“ADSORPTION OF SELECT HEMICELLULOSES TO A MODEL CELLULOSE SURFACE”

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Abstract

The adsorption of xyloglucan, arabinogalactan, xylan, and pectin to a regenerated cellulose surface was measured using a quartz crystal microbalance with dissipation monitoring. Of the four polysaccharides, the xyloglucan and pectin demonstrated the greatest adsorption to the cellulose surface. Adsorption isotherms of the two were then compiled by measuring the adsorption at various concentrations. The xyloglucan demonstrated a high affinity for the cellulose surface while the pectin demonstrated a significantly lower affinity. Both sets of data were fit to the Langmuir model, and the data suggested that a single monolayer of polysaccharide was adsorbing onto the film.

"SYNTHESIS AND CHARACTERIZATION OF NEW AROMATIC POLYMER MATERIALS FOR GAS SEPARATION MEMBRANES"

Jennifer Carter, Ruilan Guo, J. E. McGrath, Macromolecules and Interfaces Institute, Virginia Tech, Blacksburg, VA 24061

Abstract

Within the past decades, gas separation systems using polymeric membranes have undergone a rapid growth. They can offer many advantages over traditional processes such as low energy consumption, low operating costs and high flexibility. In particular, using crosslinked networks should allow us to better control the chemical resistance, selectivity and permeability of the membrane.

Accordingly, phenylethynyl-terminated aromatic polyimides were prepared from 5(6)-amino-1-(4-aminophenyl)-1,3,3-trimethylindane (DAPI) with various aromatic dianhydrides, using 4-(phenylethynyl) phthalic anhydride (PEPA) as an end-capping agent during the polycondensation reactions. Telechelic polyimide oligomers were prepared with molecular weights ranging from 3000 to 15,000 g/mol by adjusting the monomer feed ratio and the amount of end-capping agent. Endgroup functionality and molecular weights of the oligomers were established via NMR, FTIR, and SEC measurements. These telechelic polyimide oligomers displayed cure temperatures between 370 and 400 °C as determined by DSC. The resulting phenylethynyl-terminated aromatic polyimides were crosslinked thermally for one hour at their maximum cure temperature under N_2. The gel fractions of the resultant crosslinked polyimides are closely related to the molecular weights of the precursor oligomers, cure temperaure and cure time. The cured DAPI-based polyimides showed superior solvent resistance and excellent high temperature properties. The capacities for these networks to separate carbon dioxide impurities from natural gas will be evaluated by our colleagues at UT, Austin.

“DESIGN OF BIOINSPIRED IMIDAZOLIUM-CONTAINING COPOLYESTERS FOR DRUG DELIVERY APPLICATIONS”

Joe Dennis, Nancy Zhang and T. E. Long, Macromolecules and Interfaces Institute, Virginia Tech, Blacksburg, VA 24061

Abstract

In this study, melt esterification was used to synthesize a novel copolyester, poly(diethylene glycol adipate-*co*-imidazolium adipate) bis(trifluoromethanesulfonyl)imide. Progress of the polymerization was monitored using acid titrations that showed a progressive decrease in acid content. Size exclusion chromatography in DMF-LiBr was used to establish that controlled molecular weights and distributions were achieved using a stoichiometric imbalance of diol to diacid. A decrease in the temperature at which degradation began and an increase in the glass transition suggested successful incorporation of the imidazolium diol into the copolyester. Further investigation needs to be done before more conclusions can be drawn.

“BLOCK IONOMER COMPLEXES CARRYING MULTIFUNCTIONAL CATIONIC AMINOGLYCOSIDES”

L. M. Johnson, N. Pothayee, N. Jain, T. P. Vadala, R. Mejia-Ariza, C. van Duyn, N. Sriranganathan, R. M. Davis and J. S. Riffle, Institute for Critical Technologies and Applied Science, the Macromolecules and Interfaces Institute and the VA-MD Regional School of Veterinary Medicine, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061

Abstract

Polyether-polyacrylate copolymers were complexed with cationic aminoglycoside antibiotics to form nanoplexes with diameters of 170-340 nm in water. A pentablock poly(acrylate-b-ethylene oxide-b-propylene oxide-b-ethylene oxide-b-acrylate) copolymer blended with a poly(ethylene oxide-b-acrylate) diblock was condensed with gentamicin in PBS to afford nanoplexes containing up to 42 wt% of the antibiotic. The poly(propylene oxide) contributed hydrophobic interactions that enhanced nanoplex formation in aqueous media while the hydrophilic blocks provided a steric brush that kept the structures dispersed. The drug release profiles in PBS showed a significant "burst" within the first ~10 hours, then slower release up to ~40-60 hours. In vitro efficacy of the nanoplexes to reduce intracellular Brucella was studied in murine macrophage-like cells. Significant reductions of 2.78 and 2.85 logs were obtained with the nanoplexes, while free drug only reduced the bacteria by 0.75 logs. This suggests that the nanoplexes are efficient transporters of these polar antibiotics into the phagocytic cells.

"WATER SOLUBILITY OF FLAVONOIDS BY SOLID DISPERSION IN CELLULOSE DERIVATIVES"

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Abstract

Amorphous mixtures comprised of different ratios of quercetin or curcumin and carboxylated cellulose derivative polymer matrices were prepared using a spray drying technique. Different analytical methods were used to determine the ratio with optimum solubility of the flavonoids. X-ray diffraction studies showed that hydroxypropyl methylcellulose acetate succinate (HPMCAS) was a successful polymer matrix in creating amorphous mixtures. Fourier transform infrared spectral studies demonstrated that all of the spray-dried powders had enhanced hydrogen bonding. The preliminary results of the dissolution experiments indicated that the water solubility of flavonoids might be significantly enhanced through solid dispersion in HPMCAS by the spray drying method.

"IMPROVED BIOAVAILABILITY OF CLARITHROMYCIN THROUGH NANOPARTICLE FORMATION WITH CARBOXYMETHYL CELLULOSE ACETATE BUTYRATE USING A MULTI-INLET VORTEX MIXER"

J. Lindsay, R. Mejia-Ariza, J. Pereira, S. C. Fox, K. J. Edgar, R. M. Davis, Macromolecules and Interfaces Institute and the Depts of Wood Science and Forest Products and Chemical Engineering, Virginia Tech, Blacksburg, VA 24061

Abstract

Many important drugs suffer from low bioavailability due to having poor solubility in water. Carboxymethyl cellulose acetate butyrate (CMCAB) as a complexing agent has been shown to be effective at increasing the solubility of insoluble drugs due to it forming an amorphous matrix, which suppresses crystallization of the drug. An important concern with these polymer-drug complexes is that the release rate and thus solubility is greatly dependent on size due to curvature effects and increasing of surface area to volume. It is therefore important that methods are developed to produce nanoparticles of CMCAB and drug to improve solubility and thus bioavailability. Our strategy is to improve bioavailability via forming nanoparticles of CMCAB and clarithromycin using a multi-inlet vortex mixer. Our parameters were a 3:1 mass ratio of CMCAB to drug, a pH of 6.0, a 9:1 volume ratio of water to THF inside the mixer, and a temperature of 25°C. Nanoparticles of CMCAB and clarithromycin were successfully formed with a diameter of 95.1 nm with a standard deviation of 7.4 nm and an average drug loading of 81%. It was found that both the size of nanoparticles and encapsulation of drug could be controlled.

“FABRICATION AND CHARACTERIZATION OF CONJUGATED PHENOLIC ACIDS TO GELATIN MICROSPHERES AND THIN FILMS FOR PEROXYNITRITE SCAVENGING”

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Abstract

This research investigated the use of gelatin materials as small molecule delivery devices. Specifically, tyrosine mimetics were used to scavenge peroxynitrite ($ONOO^-$), a reactive nitrogen species formed through the combination of the superoxide radical anion ($\cdot O_2^-$) and nitrogen oxide ($NO\cdot$), which are produced in excess in inflammatory conditions. Quenching peroxynitrite with these mimetics could reduce damage to biomolecules in inflammatory diseases such as osteoarthritis. The carboxylate groups of seven phenolic acids (syringic, gentisic, sinapinic, ferulic, caffeic, *p*-coumaric, and *m*-coumaric acid) were conjugated to the ε-lysine groups of gelatin using 1-ethyl-3,3-dimethylaminopropyl carbodiimide hydrochloride (EDC) as the coupling agent, and the potential of these drug-polymer complexes to quench synthetic peroxynitrite was measured. Release of the drugs from the conjugates was compared to the release of non-conjugated phenolic acids along with the phenolic species vanillin. To confirm conjugation of the small molecules to the gelatin and the peroxynitrite quenching, Raman, FTIR-ATR, and UV/Vis spectroscopy were used as well as the trinitrobenzenesulfonic acid (TNBS) assay.

“ANALYZING THE BINDING INTERACTIONS BETWEEN VARYING PERCENTS OF ALKYLATION AND SUBSTITUTION OF POLY(1-VINYLIMIDAZOLE) AND HEPARIN FOR USE IN GENE THERAPY”

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Abstract

Gene therapy introduces genes into a cell for the prevention and treatment of diseases such as cancer and genetic deficiencies. The most common types of carriers used for gene therapy are altered viruses; however, viral vectors present a number of problems such as gene control, toxicity, immune and inflammatory responses, and targeting issues. Transfection, the process of introducing nucleic acids into cells, offers a non-viral means of gene therapy. Non-viral vectors are easier to synthesize, do not elicit immune responses, and allow for more controlled efficient delivery of therapeutic genes.

The present work furthers the study of non-viral vectors used in the process of transfection. Isothermal titration calorimetry (ITC), small angle laser light scattering (SALS), and microscopy were used to better understand the binding interactions between the polycation, poly(1-vinylimidazole), and heparin, a highly-sulfated molecule with a very high negative charge density, while altering the percent alkylation of poly(1-vinylimidazole). An additional three samples of poly(1-vinylimidazole) were substituted with an ethyl alkyl chain as opposed to a butyl alkyl chain. The three samples had varying percents of alkylation including 7%, 21% and 32%. ITC, SALS, and microscopy were performed to determine the associated binding thermodynamics, verify that no phase separation occurred between the polymers and heparin, and investigate the effect of counterion type on the phase separation behavior in the polyplex, respectively. ITC showed that decreasing the percent alkylation on poly(1-vinylimidazole) substituted with a butyl alkyl chain, or decreasing the alkyl chain length, increases the binding constant, or binding affinity, with the exception of the 83% alkylated poly(1-vinylimidazole) substituted with a butyl alkyl chain. SALS and a microscopy in the phase contrast mode verified that blends of poly(1-vinylimidazole) substituted with a butyl alkyl chain (21, 33, 83 and 88% alkylation) and heparin are miscible.

“SYNTHESIS AND CHARACTERIZATION OF NEW AROMATIC POLYMER MATERIALS FOR GAS SEPARATION MEMBRANES”

Tekesha Rhodes, Ruilan Guo, J. E. McGrath, Macromolecules and Interfaces Institute,
Virginia Tech, Blacksburg, VA 24061

Abstract

There have been widespread gas separation applications utilizing polymer membranes, such as separation of air, removal of CO_2 from natural gas, and removing H_2 from mixtures with N_2 or hydrocarbons in petrochemical processes, etc. For high performance polymer membranes, both high permeability and good selectivity are desirable. However, it is well known that polymers that are more permeable are generally less selective and vice versa. A classic plot by Robeson illustrates clearly this strong trade-off between permeability and selectivity defining the so-called "upper bound" relation. Over the years, substantial research effort has been directed to overcoming the limit imposed by the upper bound via designing novel polymer structures, controlling morphology, etc.

Aromatic polyimides (APIs) as gas separation membranes are of great interest due to their excellent thermal, chemical and mechanical stability. They are considered ideal for separating CO_2/CH_4 mixtures because of their high selectivities and permeabilities. However, CO_2-induced plasticization at elevated pressure limits their use in CO_2/CH_4 separations. Therefore, considerable efforts have been taken to design or modify the structure of APIs to suppress plasticization. Recently, it was reported that APIs containing *ortho*-positioned hydroxyl groups would rearrange to a polybenzoxazole (PBO) when heated in an inert atmosphere. Excellent CO_2/CH_4 separation performance as well as high resistance to plasticization were reported. However, very high processing temperatures (>400 °C) are essential for current rearrangement processes, which make it less practical. Therefore, design and synthesis of new API precursors and exploration of alternative synthetic routes to PBOs are of interest.

In this work, we synthesized a series of API precursors utilizing various combinations of aromatic dianhydrides and bisaminophenols, aiming at producing API precursors with low rearrangement temperatures as well as exploring the rearrangement mechanism. APIs containing *ortho*-positioned hydroxy groups were synthesized via polycondensation of the bisaminophenols, 2,2-bis(3-amino-4-hydroxyphenyl)hexafluoropropane (6FAP) or 3,3'-dihydroxy-4,4'-diaminobiphenyl (HAB) with various dianhydrides. API precursors were characterized by FTIR, NMR, DSC, TGA and DMA to confirm the chemical structure and assess their thermal and mechanical properties. Tough films were cast from API solutions that had good thermal and mechanical properties with high glass transition temperatures ranging from 210 to 330 °C. By means of TGA, a distinct weight loss region ascribed to the loss of CO_2 in the rearrangement process was observed for all APIs in the temperature range from 300 to 450 °C. It was found that the lower temperature of the imide-to-benzoxazole rearrangement greatly depended on the glass transition temperatures of the API precursors. APIs with high Tg's required a high rearrangement temperature to obtain high degrees of conversion to PBOs. In this regard, rearrangement temperatures were tuned and successfully reduced by up to 100 °C by simply altering the aromatic dianhydride monomers. The PBO films displayed excellent solvent resistance and thermal stability. Insolubility of the rearranged polymers in all solvents tested suggested that the rearrangements were accompanied by crosslinking. The CO_2/CH_4 separation performance of the API and corresponding PBO membranes is being actively pursued.

“NOVEL MEMBRANES FOR WATER PURIFICATION”

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Abstract

The overall goal of our research is to produce a thin film composite with a permselective layer of directly polymerized, disulfonated polysulfone (BPS) that is capable of efficiently desalinating and purifying water by reverse osmosis. The approach included three major steps. First, nanodispersions of the hydrophilic polymers and copolymers were prepared and the sizes and reproducibility of the dispersions were analyzed. Secondly, the fabrication process whereby these dispersions could be utilized to cast thin membrane films was optimized. Thirdly, thin film composites were prepared having porous polysulfone substrates overlayed with the thin permselective layers were investigated. We have found that direct application of a nanodispersion of BPS-32 to the glycerin-coated support membranes produced a novel composite material. In addition to inhibiting the BPS-32 solution from penetrating the pores of the support, glycerin additionally acted as a plasticizer.

"THE DESIGN AND FABRICATION OF BISMUTH HALL EFFECT BIOSENSORS"

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Abstract

Because of their high sensitivity, accuracy, and low cost, the use of Hall biosensors promises to be an effective diagnostic technique that may aid in the early diagnosis of diseases. In this research, Hall sensors were fabricated from thermally evaporated bismuth thin films. The bismuth films were deposited under high vacuum onto heated Si/SiO$_2$ substrates using a two-layer deposition technique. The films varied in thickness from 60 nm to 75 nm and were etched into Hall bar geometries using photolithography and wet chemical etching. Magnetoresistance and Hall measurements were taken from 4 K to 300 K. The data indicate that the sensors may be characterized using a two-carrier model with high-mobility, low-density holes and low-mobility, high-density electrons. Additionally, the sensors were exposed to magnetite nanoparticles and characterized using atomic force microscopy.

(Anthony Sigillito presented this work at the Texas APS meeting, Oct. 21-23, 2010, The University of Texas at San Antonio, San Antonio, TX 78249)

"CELLULAR UPTAKE OF FLUORESCENTLY-LABELED-FOLATE TARGETED CELLULOSE NANOCRYSTALS"

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Abstract

Nanoparticles have proven to be advantageous in the field of targeted drug delivery for use as polymeric delivery vehicles. This work has involved exploration of cellulose nanocrystals (CNCs) for targeted drug delivery. The CNCs were prepared by sulfuric acid hydrolysis of bleached soft wood pulp, then they were derivatized by several methods. Their lengths were ~130 nm and widths were 3-5 nm. Carboxylic acids were introduced onto the CNC surfaces through TEMPO/$NaClO_4$/NaBr oxidation, then the materials were further reacted with aminated folic acid (FA) or fluorescent labels. Current research suggests that KB cancer cells overexpress folate receptors. Thus, it was anticipated that functionalization with folic acid would induce binding and endocytosis. Fluorescein derivatives were employed to track this process. This theory was tested via a clathrin inhibitor, chlorpromazine, and a caveolae inhibitor, genistein, will be tested in future experiments. After each trial, the samples were viewed using fluorescent microscopy and the amount of bound fluorescein was analyzed. Understanding the mechanisms and pathways involved in cellular uptake will allow researchers to better focus their attempts at perfecting a true targeted delivery system.

“BISPHOSPHONATED HYDROXYETHYLCHITOSAN SCAFFOLDS FOR BONE REGENERATION”

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Abstract

In vitro mineralization of polymeric scaffolds can improve cellular response and also yield the high compressive strength needed for bone regeneration. Phosphates $[(P{=}O)(OR)_3]$, phosphonates $[R(P{=}O)(OR)_2]$, and their corresponding acids and anions stand out as molecular tools to bind inorganic cations and metals, form multidentate hydrogen bonds to many substrates, and provide critical biological functions associated with bone. Bisphosphonates are of tremendous interest as inhibitors of osteoclast-mediated bone resorption. In this research, a series of bisphosphonates were synthesized through an efficient double Michael addition followed by acrylation to afford acrylate-based aminobisphosphonates. These were further reacted with the pendent amino groups on hydroxyethylchitosan (HEC) via Michael additions to provide bisphosphonate-modified HEC. The materials were crosslinked with a poly(ethylene oxide)-diacrylate as they were formed into hydrogel sponges. Their capacities for stimulating *in vitro* mineralization of calcium phosphates in simulated body fluid were investigated as functions of their bisphosphonate concentration.

"EFFICACY OF POLYMERIC NANOPLEXES ENCAPSULATING GENTAMICIN FOR ELIMINATION OF INTRACELLULAR PATHOGENS *IN VITRO*"

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Abstract

Pathogens like *Listeria, Salmonella,* and *Brucella* have proven very difficult to treat, having a high capacity to occupy host cells and find a comfortable intracellular niche to avoid host defenses. With the low efficiency of many antimicrobial drugs to pass through the host cell membranes, the host organism's immune capabilities falter and intracellular pathogens are difficult to eliminate efficiently. With hopes of fabricating improved methods of drug delivery for the treatment of chronic infections related to *Listeria, Salmonella,* and *Brucella*, polymeric nanoplexes encapsulating aminoglycoside antibiotics, specifically gentamicin, were developed to pass through the membrane to allow the drug to reach therapeutic levels inside the cells. J774 monocyte-macrophages were infected with two strains of bacteria, *Listeria monocytogenes* (wild type) and *Salmonella typhimurium* LT2 strains, then treated with 50 μg of free gentamicin or nanoplexes containing gentamicin over a 6-hour period. A comparative analysis was made of different methods for developing the nanoplexes, and the bactericidal efficacy varied depending on the method used, with highly active complexes and promising results in some.