectividad, reduciendo la toxicidad en células no tumorales. Además, los materiales con un 5% de PEG mostraron el perfil más prometedor, combinando adecuada dispersabilidad y elevada actividad antitumoral.

En conclusión, la combinación de organoestaño(IV), ácido fólico y PEG en MSN representa un enfoque innovador para el desarrollo de nanomateriales multifuncionales con potencial aplicación en oncología. Estos resultados sientan las bases para estudios

futuros centrados en la optimización de la formulación y la validación *in vivo*, con el objetivo de avanzar hacia terapias más selectivas y eficaces contra el cáncer de mama.

Palabras Clave: nanomateriales; PEG; ácido fólico; estaño; cáncer de mama; nanomecidina.

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Naphthalimide–Terthiophene Low-Bandgap Conjugated Oligomers: A Multifunctional Platform for Energy Conversion Technologies

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Two novel donor–acceptor conjugated oligomers were synthesized by coupling a terthiophene donor with a naphthalimide acceptor unit.1 Using palladium-catalyzed cross-coupling with distinct linkers, NIP3T-poly and NIP3T-BDT-poly were obtained. Both semiconductors exhibit broad absorption up to 1000 nm and enhanced hole mobilities (up to 1.8×10^{-3} cm^2 V^{-1} s^{-1}), outperforming the monomeric NIP3T. Their energy levels are compatible with standard p-type dopants such as F4TCNQ, enabling thermoelectric figures of merit up to zT = 0.02 for NIP3T-BDT-poly, comparable to benchmark doped polythiophenes.

These materials were further evaluated in photovoltaic applications using high-throughput screening.2 Over 2000 devices were fabricated via doctor-blading withthickness gradients (20–600 nm), covering 24 low-bandgap donor–acceptor combinations. Power conversion efficiencies ranged from 0.06% to 1.45%. Statistical analysis revealed that material selection and energy alignment parameters (e.g., bandgap, electron affinity offset) are the primary determinants of device performance, while processing conditions have a lesser impact. Additionally, the thermal transport properties of doped conjugated oligomers were investigated.3 Upon doping, polymers with high structural order, including terthiophene–naphthalimide co-oligomers, showed reduced out-of-plane thermal conductivity. In contrast, less ordered systems exhibited increased conductivity. Grazing incidence wide-angle X-ray scattering and photooxidation experiments highlighted the influence of backbone orientation and alloy scattering. These findings emphasize the importance of measuring thermal and electrical properties in the same orientation to accurately assess thermoelectric performance.

Keywords: Organic semiconductors, Non-fullerene acceptors, Photovoltaics, thermoelectrics, ambipolar polymers, High-throughput experimentation.

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Bionanocomposites de quitosano y arcillas para liberación controlada de clorhexidina

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La creciente resistencia antimicrobiana a nivel global [1] exige el desarrollo de estrategias innovadoras que optimicen la eficacia de agentes terapéuticos existentes. Este estudio se centra en el diseño de bionanocomposites basados en el ensamblado a nivel nanométrico del polisacárido quitosano y silicatos naturales de la familia de las arcillas [2, 3], en concreto montmorillonita y sepiolita, incorporando clorhexidina, un agente antimicrobiano y antifúngico de amplio espectro, para su aplicación en sistemas de liberación sostenida. Con esta premisa, se han desarrollado varios materiales con el objetivo de lograr una cinética de liberación sostenida que permita maximizar la efectividad antimicrobiana minimizando los efectos adversos [4].

Entre las formulaciones estudiadas, los materiales basados en sepiolita, un silicato de magnesio hidratado de origen natural, con un alto contenido en quitosano y clorhexidina, demostraron poseer las mejores propiedades mecánicas, presentando una morfología homogénea y compacta, de acuerdo con resultados obtenidos por SEM-EDX (acrónimos de Scanning Electron Micoscopy- Energy Dispersive X-ray Spectroscopy), que confirmaron la formación de matrices homogéneas. La actividad antimicrobiana contra *Staphylococcus aureus* resultó significativa, con reducciones superiores al 99% en las primeras 4 horas.

La afinidad entre el polisacárido y las dos arcillas estudiadas permitió alcanzar una estabilización eficiente del principio activo en ambas, principalmente mediante interacciones electrostáticas y de enlaces de hidrógeno. Estos sistemas demostraron una alta estabilidad fisicoquímica y un prometedor potencial para aplicaciones tópicas, posicionando a estos materiales bionanocomposites como candidatos atractivos para aplicaciones biomédicas en el desarrollo apósitos de última generación.

Palabras Clave: biomateriales, quitosano, liberación controlada

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Ring-Opening Polymerization of ε-caprolactone using an Aluminium Catalyst

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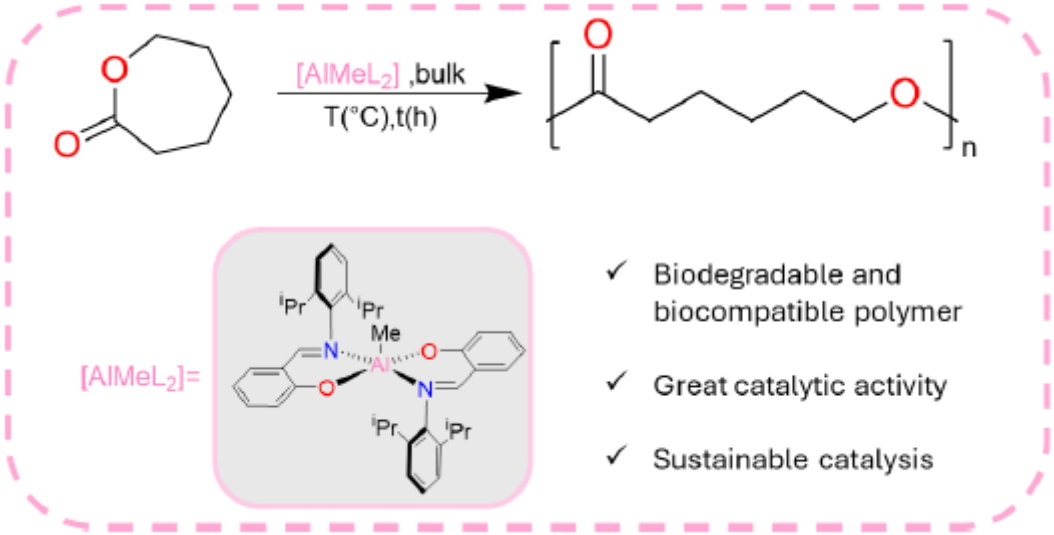
Plastic pollution has increased exponentially in recent years, increasing from 15 million tons of plastic waste in 1964 to 367 tons in 2020. It is estimated that this amount is going to be triplicated by 2060. [1] To mitigate this problem it has been proposed the use of biodegradable polymers, such as poly(ε-caprolactone), which is not just biodegradable but also flexible, hydrophobic, non-toxic, and highly processable, making it a material of great interest to the medical and plastics industries. [2]

This work seeks to optimize the ring-opening polymerization conditions for ε-caprolactone using [AlMe(N-(2,6-diisopropylphenyl)-phenoxyimine)$_2$], a complex previously developed in our research group. [3] This complex has proven to be a highly active catalyst in the presence of different cyclic monomers such as rac-β-butyrolactone and rac-lactide.



Keywords: ε-caprolactone; poli(ε-caprolactone); solvent-free; ring open polymerisation.

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Kinetics and reaction mechanism of the bulk thermal polymerization of diaminofumaronitrile: clues on the elusive chemistry of hcn oligomers

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Nitrile compounds are abundant, inexpensive, and stable, yet their transformation into functional polymers remains challenging due to their low reactivity. Within this family, dinitriles are especially relevant, since many aromatic members act as precursors of covalent triazine frameworks with semiconducting properties and applications in gas capture, separation, and catalysis. Traditionally, these polymers are obtained through ionothermal polymerization, which requires acid catalysts and temperatures above 400 °C [1]. In contrast, oligomers of hydrogen cyanide, such as the trimer aminomalononitrile and the tetramers diaminomaleonitrile (DAMN) and diaminofumaronitrile (DAFN), undergo polymerization at significantly lower temperatures without initiators or catalysts.

This work focuses on the thermal polymerization of DAFN, the E isomer of 2,3-diamino-2-butenedinitrile, and compares it with its Z counterpart, DAMN. Thermoanalytical techniques (DSC-TG) coupled with in situ mass spectrometry revealed similar behaviors between both isomers. Nonisothermal DSC showed that DAFN polymerization may begin below its melting point (~185 °C) at low heating rates, whereas higher heating rates promote a rapid process in the molten state [2,3]. Kinetic parameters were determined using model-free iso-conversional methods, and a suitable kinetic model was proposed. Complementary FTIR analyses provided preliminary structural characterization.

The results demonstrate that DAFN polymerization is autocatalytic, efficient, and occurs under relatively mild conditions. Moreover, the study provides the first systematic kinetic analysis of this system, highlighting the roles of deamination, dehydrocyanation, and monomer decomposition in the polymerization mechanism.

Keywords: Diaminofumaronitrile; diaminomaleonitrile; melt polymerization; DSC; kinetic; mechanism

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