FinnCERES
Lignocellulose Materials Cluster for Our Future

Rojas's team

BioProducts Institute

Team members 2019-2020 including visitors

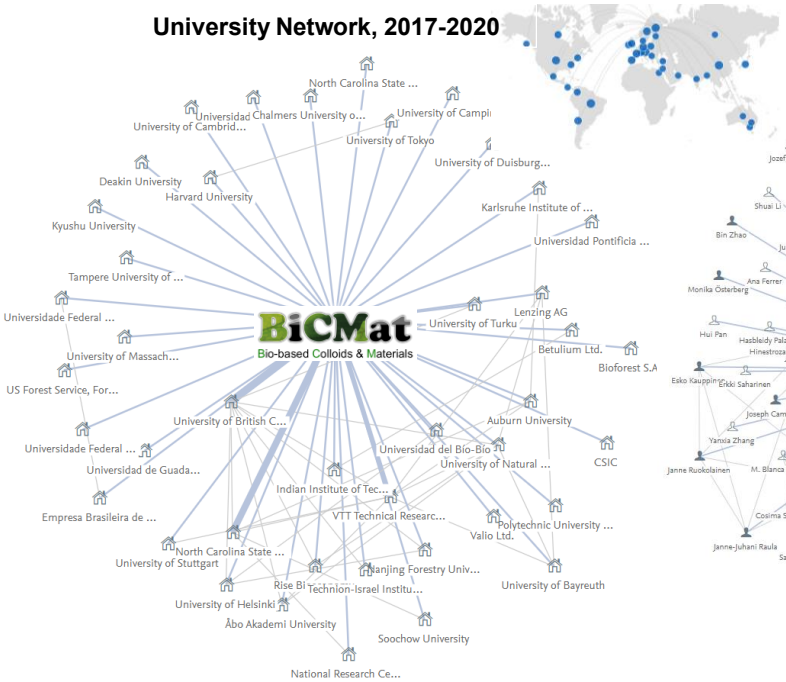
Chemical Compounds

Cellulose | Nanocellulose | Lignin | Nanocrystals | Emulsions | Water | Fibers | TEMPO | Nanoparticles | Adsorption | Oils | Nanofibers | Cellulose films | Aerogels | Carbon | Hydrogels | Membranes | Ionic Liquids | Lignocellulose | Nanostructured materials | Wetting | Wood | Oxidized cellulose | Polymers | Chitin | Foams | Composite materials | Colloids | Dispersions | Drying | Cryogels | Poly(lactide) | Electrolytes | Suspensions | Electrostatics | Self assembly | Interfacial energy | Milk fat globule | Biomass

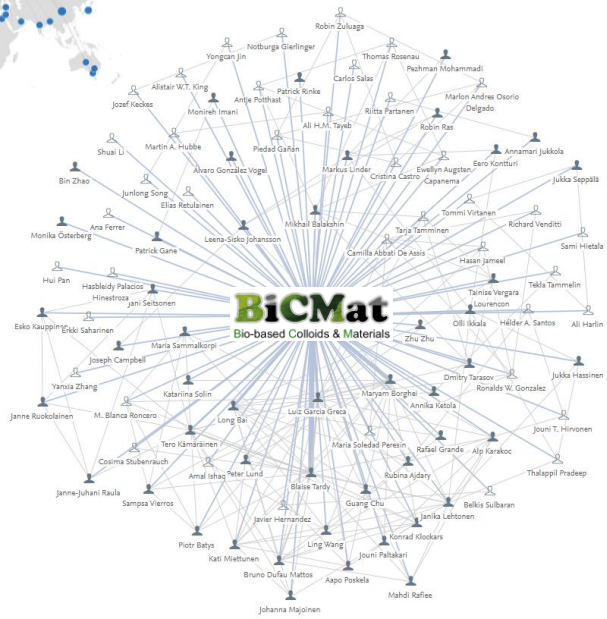
Engineering & Materials Science

Cellulose | Nanocellulose | Lignin | Nanocrystals | Emulsions | Fibers | Water | Proteins | Hydrogels | Nanoparticles | Adsorption | Cellulose films | Nanofibers | Aerogels | Chitin | Membranes | Wetting | Nanostructured materials | Wood | Foams | Colloids | Oils | Carbon | Ionic liquids | Oils and fats | Composite materials | Acids | Polymers | Enzymes | Interfacial energy | Gels | Self assembly | Coatings | Electrolytes | Electrostatics

University Network, 2017-2020

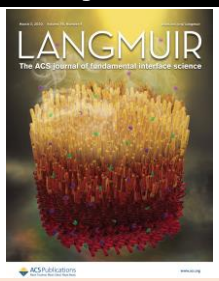


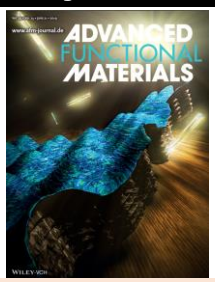
Researchers network, 2017-2020

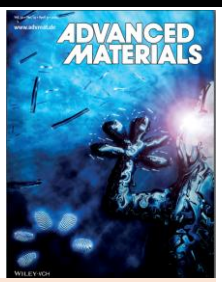


Publications January 2020-January 2021

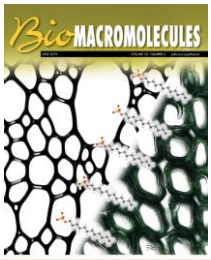
(Bacterial) cellulose nanofibers, hydrogels, biofabrication, 3D printing

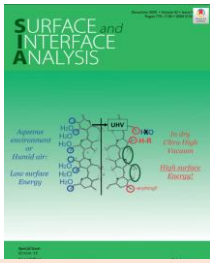




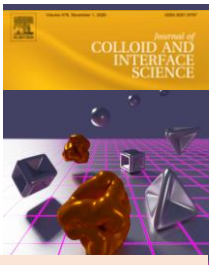


Cellulose nanocrystals, self-assembly, adsorption and adhesion



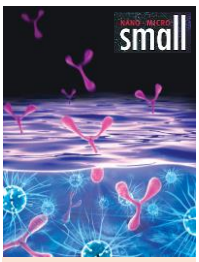


Fibers, surfaces and multiphase systems (emulsions and foams)



Lignin and tannin colloids

Nanochitin



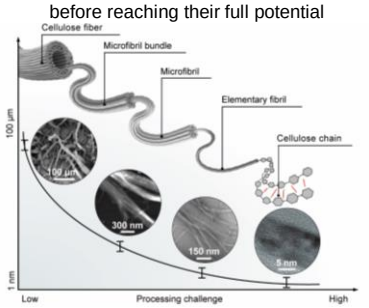
Biosensing, stimuli-responsive materials

Paper highlight: The prospects of fibrillar cellulose

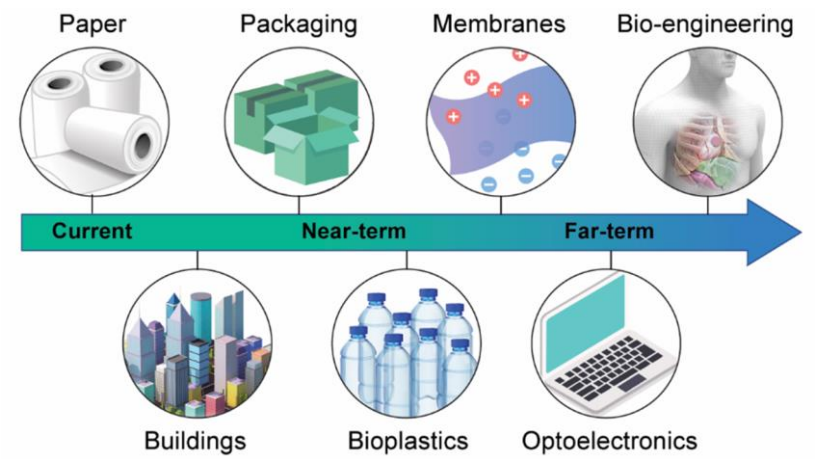
Nature 590, 47–56 (2021). DOI: 10.1038/s41586-020-03167-7

Perspective about fibrillated cellulose as current and future technological material

We discuss research directions for the practical exploitation of cellulose fibril structures and the challenges to overcome before reaching their full potential



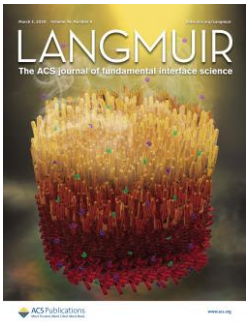
Li T., Chen C., Brozena A.H., Zhu J.Y., Xu L., Driemeier C., Dai J., Rojas O.J., Isogai A., Wågberg L., Hu L., Developing fibrillated cellulose as a sustainable technological material. **Nature** 590, 47–56 (2021). DOI: 10.1038/s41586-020-03167-7



Self-assembly (publications 2020)

Liquid crystal colloidal glass from nanocellulose particles

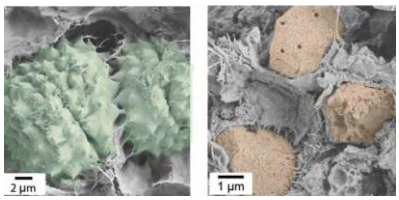
Freezing the glassy state of liquid crystal colloids through selective solvent removal



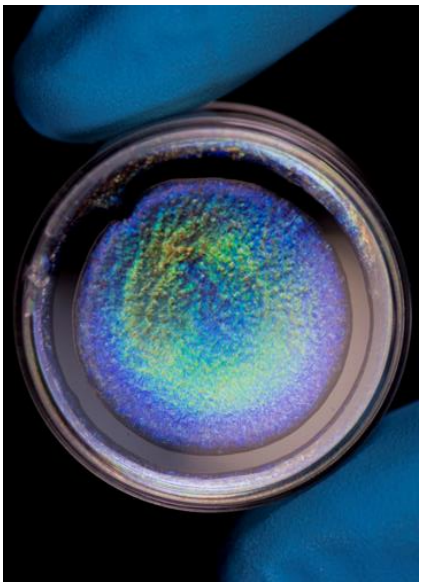
Chu, G., Vasilyev, G., Qu, D., Deng, S., Long B., Rojas O.J., Zussman E., Structural Arrest and Phase Transition in Glassy Nanocellulose Colloids, **Langmuir**, 36, 979-985 (2020). DOI: 10.1021/acs.langmuir.9b03570

Nanofibrillar networks enable universal assembly of super-structured particle constructs

We demonstrate the topology of networks formed from CNF enabling super-structuring of virtually any particle.



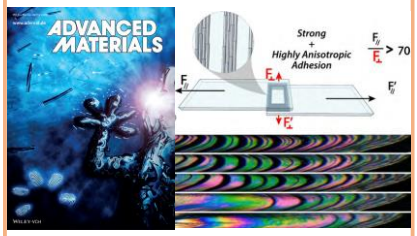
Mattos B.D., Tardy B.L., Greca L.G., Kämäräinen T., Xiang W., Cusola O., Magalhães W.L.E., Rojas O.J., Nanofibrillar networks enable universal assembly of superstructured particle constructs, **Science Advances**, 6, eaaz7328 (2020). DOI: 10.1126/sciadv.aaz7328



Self-assembly (publications 2020), cont'd

Supramolecular interactions from colloids for strong anisotropic adhesion

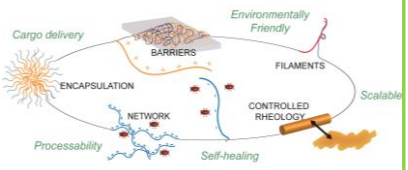
CNC superstructuring by confined EISA (shown by synchrotron and other techniques) generates anisotropic adhesion



Tardy B.L., Richardson J.J., Greca L.G., Guo J., Ejima H., Rojas O.J., Exploiting supramolecular interactions from polymeric colloids for strong anisotropic adhesion between solid surfaces, **Advanced Materials**, 1906886 (2020). DOI: 10.1002/adma.201906886

Charge matters!

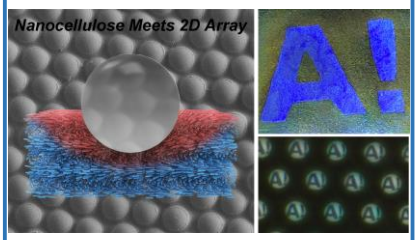
Electrostatic complexation and saloplastics are shown as a green, versatile routes to assemble materials displaying advanced functionalities



Otoni C., Queirós M., Sabadini J., Rojas O.J., Loh W., Charge matters: Electrostatic complexation as a green approach to assemble advanced functional materials, **ACS Omega**, 5, 1296-1304 (2020). DOI: 10.1021/acsomega.9b03690

Multifunctional optical films (polarization sensitive retroreflector and microlens array) produced from cellulose nanocrystals and microspheres.

Micropatterned photonic films from bottom-up cholesteric self-assembly of cellulose nanocrystals and top-down transfer imprinting of polystyrene microspheres.

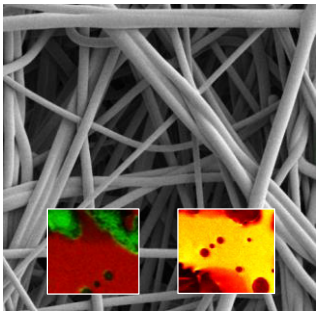


Chu, G.; Chen, F.; Zhao, B.; Zhang, X., Zussman, E. and Rojas O.J., Self-Assembled Nanorods and Microspheres for Functional Photonics: Retroreflector Meets Microlens Array **Advanced Optical Materials**, 2021, Accepted

Surface activity (publications 2020)

Surfactants migration in melt spinning studied by ToF-SIMS, XPS, WCA and SEM

Electret and Repellency toward high alcohol content solutions through the use of fluorochemical melt additive

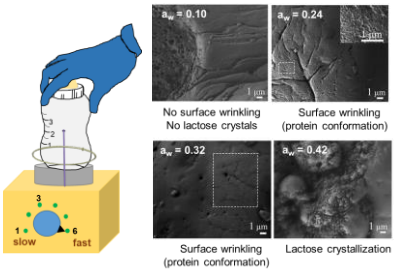


Lavoie J., Rojas O.J., Khan S.A., Shim E., Migration Effects of Fluorochemical Melt Additives for Alcohol Repellency in Polypropylene Nonwoven Materials, **ACS Applied Materials and Interfaces** 12, 36787–36798, (2020). DOI: 10.1021/acsami.0c10144

Surface activity (publications 2020), cont'd

Evolution of milk powder macronutrients (lactose, fat, and proteins) under storage conditions and

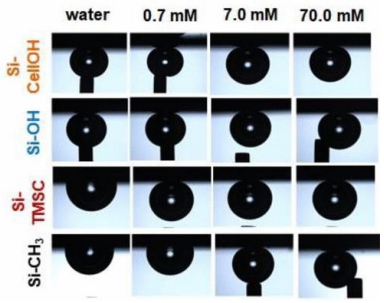
Microstructural, chemical and wettability analyses to troubleshoot the onset of related changes upon IF powder reconstitution



Nugroho R.W.N., Outinen M., Toikkanen O., Heino A., Sawada D., Rojas O.J., Effect of water activity on the functional, colloidal, physical, and microstructural properties of infant formula powder, **Journal of Colloid and Interface Science**, Accepted (2021). DOI: 10.1016/j.jcis.2020.10.069

Captive bubbles are used to understand the basics of foam forming

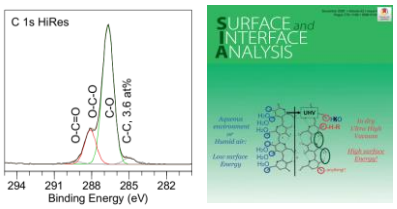
Bubble–surface interactions are studied as a function of hydrophobicity and surface tension



Ketola A.E. Xiang W., Hjelt T. Pajari H., Tammelin T. Rojas O.J., Ketoja J.A., Bubble attachment to cellulose and silica surfaces of varied surface energies: wetting transition and implications in foam forming, **Langmuir**, 36, 7296–7308 (2020). DOI: 10.1021/acs.langmuir.0c00682

Summary of useful approaches to XPS analysis of cellulosic materials

We propose cellulosic filter paper as reliable in situ reference for XPS experiments.

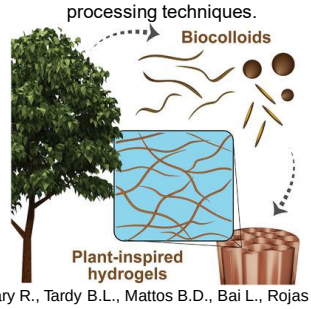


Johansson1 L.-S., Campbell J.M., Rojas O.J., Cellulose as the in-situ reference for organic XPS. Why? Because it works, **Surface and Interface Analysis**, 52, 1134-1138 (2020). DOI: 10.1002/sia.6759

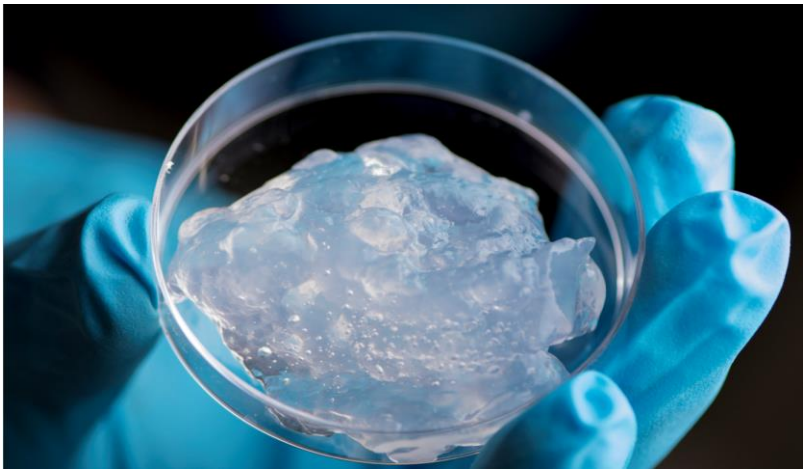
Solutions, hydrogels and lightweight materials (publications 2020)

Plant nanomaterials and inspiration from nature: water interactions and hierarchically structured hydrogels

We discuss recent developments in the area of plant-based hydrogels, especially those derived from wood and the importance of water interactions in associated structures and processing techniques.



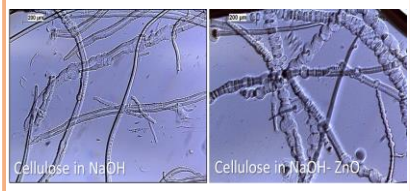
Ajdary R., Tardy B.L., Mattos B.D., Bai L., Rojas O.J., Plant Nanomaterials and Inspiration from Nature: Water Interactions and Hierarchically-Structured Hydrogels, **Advanced Materials**, 2001085 (2020). DOI: 10.1002/adma.202001085



Solutions, hydrogels and lightweight materials (publications 2020)

Cellulose dissolution NaOH–ZnO: reactivity and based on Raman spectroscopic studies.

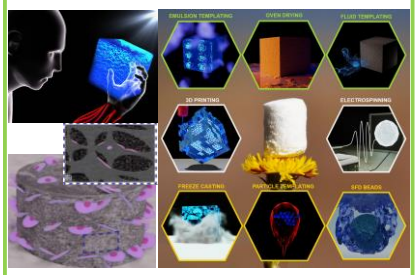
The role of metal oxide additive was studied in cellulose dissolution. A new structure is proposed for cellulose dissolved in aqueous NaOH–ZnO



Väisänen, S., Ajdary, R., Altgen, M., Nieminen, K., Kesari, K. K., Ruokolainen, J., Rojas O.J., Vuorinen, T. (2021). Cellulose dissolution in aqueous NaOH–ZnO: cellulose reactivity and the role of ZnO. **Cellulose**. 10.1007/s10570-020-03621-9

Porous nanocellulose gels and foams as scaffolds for tissue engineering

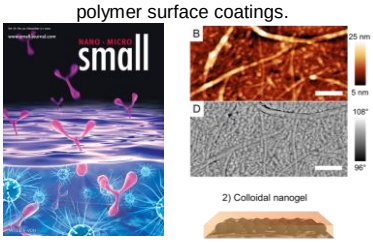
Lightweight nanocelluloses scaffolds are put in perspective as analogues to extracellular matrices, driving next-generation biomaterials



Ferreira F.V., Otoni C.G., De France K.J., Barud H.S. Lona L.M.F, Cranston E.D., Rojas O.J. Porous nanocellulose gels and foams: breakthrough status in the development of scaffolds for tissue engineering, **Materials Today**, 37, 126-141 (2020). DOI: 10.1016/j.mattod.2020.03.003

New type of surface based on a cellulose-based colloidal nanogel that brings the protein adsorption capability to unprecedented levels

Proteins interpenetrate into the soft gel layer, which provides an unprecedented level of accessibility. Immunosensing sensitivity suropasses the performance of state-of-the-art polymer surface coatings.

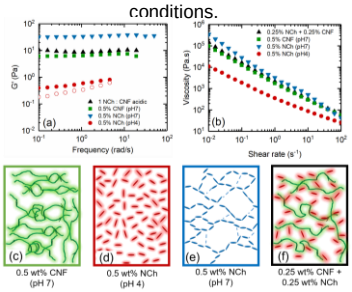


Solin K., Beaumont M., Rosenfeldt S., Orelma H., Borghei M., Bacher M., Opietnik M., Rojas O.J. Self-Assembly of Soft Cellulose Nanospheres into Colloidal Gel Layers with Enhanced Protein Adsorption Capability for Next-Generation Immunoassays, **Small**, 16, 2004702 (2020). DOI: 10.1002/smll.202004702

Rheology (publications 2020)

Associative structures form between cellulose nanofibrils and nanochitins

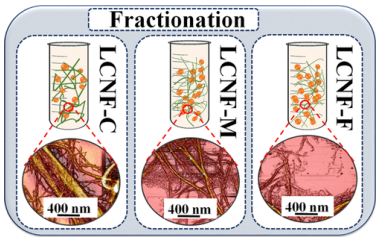
Ionic attraction, hydrophobic associations, and physical entanglement were studied for their effects on colloidal stability under broader pH conditions.



Facchine E.G., Bai L., Rojas O.J., Khan S.A., Associative structures formed from cellulose nanofibrils and nanochitins are pH-responsive and exhibit tunable rheology, **Journal of Colloid and Interface Science**, Accepted (2021). DOI: 10.1016/j.jcis.2020.12.041

Correlation between fibril morphology, rheology and dewatering

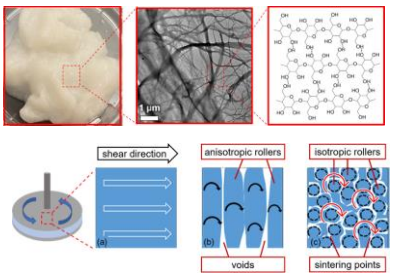
The rheological behavior of aqueous suspensions of lignocellulose nanofibrils is investigated systematically by considering the coupled effect of residual lignin and morphology.



Imani M., Dimic-Misic K., Tavakoli M., Rojas O.J., Gane P.A.C., Coupled Effects of Fibril Width, Residual and Mechanically-Liberated Lignin on the Flow, Viscoelasticity and Dewatering of Cellulosic Nanomaterials, **Biomacromolecules**, 21, 10, 4123–4134 (2020). DOI: 10.1021/acs.biomac.0c00918

Regimes of MNFC suspensions under shear flow observed and explained on the basis of floc mechanics.

We assess the recovery of the network structure as a function of breakdown conditions and critical conditions leading to floc dynamics

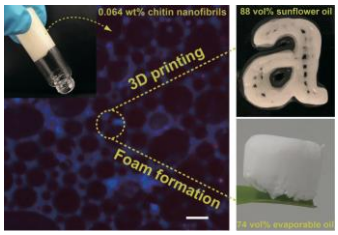


Facchine E.G., Spontak R.J., Rojas O.J., Khan S.A., Shear-dependent Structures of Flocculated Micro/Nanofibrillated Cellulose (MFNC) in Aqueous Suspensions, **Biomacromolecules**, 21, 3561–3570 (2020). DOI: 10.1021/acs.biomac.0c00586

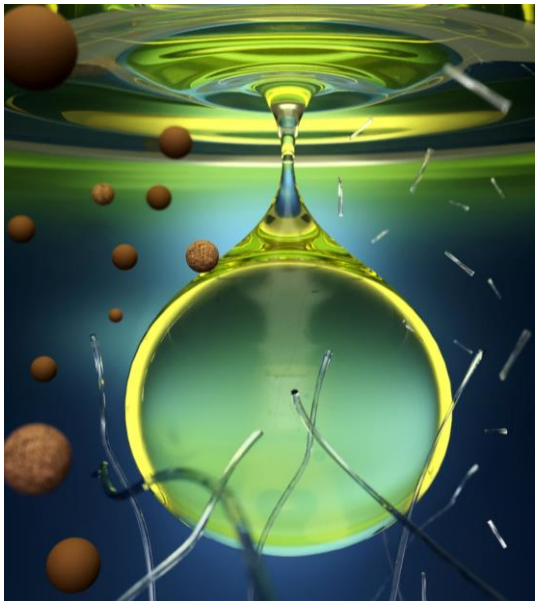
Emulsions (publications 2020)

High internal phase oil-in-water Pickering emulsions stabilized by chitin nanofibrils (3D structuring and foams)

Stable high-internal-phase (88%) Pickering emulsions stabilized by chitin nanofibrils were prepared and used as emulgel inks for 3D printing edible functional food and ultra-light solid foams.



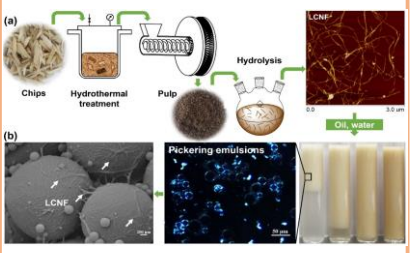
Zhu Y., Huan S., Bai L., Ketola A., Shi X., Zhang X., Ketoja J.A., Rojas O.J., High Internal Phase Oil-in-Water Pickering Emulsions Stabilized by Chitin Nanofibrils: 3D Structuring and Solid Foam, **ACS Applied Materials & Interfaces,** 12, 11240-11251 (2020). DOI: 10.1021/acsami.9b23430



Emulsions (publications 2020), cont'd

Effect of residual lignin in cellulose nanofibrils enhances the interfacial stabilization of Pickering emulsions

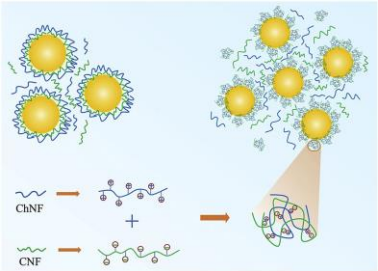
We systematically investigated the effect of residual lignin in LCNF in the stabilization of O/W Pickering emulsions.



Guo S., Li X., Kuang Y., Liao J., Li J., Mo L., He S., Zhu W., Song J., Song T., Rojas O.J., Residual Lignin in Cellulose Nanofibrils Enhances the Interfacial Stabilization of Pickering Emulsions, **Carbohydrate Polymers**, 253, 117223 (2021). DOI: 10.1016/j.carbpol.2020.117223

Pickering emulsions produced by combining nanochitin and nanocellulose.

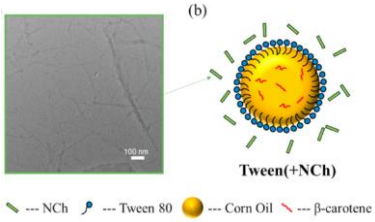
The Pickering emulsions produced show good stability against coalescence during storage.



Lv S., Zhou H., Bai L., Rojas O.J., McClements D.J., Development of food-grade Pickering emulsions stabilized by a mixture of cellulose nanofibrils and nanochitin, **Food Hydrocolloids**, 113, 106451 (2021). DOI: 10.1016/j.foodhyd.2020.106451

Chitin nanocrystals reduce lipid digestion and β-carotene bioaccessibility

The impact of chitin nanocrystals on the gastrointestinal fate of a model emulsion was investigated using a standardized in vitro digestion model (INFOGEST).

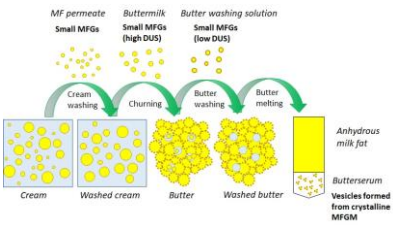


Zhou H., Dai T., Liu J., Tan Y., Bai L., Rojas O.J., McClements D.J., Chitin Nanocrystals Reduce Lipid Digestion and β-Carotene Bioaccessibility: An In-Vitro INFOGEST Gastrointestinal Study, **Food Hydrocolloids**, 113, 106494 (2021). DOI: 10.1016/j.foodhyd.2020.106494

Emulsions (publications 2020), cont'd

Milk fat globule membranes (MFGM) is studied for valuable nutrients and in bringing structure and stability in emulsified food systems

Milk fat globule membranes: size, thermal behavior, crystallization, phospholipids, buttermilk, butter serum, cream washing



Hokkanen S.P., Partanen R., Jukkola A., Frey A.D., Rojas O.J., Partitioning of the milk fat globule membrane between buttermilk and butter serum is determined by the thermal behaviour of the fat globules, **International Dairy Journal**, 112, 104863 (2021). DOI: 10.1016/j.idairyj.2020.104863
Bai

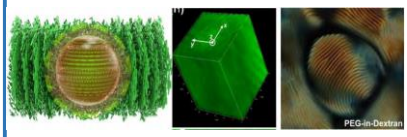
The future food nanotechnologies based on renewable nanoparticles

We consider nanocelluloses as materials that offer interesting opportunities in foodstuff, especially in the formulation of food emulsions.

Bai L., Huan S., Zhu Y., Chu G., McClements D.J., Rojas O.J., Recent Advances in Food Emulsions and Engineering Foodstuffs Using Plant-Based Nanocelluloses, **Annual Review of Food Science and Technology**, Accepted (2021): https://doi.org/10.1146/annurev-food-061920-123242

All-aqueous liquid crystal nanocellulose emulsions with permeable interfacial assembly

First report of fully aqueous liquid crystal (water-in-water) emulsions containing permeable colloidal assemblies with osmotic-driven transfer of the nanoparticles (organized via long-range forces across the water/water interface)



Bai L., Huan S., Zhao B., Zhu Y., Esquena J., Chen F., Gao G., Zussman E., Chu G., Rojas O.J., All-Aqueous Liquid Crystal Nanocellulose Emulsions with Permeable Interfacial Assembly, **ACS Nano**, 14, 13380-13390 (2020). DOI: 10.1021/acsnano.0c05251

Emulsions (publications 2020), cont'd

Partially acetylated cellulose nanofibrils were obtained from the major residual stream associated with tequila production

Agave Bagasse CNF offers a great potential as Pickering emulsion stabilizers, which can be considered in the food, cosmetic and pharmaceutical fields

Sulbarán-Rangel B., Hernández Díaz J.A., Guzmán González C.A., Rojas O.J., Partially acetylated cellulose nanofibrils from *Agave tequilana* bagasse and Pickering stabilization, **Journal of Dispersion Science and Technology**, Accepted (2021). DOI: 10.1080/01932691.2020.1858855

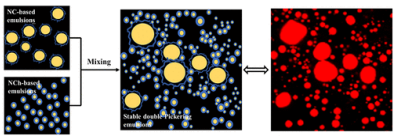
Lipid digestion and vitamin D3 bioaccessibility in Pickering emulsions

Nanochitin-stabilized Pickering emulsions were used to regulate the digestion of ingested lipids, as well as the bioaccessibility of vitamin.

Zhou H., Tan Y., Lv S., Liu J., Muriel Mundo J.L., Bai L., Rojas O.J., McClements D.J., Nanochitin-Stabilized Pickering Emulsions: Influence of Nanochitin on Lipid Digestibility and Vitamin Bioaccessibility, **Food Hydrocolloids**, 106, 105878 (2020). DOI: 10.1016/j.foodhyd.2020.105878

Utilization of Nanocellulose- and Nanochitin-Coated Lipid Droplet Blends in Pickering Emulsions

The physicochemical properties, shelf life, and functional performance of Pickering emulsions can be modulated by blending different kinds of biomass particle-stabilized lipid droplets together.

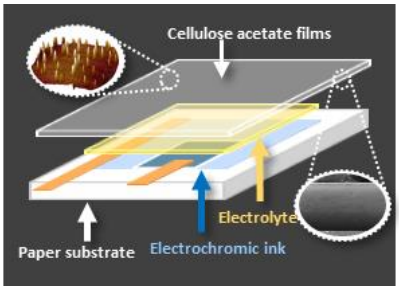


Zhou H., Lv S., Liu J., Tan Y., Muriel Mundo J.L., Bai L., Rojas O.J., McClements D.J., Modulation of Physicochemical Characteristics of Pickering Emulsions: Utilization of Nanocellulose and Nanochitin-coated Lipid Droplet Blends, **Journal of Agricultural and Food Chemistry**, 68, 603-611 (2020). DOI: 10.1021/acs.jafc.9b06846

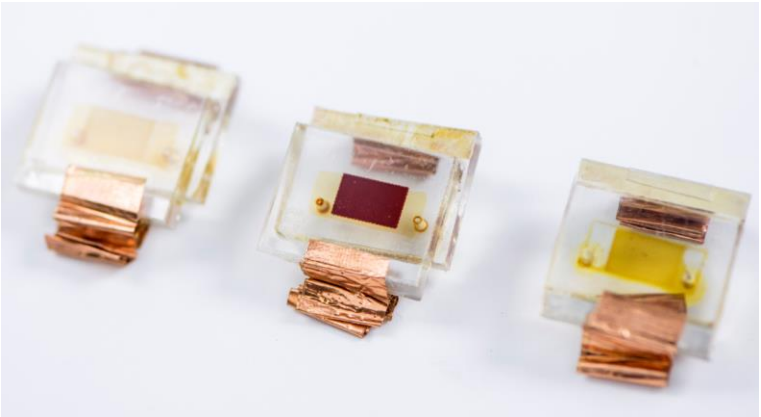
Energy, phase change materials (publications 2020)

Highly transparent and solvent resistant cellulose acetate films for electronics.

We produced substrates suitable for electrochromic devices.



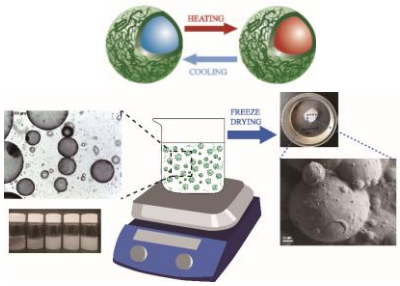
Kaschuk J.J., Borghei M., Solin K., Tripathi A., Khakalo A., Leite F.A.S., Branco A., de Sousa M.C.A., Frollini E., Rojas O.J., Cross-linked and surface-modified cellulose acetate as a cover layer for paper-based electrochromic devices, **ACS Applied Polymer Materials** (2021). DOI:



Energy, phase change materials (publications 2020), Cont'd

Leakage-proof microencapsulation of phase change materials (PCM) by emulsification with acetylated CNF

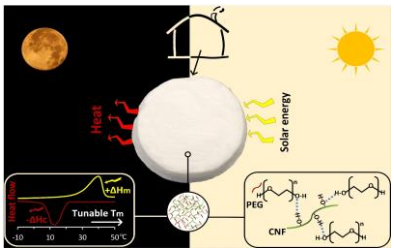
AcCNF-supported PCM forming shape- and thermally-stable systems, exhibits ideal thermal energy storage properties and durability.



Shi X., Yazdani M.R., Ajdary R., Rojas O.J., Leakage-proof microencapsulation of phase change materials by emulsification with acetylated cellulose nanofibrils, **Carbohydrate Polymers**, 254, 117430 (2021). DOI: 10.1016/j.carbpol.2020.117279

Cellulose nanofibrils for thermal energy storage and light-to-heat conversion

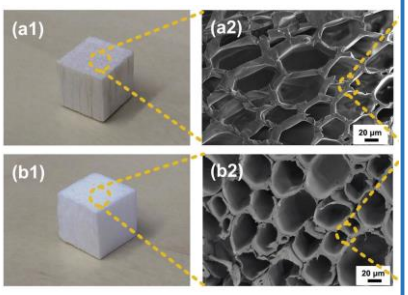
Lightweight, green nanohybrid structures were developed for smart-energy buildings and waste heat generating electronics for thermal energy storage and management.



Yazdani, M., Ajdary, R., Kankkunen, A, Rojas O.J., Seppala A. Cellulose nanofibrils endow phase change polyethylene glycol with form control and solid-to-gel transition for thermal energy storage and light-to-heat conversion, **ACS Applied Nanomaterials,** (2021). DOI:

Form-stable phase change material (FPCM) prepared from balsa.

Reversible thermoregulation is observed for operation at high room temperatures.

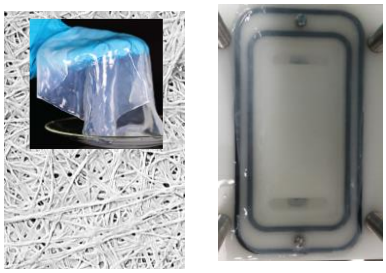


Meng Y., Majoinen J., Zhao B., Rojas O.J., Form-Stable Phase Change Materials from Mesoporous Balsa after Selective Removal of Lignin, **Composites B**, 199, 108296 (2020). DOI: 10.1016/j.compositesb.2020.108296

Microbial cellulose, Biofabrication (publications 2020)

Impact of incubation conditions and post-treatment on the properties of bacterial cellulose membranes

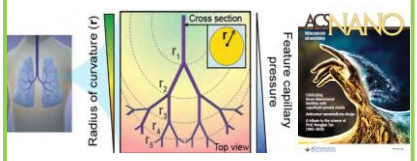
We investigate the performance of BNC in pressure-driven filtration as a function of incubation conditions and post-culture treatment.



Lehtonen J., Chen X., Beaumont M., Hassinen J., Orelma H., Dumée L.F., Tardy B.L., Rojas O.J., Impact of incubation conditions and post-treatment on the properties of bacterial cellulose membranes for pressure-driven filtration, **Carbohydrate Polymers**, 251, 117073 (2021). DOI: 10.1016/j.carbpol.2020.117073

Guiding bacterial activity for biofabrication of complex materials via controlled wetting of superhydrophobic surfaces

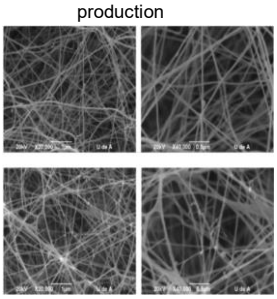
We utilize surface plastrons in superhydrophobic molds to achieve unparalleled morphological control over 3D-biofabrication



Greca L.G., Rafiee M., Karakoç A., Lehtonen J., Mattos B., Tardy B., Rojas O.J., Guiding Bacterial Activity for Biofabrication of Complex Materials via Controlled Wetting of Superhydrophobic Surfaces, **ACS Nano**, 14, 12929–12937 (2020). DOI: 10.1021/acsnano.0c03999

Yield and dynamics of carbon consumption during fermentation to produce BNC were determined

Production levels: glucose > sucrose > fructose, for consideration in BNC industrial production

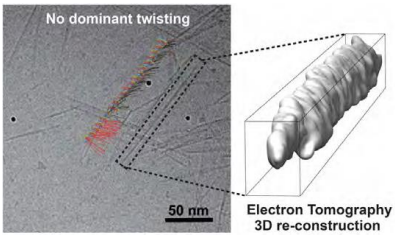


Molina-Ramírez C., Castro M., Osorio M., Torres-Taborda M., Gómez B., Zuluaga, R., Gómez C., Gañán P., Rojas O.J., Castro C. Effect of Different Carbon Sources on Bacterial Nanocellulose Production and Structure Using the Low pH Resistant Strain *Komagataeibacter Medellinensis*, **Materials**, 10, 639 (2020). DOI: 10.3390/ma10060639

Nanoparticles and morphogenesis (publications 2020)

Chirality from cryo-electron tomograms of nanocrystals obtained by lateral disassembly and surface etching of never-dried chitin

Direct access of twisting features of chitin nanocrystals by using electron tomography



Bai L., Kämäräinen T., Xiang W., Majoinen J., Seitsonen J., Grande R., Huan S., Liu L., Fan Y., Rojas O.J., Chirality from Cryo-Electron Tomograms of Nanocrystals Obtained by Lateral Disassembly and Surface Etching of Never-Dried Chitin, **ACS Nano,** 14, 6921–6930 (2020). DOI: 10.1021/acsnano.0c01327

Nanoparticles and morphogenesis (publications 2020), cont'd

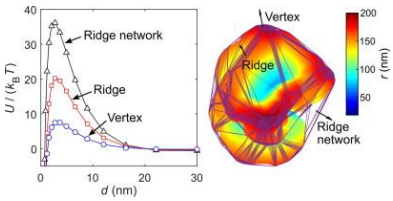
Cellulose nanostructures by hydrolysis of quila with sulfuric and oxalic acid

Bamboo bushes of Chusquea quila pose economic and ecological problems in the south-central part of Chile. Here, we use quila to produce CNC.

Oliveira P.E., Petit-Breuilh X., Rojas O.J., Gacitúa W., Production of cellulose nanostructures from Chilean bamboo, Chusquea quila, **Agronomy Research**, 2020, 18. DOI: https://doi.org/10.15159/ar.20.193

Colloidal interactions were investigated using tomography-based 3D models of wrinkled colloidal lignin particles

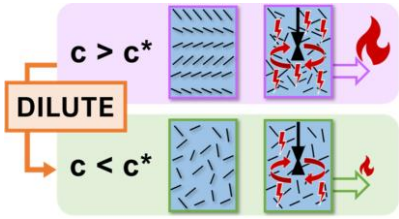
Engineering the interactions of wrinkled colloidal particles relies on the design of morphological features including surface roughness and large-scale ridge structures encompassing vertices, ridges and ridge networks



Kämäräinen T., Tardy B.L., Nikkhah S.J., Batys P., Sammalkorpi M., Rojas O.J., Effect of particle surface corrugation on their colloidal interactions, **Journal of Colloid and Interface Science**, 579, 794-804 (2020). DOI: 10.1016/j.jcis.2020.06.082

A new, simple and accurate method to assess CNC critical concentration c* (<2 h) from a small sample volume

A new technique for quantifying the onset of phase separation (critical concentration c*) in lyotropic cellulose nanocrystal (CNC) suspensions.

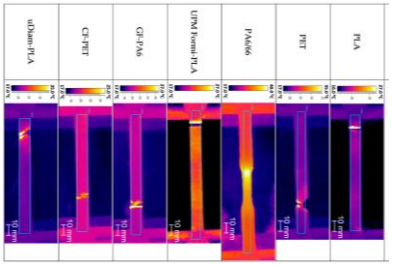


Facchine E.G., Jin S-A., Spontak R.J., Khan S.A., Rojas O.J., Quantitative Calorimetric Studies of the Chiral Nematic Mesophase in Aqueous Cellulose Nanocrystal Suspensions, **Langmuir**, 36, 36, 10830 (2020). DOI: 10.1021/acs.langmuir.0c01871

3D Printing (publications 2020)

Commercial filaments and composites: comparison and thermo-mechanical properties in Fused deposition modeling (FDM).

We reveal new insights into the size, morphology and distribution of the constituents and interphases of polymer filaments for FDM.

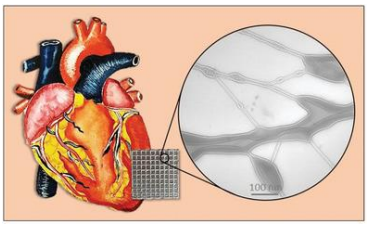


Karakoç A., Rastogi V.K., Isoaho T., Tardy B., Paltakari J., Rojas O.J., Comparative screening of the structural and thermomechanical properties of FDM filaments comprising thermoplastics loaded with cellulose, carbon and glass fibers, **Materials** 13, 422 (2020). DOI: 10.3390/ma13020422

3D Printing (publications 2020), cont'd

Multifunctional 3D-printed patches for long-term drug release therapies after myocardial infarction

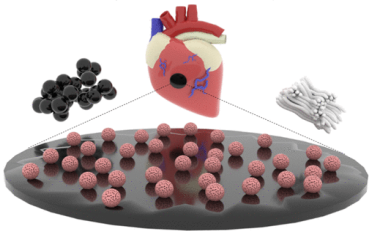
Biocompatible elastic and electrically-conductive hydrogel compositions were loaded with drugs and 3D printed (Direct Ink Writing) for application as cardiac patches. Cardiomyoblast cells attached extensively and proliferated for 28 days.



Ajdary R., Ezazi N.Z., Correia A., Kemell M., Huan S., Ruskoaho H.J., Hirvonen J., Santos H.A., Rojas O.J., Multifunctional 3D-printed patches for long-term drug release therapies after myocardial infarction, **Advanced Functional Materials**, 30, 202003440 (2020). DOI: 10.1002/adfm.202003440

Fabrication of drug-loaded conductive poly(glycerol sebacate)/nanoparticle-based composite patch for myocardial infarction applications

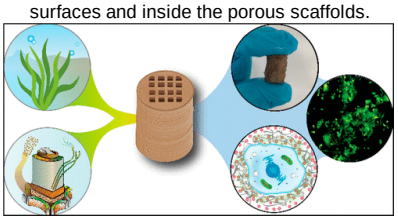
Collagen-based patches were produced by casting. They were drug-loaded to treat myocardial Infarction. The patches show high blood wettability and drug release, tracking with the rate of degradation of the polymer matrix.



Ezazi N.Z., Ajdary R., Correia A., Mäkilä E., Salonen J., Kemell M., Hirvonen J., Rojas O.J., Ruskoaho H.J., Santos H.A., Fabrication and characterization of drug-loaded conductive poly(glycerol sebacate)/nanoparticle based composite patch for myocardial infarction applications, **ACS Applied Materials & Interfaces,** 12, 6899-6909 (2020). DOI: 10.1021/acsami.9b21066

Three-dimensional printed cell culture model based on spherical colloidal lignin particles and cellulose nanofibril-alginate hydrogel

Spherical colloidal lignin particles (LPs) were used to prepare CNF-alginate-LP scaffolds. Cell viability tests using hepatocellular carcinoma cell line HepG2 showed no negative effect of LPs on cell proliferation. HepG2 cells grew on the surfaces and inside the porous scaffolds.



Zhang X., Morits M., Jonkergouw C., Ora A., Valle-Delgado J.J., Muhammad F., Ajdary R., Huan S., Linder M., Rojas O.J., Sipponen M.H., Österberg M., Three-Dimensional Printed Cell Culture Model Based on Spherical Colloidal Lignin Particles and Cellulose Nanofibril-Alginate Hydrogel, **Biomacromolecules**, 21, 1875–1885 (2020). DOI: 10.1021/acs.biomac.9b01745

Sensing and actuation (publications 2020)

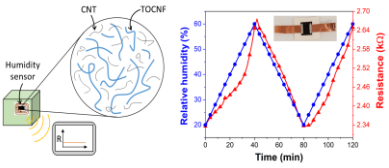
Conductive electrolyte hydrogels with tolerance to dehydration and extreme cold with double networks of PAM/CNF/LiCl

LiCl in the hydrogel provides freezing and dehydration tolerance, stretchability and conductivity

Ge W., Cao S., Yang Y., Rojas O.J., Wang X., Nanocellulose/LiCl Systems Enable Conductive and Stretchable Electrolyte Hydrogels with Tolerance to Dehydration and Extreme Cold Conditions, **Chemical Engineering Journal**, 408, 127306 (2021). DOI: 10.1016/j.cej.2020.127306

Humidity sensors from conductive nanocellulose films

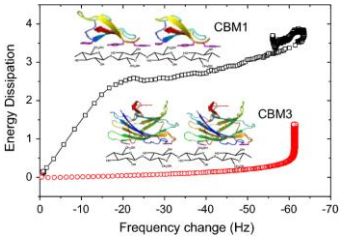
Water interactions in humidity-responsive films were evaluated. We monitored the changes in gravimetrical, viscoelastic and mechanical parameters during water-uptake and enabled humidity detection via electrical resistance measurement.



Solin K., Borghei M., Sel O., Orelma H., Johansson L-S., Perrot H., Rojas O.J., Electrically-Conductive Thin Films Based on Nanofibrillated Cellulose: Interactions with Water and Applications in Humidity Sensing, **ACS Applied Materials & Interfaces**, 12, 36437–36448 (2020). DOI: 10.1021/acsami.0c09997

Specific interactions between carbohydrate binding modules (CBMs) and cellulose

We follow in situ and in real-time the adsorption, conformational changes for the specific interactions between type A CBMs and cellulose (crystalline and nanofibrillated).

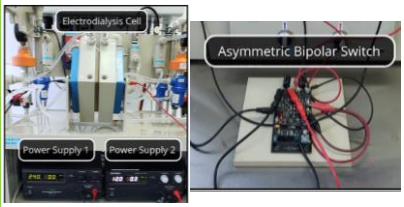


Zhang Y., Wang X., Wang P., Song J., Jin Y., Rojas O.J., Interactions between type A carbohydrate binding modules and cellulose studied with a quartz crystal microbalance with dissipation monitoring. **Cellulose,** 27, 3661–3675 (2020). DOI: 10.1007/s10570-020-03070-4

Separation (publications 2020)

Electrodialysis (ED) intensification is introduced by application of symmetric pulses of reverse polarity.

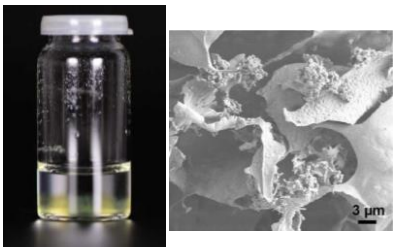
A new strategy for desalination is expected to decrease the capital costs of ED plants



Gonzalez-Vogel A., Rojas O.J., Exploiting electroconvective vortices in electrodialysis with high-frequency asymmetric bipolar pulses for desalination in overlimiting current regimes, **Desalination**, 474, 114190 (2020). DOI: 10.1016/j.desal.2019.114190

Phosphorylated cellulose nanofibers exhibit exceptional capacity for uranium capture

We demonstrate one thehighest adsortion affinity between phosphorylated cellulose nanofibers and uranium.

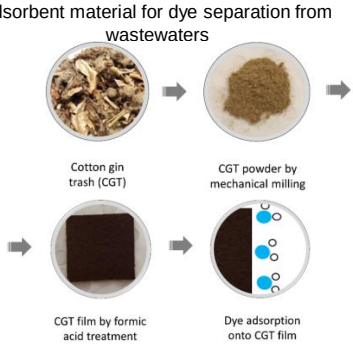


Lehtonen J., Hassinen J., Kumar A.A., Johansson L.-S., Mäenpää R., Pahimanolis N., Pradeep T., Ikkala O., Rojas O.J., Phosphorylated cellulose nanofibers exhibit exceptional capacity for uranium capture, **Cellulose**, 27, 10719–10732 (2020). DOI: 10.1007/s10570-020-02971-8

Separation (publications 2020), cont'd

Cotton gin trash (CGT), a residual lignocellulosic biomass is proposed for application in environmental remediation.

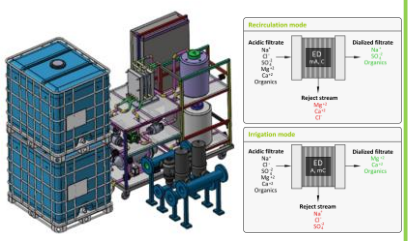
CGT has an enormous potential as an adsorbent material for dye separation from wastewaters



Haque A.N.M.A., Remadevi R., Rojas O.J., Wang X., Naebe M., Kinetics and equilibrium adsorption of methylene blue onto cotton gin trash bioadsorbents, **Cellulose**, 27, 6485–6504 (2020). DOI: 10.1007/s10570-020-03238-y

Desalination by pulsed electrodialysis reversal: Approaching fully close-loop water systems

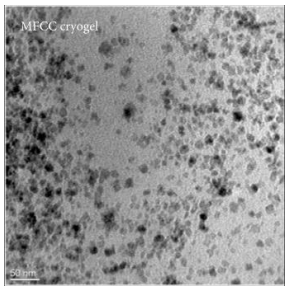
Pulsed electrodialysis reversal pilot is proposed to desalinate water, affording close-loop processing, minimizing the need for fresh water intake while maintaining the quality of recirculating process streams.



Gonzalez-Vogel A., Moltedo J.J., Quezada R., Schwarz A., Rojas O.J., Pilot treatment of bleaching acidic filtrate in Kraft pulping with high frequency pulsed electrodialysis, **Journal of Environmental Management**, 282, 111891, (2021). DOI: 10.1016/j.jenvman.2020.111891

Cryogels based on microfibrillar cellulose and reinforced with chitosan were loaded with magnetite nanoparticles (MNPs)

The introduced bicomponent cryogels for nanoparticle loading show to a remarkably high metal ion sorption capacity

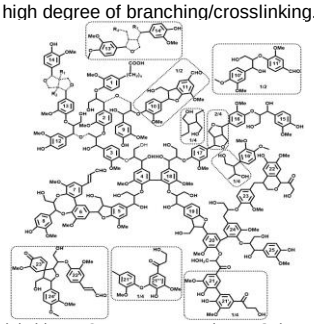


Yan J., Yang H., da Silva J.C., Rojas O.J., Loading of iron (II, III) oxide nanoparticles in cryogels based on microfibrillar cellulose for heavy metal ion separation, **Advances in Polymer Technology**, 9261378 (2020). DOI: 10.1155/2020/9261378

Bioactivity, lignin and tannins (publications 2020)

Up-to-date structural model of spruce MWL in agreement with the current structural and molecular weight data.

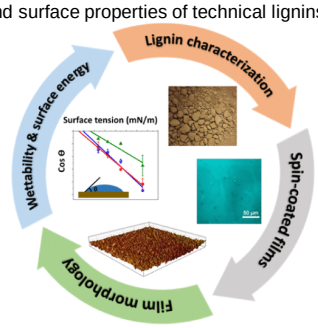
We show that conventional lignification theory doesn't correlate with the presence of key moieties in softwood MWL and the observed high degree of branching/crosslinking.



Balakshin M., Capanema E.A, Zhu X., Sulaeva I., Potthast A., Rosenau T., Rojas O.J., Spruce Milled Wood Lignin: Linear, Branched or Cross-linked? **Green Chemistry**, 22, 3985-4001 (2020). DOI: 10.1039/D0GC00926A

Morphological and wettability properties of thin coating films produced from technical lignins

Deepening or understanding on the wetting and surface properties of technical lignins.

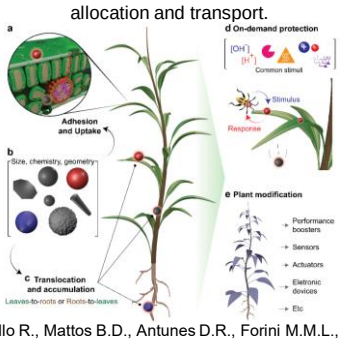


Borrega M., Päärnilä S., Greca L.G., Jääskeläinen A.-S., Ohra-aho T., Rojas O.J., Tamminen T., Morphological and wettability properties of thin coating films produced from technical lignins, **Langmuir**, 36, 9675–9684 (2020). DOI: 10.1021/acs.langmuir.0c00826

Bioactivity, lignin and tannins (publications 2020), Cont'd

Particulate delivery systems within nano-enabled agriculture

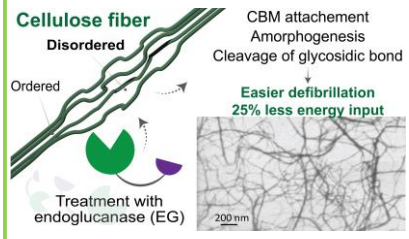
We review interactions between particles and plant tissues, considering adhesion, uptake, allocation and transport.



Grillo R., Mattos B.D., Antunes D.R., Forini M.M.L., Monikh F.A., Rojas O.J. Foliage adhesion and interactions with particulate delivery systems for plant nanobionics and intelligent agriculture, **Nano Today** 37 101078 (2021). DOI: 10.1016/j.nantod.2021.101078

Monocomponent endoglucanase for energy efficient CNF production

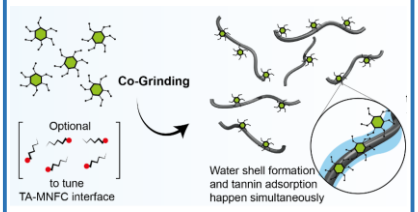
We investigated the effect of process parameters on the enzyme-cellulose interactions and correlation with the energy intake for fiber defibrillation.



Berto G.L., Mattos B.D., Rojas O.J., Arantes V., Single-step fiber pre-treatment with monocomponent endoglucanases: defibrillation energy and cellulose nanofibril quality, **ACS Sustainable Chemistry & Engineering**, Accepted, (2021). DOI: 10.1021/acssuschemeng.0c08162

Co-grinding wood fibers with tannins for functional hybrid nanofibers

We developed a single-step process to embed tannins in nanocelluloses and to synthesize bioactive films.

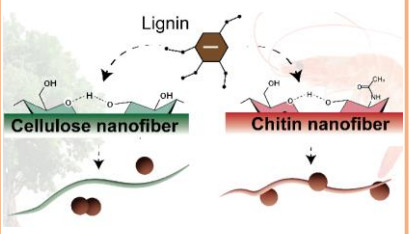


Missio A.L., Mattos B.D., Otoni C.G., Gentil M., Coldebella R., Khakalo A., Gatto D.A., Rojas O.J. Co-grinding wood fibers and tannins: Surfactant effects on the interactions and properties of functional films for sustainable packaging materials, **Biomacromolecules**, 21, 1865–1874 (2020). DOI: 10.1021/acs.biomac.9b01733

Bioactivity, lignin and tannins (publications 2020), Cont'd

Lignin nanoparticle nucleation and growth on nanopolysaccharides

We developed a new process to produce lignin nanoparticles in the presence of bio-based nanofibers via solvent shifting.



Pasquier E., Mattos B.D., Belgacem N., Bras J., Rojas O.J., Lignin nanoparticle nucleation and growth on cellulose and chitin nanofibers, **Biomacromolecules**, Accepted (2021). DOI: 10.1021/acs.biomac.0c01596

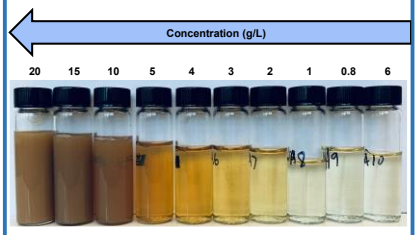
Lignin to enhance the mechanical properties of castor oil-based polyurethanes.

Differences of four orders of magnitude in viscoelastic moduli are observed by using lignin: Outstanding resistance and cushioning properties are obtained

Borrero-López A.M., Wang W., Valencia C., Franco J.M., Rojas O.J., Lignin effect in castor oil-based elastomers: Reaching new limits in rheological and cushioning behaviors, **Composites Science and Technology**, 203, 108602 (2021). DOI: 10.1016/j.compscitech.2020.108602

Nucleation and growth of LPs to develop value-added applications for kraft lignin

We elucidate solvent–lignin–water interactions in relation to molecular weight and functional groups of the lignin fractions and solvent/water polarity.

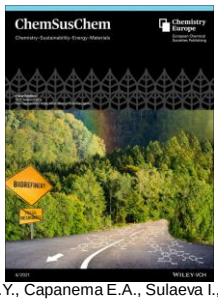


Zwilling J., Jiang X., Venditti R.A., Jameel H., Velev O.D., Rojas O.J., Gonzalez R., Synthesis of Lignin Micro-and Nanoparticles with Tunable Nucleation and Stability by Solvent Fractionation, Accepted, **Green Chemistry** (2021). DOI: 10.1039/D0GC03632C

Bioactivity, lignin and tannins (publications 2020), Cont'd

New opportunities in the valorization of technical lignins – lignin-centered biorefineries

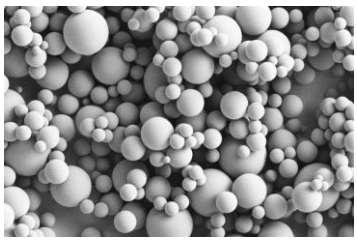
Critical review on the state-of-the-art in the valorization of technical, biorefinery lignins. We discuss "best-for everything" lignin or "killer application" for all lignin types.



Balakshin M.Y., Capanema E.A., Sulaeva I., Schlee P., Huang Z., Feng M., Borghei M., Rojas O.J., Potthast A., Rosenau T. New opportunities in the valorization of technical lignins, **ChemSusChem**, Accepted (2021). DOI: 10.1002/cssc.202002553

Sustainability and applications prospects of lignin particles

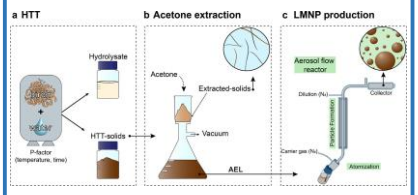
We discuss the use of spherical lignin particles as dispersants and in the formulation of coatings, adhesives and composites, focusing on the advantages of the spherical shape and nanoscaled size.



Österberg M., Sipponen M.H., Mattos B.D., Rojas O.J., Spherical lignin particles: A review on their sustainability and applications, **Green Chemistry**, 22, 2712-2733 (2020). DOI: 10.1039/D0GC00096E

Lignin-first integrated hydrothermal treatment (HTT) and synthesis of low-cost biorefinery particles

Inexpensive lignin nano and microparticles were produced from a hydrothermal treatment-based biorefinery concept. Low-cost production, but of high lignin valorization potential.

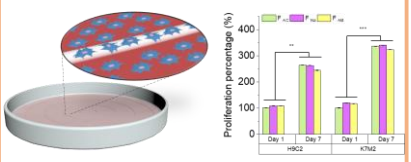


Lourençon T.V., Greca L.G., Tarasov D., Borrega M., Tamminen T., Rojas O.J., Balakshin M.Y., Lignin-first integrated hydrothermal treatment (HTT) and synthesis of low-cost biorefinery particles, **ACS Sustainable Chemistry & Engineering**, 8, 1230-1239 (2020). DOI: 10.1021/acssuschemeng.9b06511.

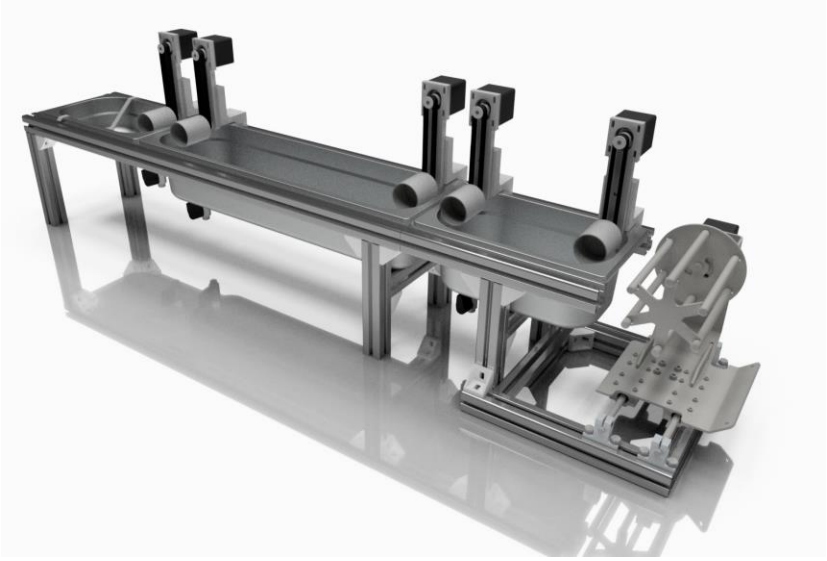
Filament spinning (publications 2020)

Wet spinning of nanochitin for cell proliferation

We investigate the effect of chitin nanofibril (ChNF) loading, extrusion rate and coagulant type on wet spinning. Wet-spun ChNF microfibers show excellent cell viability and perliferation.



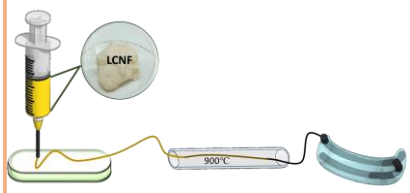
Wang L., Ezazi N.Z., Liu L., Ajdary R., Xiang W., Borghei M., Santos H.A., Rojas O.J., Microfibers Synthesized by Wet-Spinning of Chitin Nanomaterials: Mechanical, Structural and Cell Proliferation Properties, **RSC Advances**, 10, 29450 (2020). DOI: 10.1039/D0RA06178F



Filament spinning (publications 2020), cont'd

Porous carbon fibers achieved by wet-spinning of lignocellulose nanofibrils

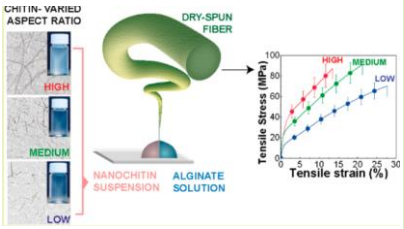
We demonstrate a green and facile route to convert wood into carbon microfibers suitable for fiber-shaped supercapacitors.



Wang L., Borghei M., Ishaq A., Lahtinen P., Ago M., Papageorgiou A.; Lundahl M., Johansson L.-S., Kallio T., Rojas O.J., Mesoporous carbon microfibers for electroactive materials derived from lignocellulose nanofibrils, **ACS Sustainable Chemistry & Engineering**, 8, 8549–8561 (2020). DOI: 10.1021/acssuschemeng.0c00764

Nanochitin/alginate fibers achieved via interfacial complexation

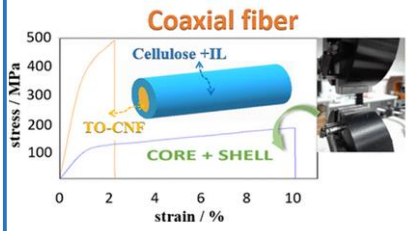
We elucidate the effect of the nanofiber aspect ratio on the mechanical performance of the composite microfibers after considering variables such as concentration, pH, and drawing rate.



Grande R., Bai L., Wang L., Xiang W., Ikkala O., Carvalho A.F.K., Rojas O.J., Nanochitins of varying aspect ratio and properties of microfibers produced by interfacial complexation with seaweed alginate, **ACS Sustainable Chemistry & Engineering**, 8, 1137-1145 (2020). DOI: 10.1021/acssuschemeng.9b06099

All cellulose filaments by coaxial spinning

Regenerated cellulose in Ionic Liquids (shell) facilitates the production of filaments from materials with poor spinnability (core)

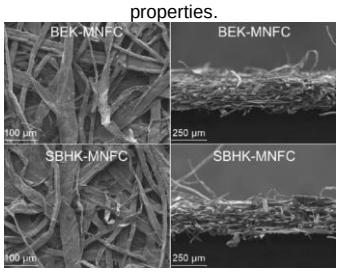


Reyes-Torres G., Lundahl M.J., Alejandro-Martín S., Arteaga-Pérez, L.E., Oviedo C., King A.W.T., Rojas O.J., Coaxial spinning of all-cellulose systems for enhanced toughness: filaments of oxidized nanofibrils sheathed in cellulose II regenerated from a protic ionic liquid, **Biomacromolecules**, 21, 878-891 (2020). DOI: 10.1021/acs.biomac.9b01559

Composites, films and paper (publications 2020)

Effect of micro- and nanofibrillated cellulose (MNFC) on the tensile index, softness, and water absorbency of tissue paper.

MNFC increased the tensile index of tissue paper but decreased water absorbency and softness. MNFCs from NBSK and SBHK yielded comparable trade-offs in tissue properties.

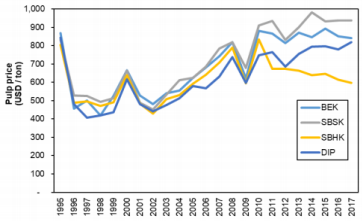


Zambrano F., Wang Y., Zwilling J.D., Venditti R.A., Jameel H., Rojas O.J., Gonzalez R., Micro- and nanofibrillated cellulose from virgin and recycled fibers: A comparative study of its effects on the properties of hygiene tissue paper, **Carbohydrate Polymers**, 254, 117430 (2021). DOI: 10.1016/j.carbpol.2020.117430

Composites, films and paper (publications 2020), Cont'd

Review about the use of micro- and nanofibrillated cellulose (MNFC) in papermaking applications.

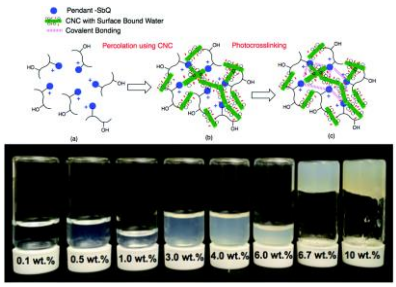
Improved performance in terms of strength development is associated with a higher degree of MNFC fibrillation, offsetting its high manufacturing cost



Zambrano F., Starkey H., Wang Y., Abbati de Assis C., Venditti R., Pal L., Jameel H., Hubbe M.A., Rojas O.J., Gonzalez, R., Using micro- and nanofibrillated cellulose as a means to reduce weight of paper products: A review, **BioResources**, 15, 4553-4590 (2020). DOI: BioRes_15_2_7691

Combining cellulose nanocrystals with photoactive poly(vinyl alcohol) to form photocrosslinked nanocomposite hydrogels.

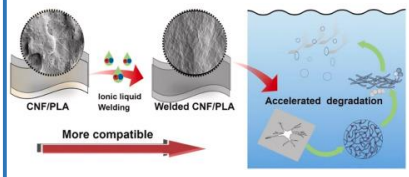
We show the ability of CNC to significantly alter the storage moduli of crosslinked polymer gels at low loading fractions through percolation-induced reinforcement.



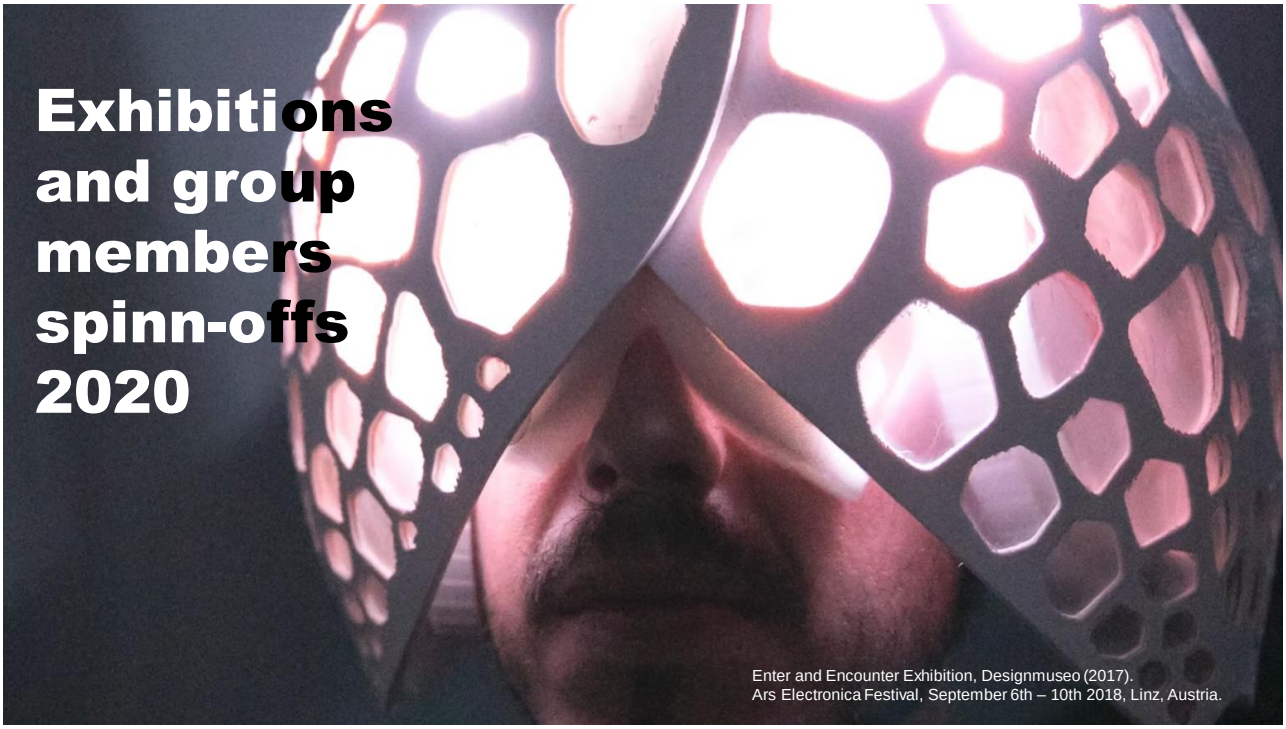
Corder R.D., Adhikari P., Burroughs M.C., Rojas O.J., Khan S.A., Cellulose Nanocrystals for Gelation and Percolation-induced Reinforcement of a Photocurable Poly (vinyl alcohol) Derivative, **Soft Matter** 16, 8602-8611 (2020). DOI: 10.1039/D0SM01376E

Green and facile method to compatibilize polylactide (PLA) with cellulose nanofibers (CNF) by using ionic liquid welding with gamma-valerolactone cosolvent

Incorporation of nanocellulose and welding accelerates the otherwise slow degradation of PLA in seawater. The welding process makes it possible to achieve strong, lightweight and transparent films.



Niu X., Huan S.Q., Li H.M., Pan H., Rojas O.J., Transparent films by ionic liquid welding of cellulose nanofibers and polylactide: Enhanced biodegradability in marine environments, **Journal of Hazardous Materials**, 402, 124073 (2021). DOI: 10.1016/j.jhazmat.2020.124073



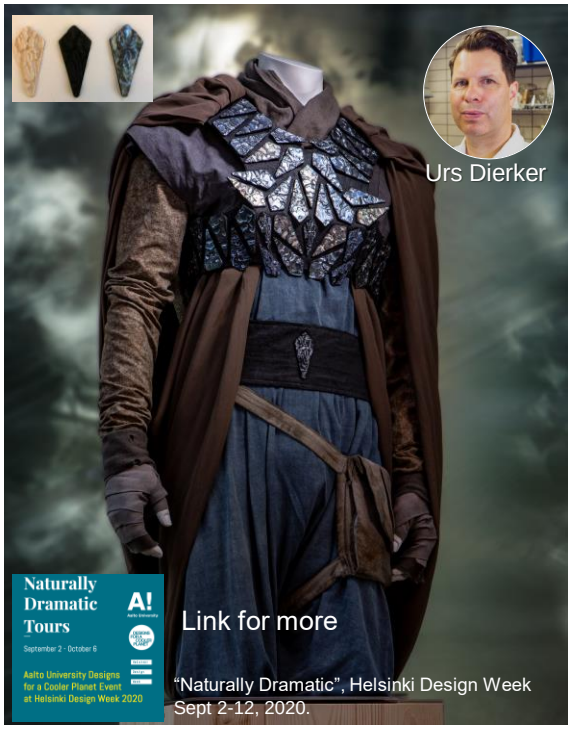
Solar energy through ChemisTree

https://www.aalto.fi/en/events/solar-energy-through-chemistree

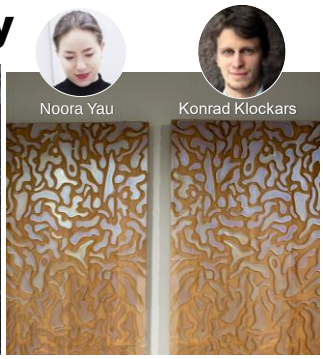
Bacteria as micro-3D printers

https://www.aalto.fi/en/news/scientists-use-bacteria-as-micro-3d-printers

https://youtu.be/U6mE9cRyZfU



Exhibitions by



Noora and Konrad founded the **Structural Colour Studio** **CONGRATS!!!**

The studio presented **Shimmering Wood** (see images) at the Designs for a cooler planet exhibition in Aalto University during September

Video, news article & website: https://www.youtube.com/watch?v=qfa2VK4YRJQ

https://www.aalto.fi/en/news/parallel-paths-designer-and-materials-scientist-conjure-up-glimmering-colours-out-of-wood

https://areena.yle.fi/audio/1-50599733

www.structuralcolourstudio.com

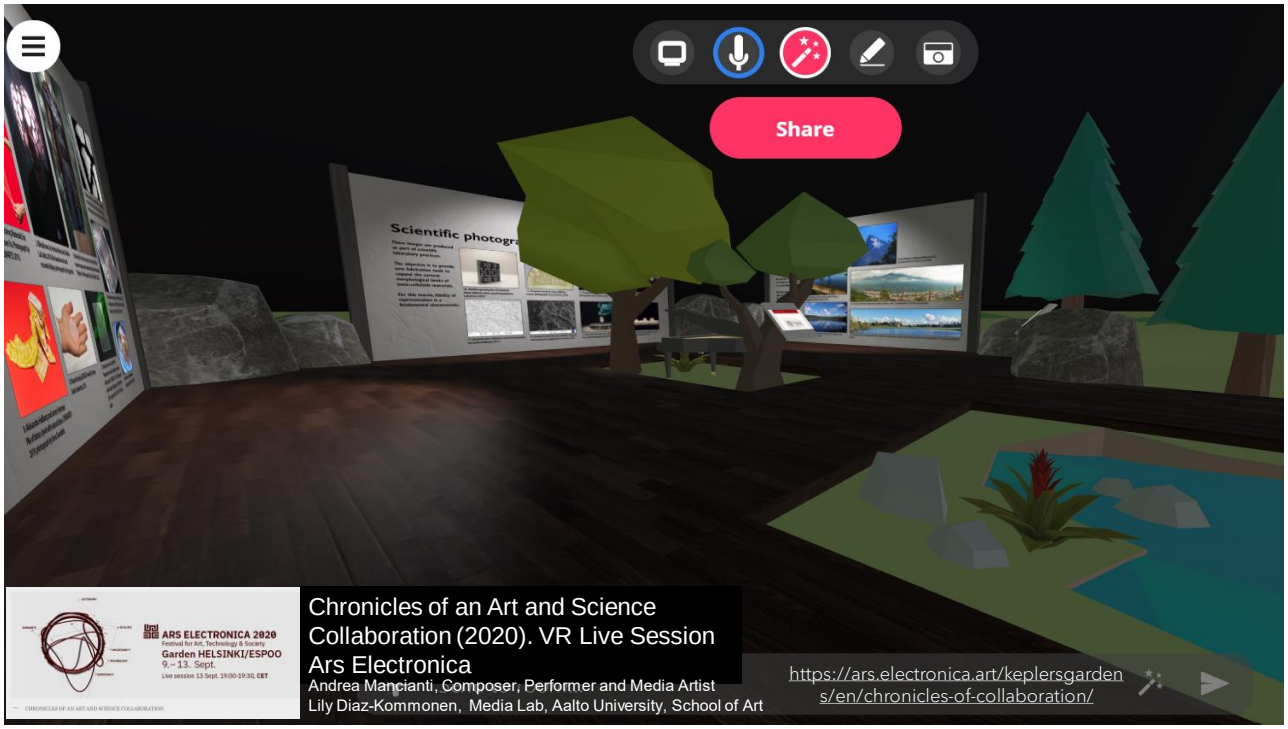
Part of the work was displayed at the Wood Wonders exhibition in Finavia Helsinki-Vantaa. From 5.2.2020 until 13.6.2021

And in Designing for the Senses -exhibition, Curated by Material Driven / London / Architect@Work

Financial Times: https://www.ft.com/content/6240dd78-4e8b-11ea-95a0-43d18ec715f5?fbclid=IwAR0h6LR-8zQTrDxaWtX2pS-4QR6HpMgOtpMjaKGBNMhoSVx6a0h737tEVE0

Specification Today: https://edition.pagesuite-professional.co.uk/html5/reader/production/default.aspx?pubname=&edid=8d2beee8-46d9-4886-a053-01cd2a7cd8a0&pnum=1

Noora Yau gave a conference presentation at the AIC Natural colors– Digital Colors 2020 meeting, and also submitted a conference article on the following topic: **The Highlight effect in structural color from cellulose nanocrystals** (poster)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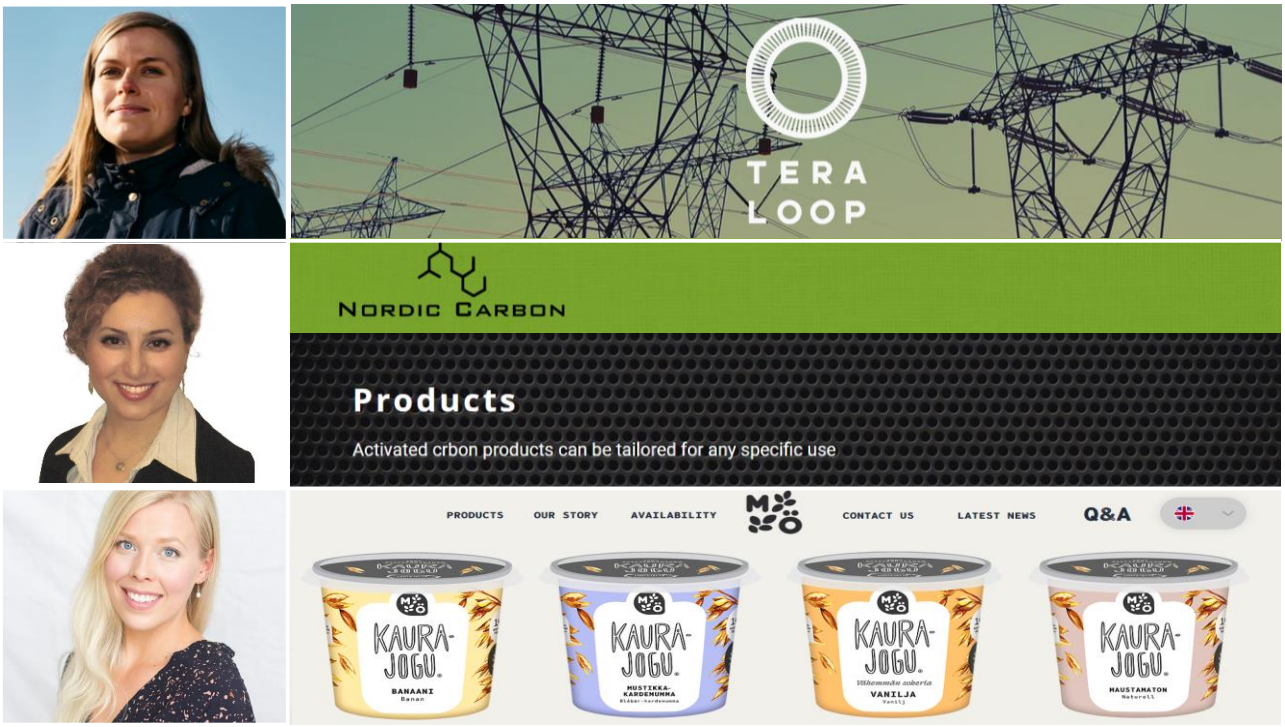
Ars Electronica
Andrea Mancianti, Composer, Performer and Media Artist
Lily Diaz-Kommonen, Media Lab, Aalto University, School of Art
https://ars.electronica.art/keplersgardens/en/chronicles-of-collaboration/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