Clemson University Technology Feature:

Optic and Laser Technologies

Fall 2013

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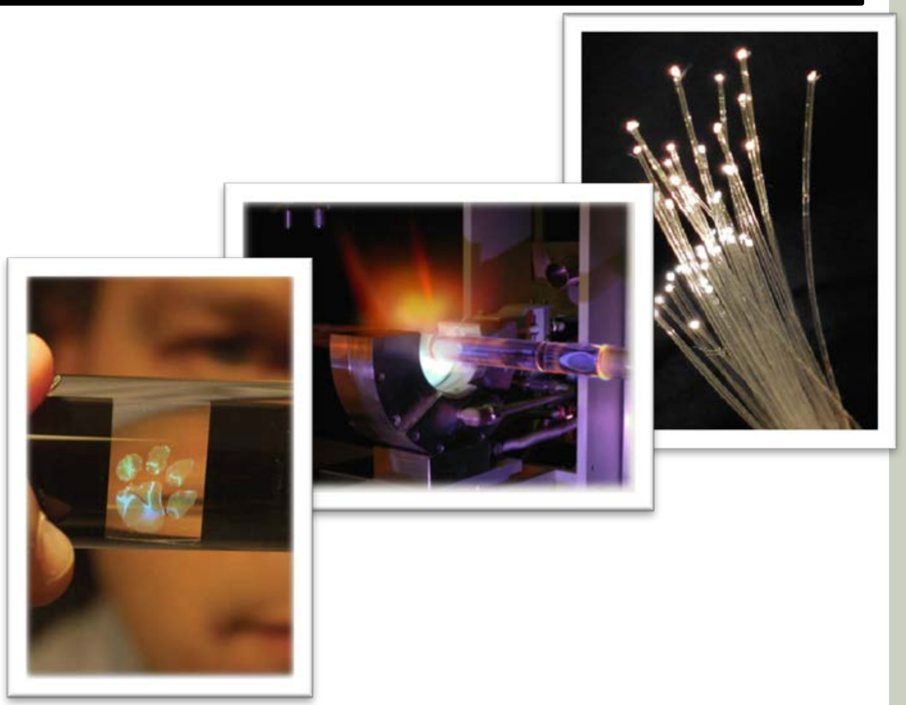

Abstract

This **CURF Technology Feature** highlights emerging technologies developed at **Clemson University.** These technologies relate to optical advancements in the areas of imaging, fiber lasers, coatings, and other advanced material developments.

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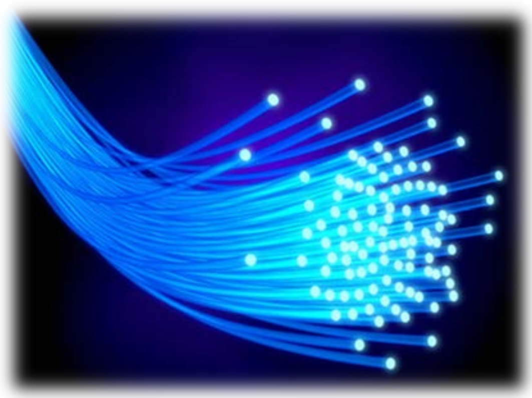
Optical Fibers/ Laser Applications



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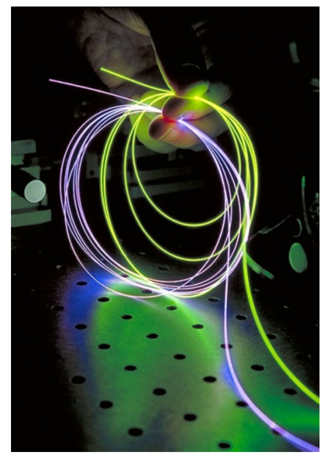
Sapphire-Derived Brillouin Athermal Optical Fiber

Description:

Optical fibers are enablers of a wide variety of modern technologies. However, during use, optical fibers heat up and their performance can change. While not always critical to the application, such thermal dependence is especially problematic for high energy fiber laser and optical fiber sensor systems. The addition of alumina to the silica fibers can mitigate the thermal effects of the fibers. However, conventional methods severely limit the addition of alumina to silica.

This is a novel technology that uses a molten-core technique to add sapphire (Al_2O_3) to silica (SiO_2) glass. The core material melts at a temperature where the cladding glass draws into fiber. The core material melts at a temperature where the cladding glass draws into fiber. The high quench rates permit unstable glasses to be directly obtained in fiber form. It is a continuous process, allows for geometric control, can draw long lengths and allows for high speed manufacturing. The acoustic spectrum is temperature independent which has never before been reported. This technology features an all-glass optical fiber derived from sapphire exhibiting alumina concentrations which are considerably greater than conventionally possible and enables a series of remarkable properties.



Applications:

- High energy fiber lasers
- Optical fiber sensors

Benefits:

- High performance at higher temperatures
- Simple design
- Can be used in combination with conventional fabrication techniques

Licensing Status: This technology is available for licensing

Protection Status: A patent application has been filed

CURF Reference: 2012-082

Inventor(s): John Ballato, et al.

Related Publications:

1) "Sapphire-derived all-glass optical fibres", *Nature Photonics*, 6, 627-633 (2012) http://www.nature.com/nphoton/journal/v6/n9/full/nphoton.2012.182.html

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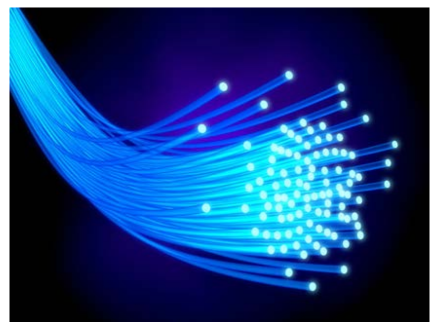
Method to Reduce Insertion Losses in Optical Fibers

Description:

Whenever light travels from one medium into another, there is a resultant reflection that occurs. This reflective loss becomes ever more critical as the optical power continues to scale to higher powers. The conventional approach to reducing reflections is to use anti-reflective coatings where a plurality of layers of varying refractive index and selected thickness are deposited on a surface. These layers are generally discrete with layer thickness that is approximately quart-wavelength and refractive index that is intermediate in value between the adjacent materials, although more complex profiles have been proposed.

This is a novel technology in which MCVD-derived germanosilicate fibers were fabricated that exhibited gradients are about 1900 times greater than previously reported fibers. The method employed is very straight-forward and provides for a wide variety of longitudinal refractive index and acoustic velocity profiles, as well as core shapes, that could be especially valuable for SBS suppression in high energy laser systems. With this, such an anti-reflective character can be generated in an optical fiber which would be of great for a wide variety of optical fiber-based technologies.



Applications:

- High energy laser systems
- Communications
- Amplifier
- Sensing optical fibers

Benefits:

- Minimizes resultant back reflections
- Maintains a constant V-value along its length while having changing diameters

Licensing Status: This technology is available for licensing

Protection Status: A patent application has been filed

CURF Reference: 09-030

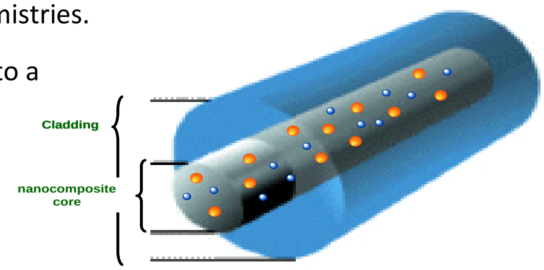
Inventor(s): John Ballato, et al.

Direct Link: http://curf.technologypublisher.com/technology/11859

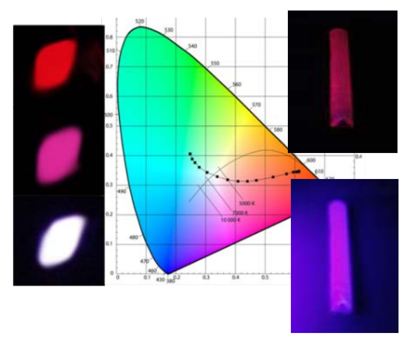
Method of Designer Doping of Optical Fibers

Description:

Rare-earth-doped materials have found an extraordinary range of practical applications, including use in displays, lasers/amplifiers, and lighting. However, energy transfer associated with rare-earth-doped materials is not always desirable, and deleterious effects of co-dopants can significantly reduce the performance of the principal dopant. Energy transfer tends to limit the ability to design a specific spectral profile from an active material. Current technologies do not consider spectral control and tailoring or the very broad diversity of dopants or nanoparticle chemistries.



This technology features devices with optically active ions doped into a carrier matrix in a heterogeneous fashion so as to provide the desired dopants spatially localized within the matrix. This technology targets the need for methods and materials that can provide heterogeneous optical materials with optically active dopants provided in high concentration in localized areas within a larger bulk carrier environment. The composites can be readily processed by conventional techniques to yield bulk optics, films, in addition to optical fibers. Example optical applications include the use of the composite materials to form the elements of up-conversion light sources, standard light sources, volumetric displays, flat-panel displays, and sources operating in wavelength-division-multiplexing schemes.



Applications:

- Broad-band fiber amplifiers for telecommunications
- White light fibers for spectroscopy and analytical chemistry
- Tm doped fiber lasers (defense and security applications)
- IR fiber lasers (biomedical applications)

Benefits:

- Multiple dopants can be contained locally within a matrix allowing for energy transfer
- Allows for high local dopant concentration while maintaining low global concentration
- Process by conventional techniques such as vapor deposition

Licensing Status: This technology is available for licensing

Protection Status: A patent application has been filed

CURF Reference: 09-030

Inventor(s): John Ballato, et al.

Direct Link: http://curf.technologypublisher.com/technology/11859

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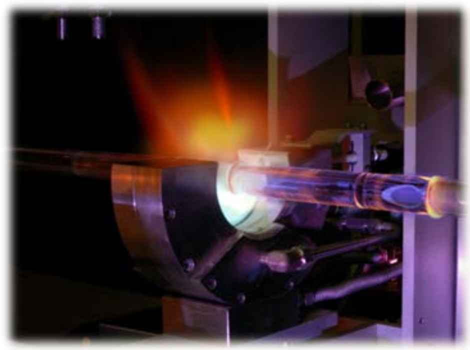
Optical Fiber Systems and Methods

Description:

This technology features a composite perform having a core material rod that comprises single crystal silicon and a cladding material perform surrounding the core rod. These optical fibers provide better removal of dissipated heat from the beam in comparison to a nonlinear optical device fabricated from a traditional bulk crystal which promises higher operating power levels, better thermal stability and improved control of phase matching if required. This technology could enable short fibers for reduced nonlinear effects such as SBS and SRS when desired and could significantly reduce the cost of diode pumped crystal host lasers.



Applications:

- Lasers for Defense Applications
- Lasers for Biomedical Applications

Benefits:

- Excellent thermal properties
- One-step fabrication of fiber
- Good continuity over the length of the fiber
- Utilizes conventional and commercially-available draw methods

Licensing Status: This technology is available for licensing

Protection Status: A patent application has been filed

CURF Reference: 08-029

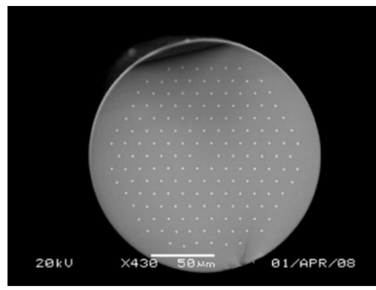
Inventors: John Ballato, Robert Rice

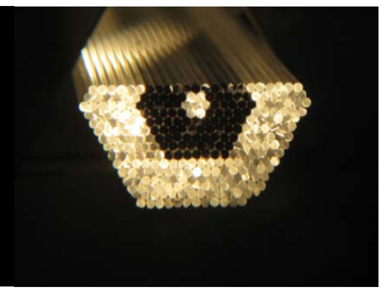
Direct Link: http://curf.technologypublisher.com/technology/6409

All Solid Large Core Photonic Bandgap Fibers for use in Optical Fiber Lasers

Description:

Commercial usage of the fiber laser has significantly grown over the past decade with applicability in diverse sectors such as industrial, medical, sensing and defense markets due to its robustness, high efficiency and compactness. However, there are still limitations and areas of improvement for the fiber laser. Scaling of fiber lasers is limited by the fiber nonlinearities. Nonlinear optical effects are scattering which happen within the fiber that limit the core diameter and ultimately reduce efficiency and power in a fiber laser.





This novel technology features an all solid photonic bandgap fiber design. These fibers far exceed any known fiber designs in higher order suppression at large core diameters which allows for higher power lasers. This is due to the unique guidance properties of these fibers. Fibers with strong higher order mode suppression are critical for further power scaling of single mode fiber lasers to beyond kW levels.

Applications:

- Industrial machining
- Electronics manufacturing
- Material processing
- Medical imaging and surgery guide
- Sensors
- Defense

Benefits:

- Increased power
- Application flexibility

Licensing Status: This technology is available for licensing

Protection Status: A patent application has been filed

CURF Reference: 2011-094

Inventor(s): Liang Dong, et al.

Direct Link: http://curf.technologypublisher.com/technology/11858

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Enhanced Silicon Optical Fiber

Description:

Silicon optical fibers that transmit in the Infrared range have a wide variety of applications, including applications in defense (sensing, counter-measures, high energy laser beam clean up) and biomedical (laser surgery). Currently the processing temperatures for silicon optical fibers are high which increase oxygen impurities. The oxygen impurities promotes optical scattering and reduces transparency and performance of the fibers. Current technologies do not eliminate the oxygen impurities in the high temperature processing of silicon optical fibers.

This technology features a novel process to reduce oxygen impurities in infrared silicon optical fibers. An in-situ scavenger reacts with the oxygen and is released as a vapor. During formation, the scavenger reduces oxide precipitate to form the core primary component and volatile products. The primary material of the core can melt during the fiber formation process and crystallize upon cooling leaving the formed optical fiber with a crystalline core and little or no impurities due to precipitation of oxide into the core.

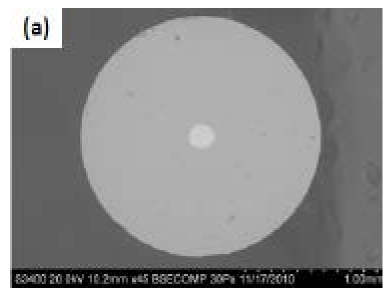

Figure 1: SEM image of optical fiber drawn using a scavenger.

Applications:

- Fiber lasers for defense IR sensors
- Fiber lasers for security
- Fiber lasers for IR laser surgery

Benefits:

- Reduced oxygen/oxide impurities
- Enhanced transparency
- Minimal light scattering out of core
- Higher strength
- Process compatible with conventional perform and fiber draw processes

Licensing Status: This technology is available for licensing

Protection Status: A patent application has been filed

CURF Reference: 2011-061

Inventors: John Ballato, Robert Rice

Direct Link: http://curf.technologypublisher.com/technology/8147

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Gain-Guiding Index Anti-Guiding Fiber Laser Structure

Description:

This is a novel technology for fiber lasers that is based on index anti-guiding plus gain-guiding. The invention is an optical waveguide comprised of a cladding that surrounds an active core wehre the optical dispersion of the core and cladding are separately engineered to create desirable properties for the fiber laser. The dispersive structure is used to force a fiber laser device to amplify or oscillate preferentially at one of the relatively weaker laser transitions associated with the dopant. This structure allows for fibers with high power output.

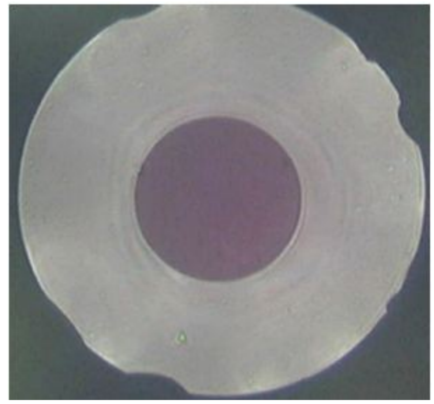

Figure 1: Photograph of the Nd: Phosphate fiber

Licensing Status:	This technology is available for licensing
Protection Status:	A patent has been issued (US 7,668,211).
CURF Reference:	07-038
Inventors:	John Ballato, et al.
Direct Link:	http://curf.technologypublisher.com/technology/5810

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On-chip Broad-area Semiconductor Lasers for High Power, High Brightness Applications

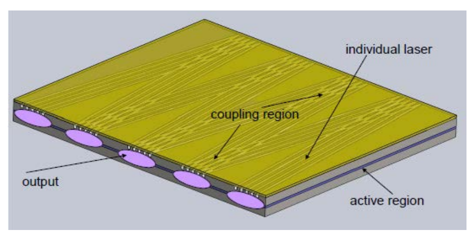
Description:

Semiconductor diode lasers provide many unique advantages over other laser systems, such as a wide range of operation wavelengths, high electrical to optical conversion efficiency, high compactness, and low cost. On the negative side, high power, high brightness (diffraction-limited beam quality) operation is difficult to obtain due to highly nonlinear materials and strong coupling between gain and index. Today, broad area diode lasers are usually used for high power applications, such as material processing and pumping sources for solid-state and fiber lasers. Higher optical power and brightness can be obtained through laser beam combining. There are two main beam combining techniques: coherent beam combining (CBC) and spectral beam combining (SBC). Although current SBC and CBC systems can provide high diffraction-limited power, they cannot be monolithically implemented and are inefficient, complex, bulky, and expensive. Furthermore, it is very difficult to apply these techniques for diode laser arrays.

This invention features high power, high brightness broad area semiconductor lasers with diffraction-limited beam quality without any external optical components or differential phase feedback mechanisms through use of an angled grating confined broad area laser as the building element and take advantage of its zig-zag mode profile. By evenly interleaving two symmetric grating confined laser arrays with opposite tilt angles, direct optical coupling can be obtained, induced by Bragg diffraction, between any two adjacent elements.

Applications:

- Free space communication and remote sensing
- Laser radar arrays
- Laser weapons
- Pumping sources for high energy laser systems



Benefits:

- Converts an array of incoherent broad area lasers with poor beam quality to a single high power, high brightness laser
- Enhanced system efficiency

Licensing Status: This technology is available for licensing

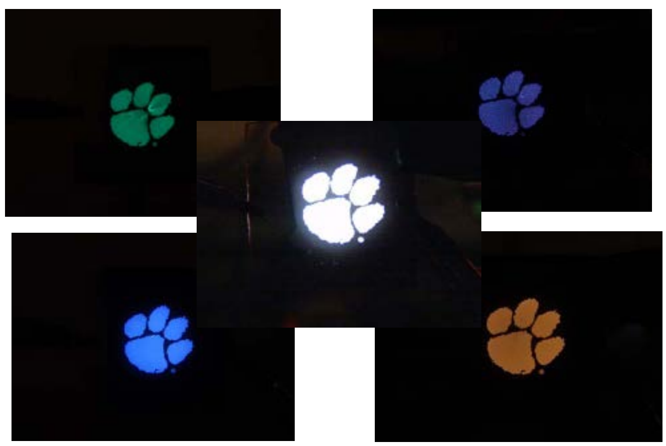
Protection Status: A patent application has been filed

CURF Reference: 2010-043

Inventor(s): Lin Zhu, et al.

Direct Link: http://curf.technologypublisher.com/technology/8146

Optical Materials/ Coatings



Polymer Conducting Colloids: Color Tunable Organic Light Emitting Diode

Description:

Currently small organic molecules and polymer systems exploited in organic light emitting devices (OLEDs) are cost –prohibitive as well as have lengthy synthesis. Similarly inorganic quantum dot light emitting devices are far too costly to implement on an industrial scale. Alternatively, electroluminescent (EL) dyes can achieve the same properties, if not better, and at a much lower cost.

This invention features single color and white-light emissive conducting polymer colloid-based optical light emitting diodes. The electroluminescent (EL) dye-containing colloids are fabricated from a miniemulsion method to create individual dye-doped colloids that emit in the red, green and blue regions of the visible spectrum and upon simple mixing of the colloids single color and white-light can be achieved. This system is advantageous over current methodologies due to its simplicity, color tailorability, and scalability using conventional printing mechanisms.

Applications:

- Electroluminescent devices
- Automotive lighting, decorating light, marketing and other novelty luminaire lighting
- Printable inks: ink jets, flexographic inks, silk screening, etc.

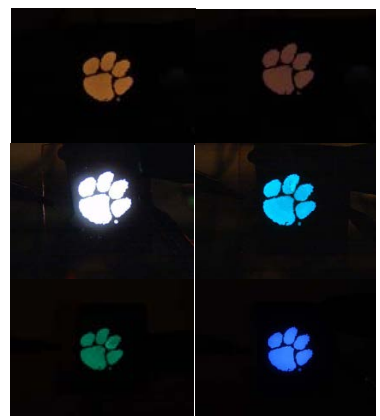


Figure 2: Tunable emission of light

Benefits:

- Low energy requirement
- Can be printed on any substrate (rigid or flexible)
- Color tailorability
- Ink can include carrier liquids and additives such as plasticizers, humectants, etc. for tailored effects
- Any polymeric material or number of materials can be used depending on the size specification desired for the ink

Licensing Status: This technology is available for licensing

Patent Status: A patent has issued (#8,003,008)

CURF Reference: 07-052

Inventors: Stephen Foulger, et al.

Direct Link: http://curf.technologypublisher.com/technology/6107

Additional Materials:

Huebner, C.F.; et al. "Electroluminescent colloidal inks for flexographic roll-to-roll printing" *J. Mater. Chem.*, **2008**, *18*, 4942-4948.

Conducting Polymer Inks from Core-Shell Colloidal Nanoparticles for Flexographic Direct-Print

Description:

Metal-based nanoparticles and carbon black particles have been used previously as the conducting phase in inks for the printing market due to their high conductivity. Polymeric conductive materials can alleviate the high-cost burden of metals but have had significant problems with solubility and some resulting in lower than desirable conductivities. The technology discussed herein solves both of these barriers.

The conducting polymer ink technology includes a suspension of conductive core-shell nanoparticles in a carrier fluid. The ink can utilize any carrier liquid. The shell is formed of conducting polymer and the core material can be selected depending on the required characteristics of the ink. The electrochemical ink in this conducting polymer colloidal nanocomposite invention includes a dispersion of colloidal nanocomposite particles in liquid carrier.

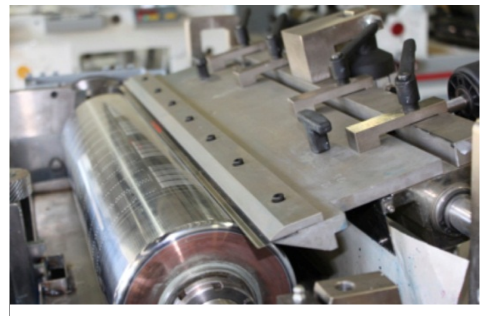


Figure 1: Flexographic Printing

Applications:

- Printing processes: Lithography, flexography, screen, and inkjet printing
- Photovoltaics
- Radio Frequency Identification (RFID) components
- Sensors
- Memory devices

Benefits:

- Environmentally-friendly benign solvents (water, alcohols)
- The conducting polymer inks can be printed at high-speeds and high-volume
- Can be printed on a variety of substrates
- Low cost

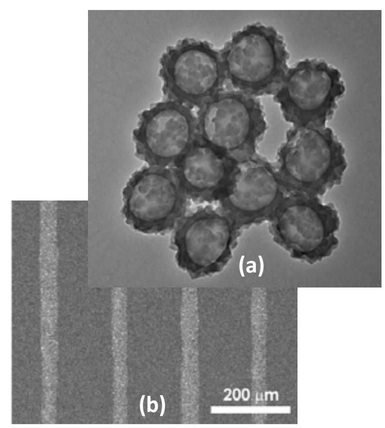


Figure 2. Technology examples a) micrograph of polyaniline-coated poly(butyl methacrylate) particles b) sample flexographically printed with conductive ink

Licensing Status: This technology is available for licensing

Patent Status: A patent application has been filed

CURF Reference: 06-034

Inventors: Stephen Foulger et al.

Direct Link: http://curf.technologypublisher.com/technology/6106

Additional Materials:

Han, M.G. et al., "Polyaniline coated poly(butyl methacrylate) core–shell particles: roll-to-roll printing of templated electrically conductive structures" *J. Mater. Chem.,* 2007, 17, 1347–1352.

Electrochromic Inks and Devices Composed of Conducting Nano Composites

Description:

Inkjet-printing of electrochromic devices requires two main characteristics to be carefully controlled for successful printing: viscosity and surface tension of the ink. Intrinsically conducting polymers (ICPs) have had trouble determining concentrations for a low viscosity. Additionally the harsh organic solvent used with ICPs can damage ink jet cartridges. Colloidal ICP particles have been employed because their high molecular weight causing low viscosity and use in common solvents.

This invention comprises of electrochromic inks made from conducting polymer colloidal nano composites for use in ink jet printing. Fabrication of flexible electrochromic display devices through high resolution direct patterning of electro-active materials is achieved. Electrochromic inks from conducting polymer colloidal nano composites and various additives such as humectants, penetrating and drying agents are utilized within the device. The electrochromic material is inkjet printed on a conducting polymer gel electrolyte on a second conducting surface. This ink can be used in commercial settings via a desk top inkjet printer with high resolution.

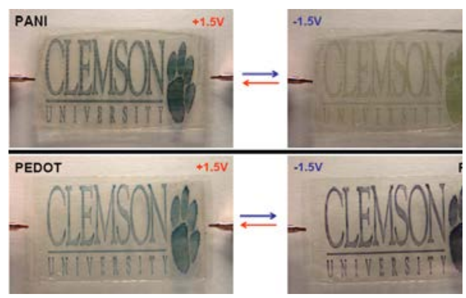


Figure 1: Color change upon application of electrical current

Applications:

- Smart glass (automobile, building)
- Photovoltaic applications
- Printed electronics

Benefits:

- Low cost manufacturing
- Can be printed on a variety of substrates (flexible or rigid)
- Easily scaled for high-volume processing and high-speed printing
- Long lifetime of flexible electrochromic display technology

Inventors: Stephen Foulger, et al.

Patent Status: A patent has issued (#7,785,496)

Licensing Status: This technology is available for licensing

CURF Reference: 06-054

Direct Link: http://curf.technologypublisher.com/technology/6105

Additional Materials:

Shim, G.H. et al.,“Inkjet-printed electrochromic devices utilizing polyaniline–silica and poly(3,4-ethylenedioxythiophene)–silica colloidal composite particles”, J. Mater. Chem., 2008, 18, 594–601.

Robust Matrics for Encapsulation of Crystalline Colloidal Arrays (CCA) for Optical Applications

Description:

Crystalline Colloidal Arrays are submicron periodic structures that self assemble from monodisperse colloidal spheres. The ordered structures can be fabricated to length scales that diffract light according to Bragg's Law and are used with many optical applications such as active photonic switching and sensors. Liquid phase arrays are sensitive to mechanical shock and ionic contamination and are easily destroyed. This invention is a composition of matter that extends the repertoire of monomer and polymers that can be utilized to successfully encapsulate CCA's and impart robustness.

This is a novel technology for Crystalline Colloidal Arrays (CCA) which have been encapsulated in a polymer matrix. It is a Polyethylene glycol based matrices which has very low toxicity and increases mechanical and chemical robustness. The use of the PEG-MA monomer with the PEG-DMA as a crosslinker to generate thermoset hydrogels is a substantial advancement in the stabilization of CCA's.

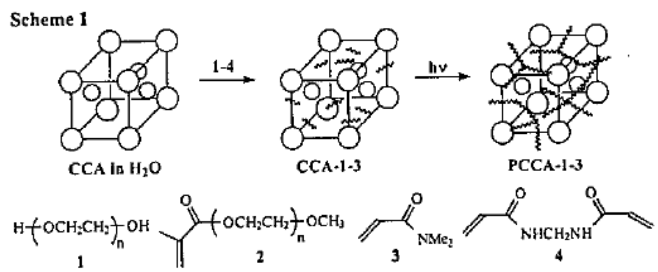


Figure 1: Scheme for stabilizing Crystalline Colloidal Arrays in polymer matrices

Applications:

- Optical Communications Technology
- Optical Routing, Multiplexing, Switching, signal processing
- Sensors

Benefits:

- Increased Mechanical and Chemical Robustness
- Low Toxicity

Inventors: Stephen Foulger et al.

Patent Status: A patent has been issued

Licensing Status: This technology is available for licensing

CURF Reference: 01-027

Direct Link: http://curf.technologypublisher.com/technology/5701

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Photonic Bandgap Composites

Description:

Crystalline colloidal arrays (CCAs) are able to create three-dimensional periodic dielectric structures However, they can be impractical for some applications due to a liquid dispersion which can disturb the crystalline order from a weak shear, gravitational, electric field or thermal forces. This invention establishes a new method for generating robust, thermally stable, water-free polymeric colloids. These composites endow photonic band gap (PBG) and mechanochromic properties. The composites contain ordered arrays of self-assembled nanometer-sized spheres which are encapsulated by other polymeric systems in order to lock in the crystalline nature of the arrays and introduce a systematic way to tune the mechanical properties of the final composites. A water-free method is utilized to produce and encapsulate the collodial crystals which is beneficial because the organic gels are more stable than hydrogels due to a lack of water evaporation. Furthermore, this encapuslated solution can be easily scaled in flexographic printing processes.

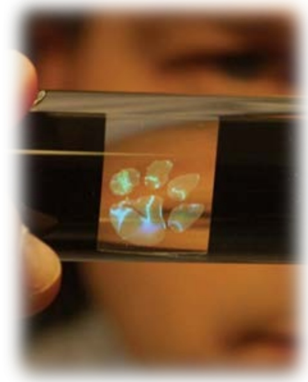


Figure 3: Photonic Bandgap Composites

Applications:

- Biological and gas sensors
- Counterfeiting applications

Benefits:

- Tunable mechanical characteristics for specific applications
- Scalable and low cost materials
- Printable on variety of substrates therefore increasing versatility

Inventors: Stephen Foulger et al.

Patent Status: Two patents have issued (#7008567 & #7582231)

Licensing Status: This technology is available for licensing

CURF Reference: 02-002

Direct Link: http://curf.technologypublisher.com/technology/5809

High Density Atmospheric Plasma Jet Devices for Biomedical and Electronic Surface Modifications

Description:

Thin films have a wide variety of use in engineering applications. They are used in microelectronics, aerospace applications, biomedical applications among others. Current deposition techniques include sputtering, physical vapor deposition, chemical vapor deposition and electrochemical deposition. The main parameters for depositions are the quality and uniformity of the film, growth control and the geometry of the growth. Biomedical thin film coatings have to be free of defects and need a high level of process control for uniformity and adhesion.

This invention utilizes a high density plasma emission by plasma jet-to-jet interaction in the plasma jet array device which has a honeycomb structure with quartz tubes. This plasma concentration behavior by jet-to-jet interaction enables diverse applications to need strong discharge processes involving lots of charged particle transports and chemical reactions of the plasma with a simple structure and equipment. This novel plasma platform allows new material surface possibilities in an acheivable manner.

Applications:

- Decontamination/sterilization systems
- Energy storage related material surface applications
- Biomedical device surface modification

Benefits:

- Ability to achieve uniform coating
- Easy and safe cold plasma implementation
- Cost-effective surface modification

Licensing Status: This technology is available for licensing

Protection Status: A patent application has been filed

Inventors: Sung-O Kim, Jae-Young Kim

CURF Reference: 2010-064

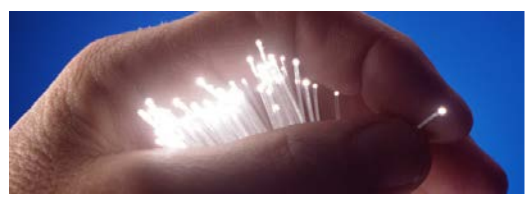
Improved Solution-based Synthesis of Chalcogenide Glass/polymer Hybrid Films for Optical Applications

Description:

Chalcogenide glasses are of increasing interest for optical applications due to their large optical nonlinearities, high infrared transparency, and thermally stable refractive indices. These materials are of interest for next-generation thin film-based planar infrared (IR) optical applications such as planar waveguides, IR sensors, etc. Traditionally, the methods of deposition of chalcogenide films include physical vapor deposition (PVD) techniques such as thermal evaporation, pulsed laser deposition or sputtering. While these methods are generally simple, they suffer from several shortcomings that can restrict their use. One complication is the observation that the resulting film often has a different composition from that of the parent glass target, or is inhomogeneous across its thickness, due to differential volatility in multi-component materials. This invention overcomes some of the shortcomings of existing deposition technology.

This invention features an improved solution based synthesis method for hybrid chalcogenide/glass films. Chalcogenide/polymer systems are formed through solution processing and features direct fabrication of glass/polymer optical structures in a single step using, e.g., micro-stamping techniques. Through this process, solution-derived thin films can have essentially the same molecular structure as the parent bulk glass and the optical and mechanical properties of the formed composites can be tailored over a broad range, which can be important for applications in IR optical coatings.

Applications:



- Evanescent wave bio-sensing
- Resonant optical sensors
- Interferometers
- Lasers
- Optoelectronics

Benefits:

- Vastly improved performance due to decreased surface roughness
- Makes new applications for integrated waveguide lasers possible
- Transparent (other polymers result in loss of transparency)
- Improved mechanical properties over glass alone
- Source of raw materials is less susceptible to supply constraints

Licensing Status: This technology is available for licensing

Protection Status: A patent application has been filed

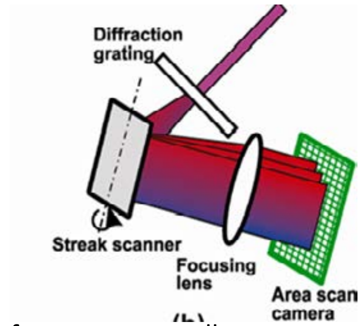
CURF Reference: 2010-038

Direct Link: http://curf.technologypublisher.com/technology/6046

Imaging

Improved OCT Imaging Utilizing Streak Mode Doppler

Description:



Optical Coherence Tomography (OCT) is an imaging technique that combines fundamental aspects of confocal microscopy and ultrasound for in vivo biomedical imaging. Current OCT imaging does not allow for fast enough scanning to capture rapid changes in blood flow. Rapid acquisition techniques are needed for analysis of liquid and solid interactions for use in endoscopic and external monitoring of these environments.

This novel technology allows for simultaneous imaging of both the morphology of an organ as well as blood-flow velocity. Through this invention, images are captured at an increased speed and the time between scans in reduced through the usage of an area scan camera as compared to line scan techniques of competing technologies. Additionally, the usage of traditional Fourier Domain OCT, the signal to noise ratio is greatly decreased, and velocity is able to be captured due to the ability to record phase shifts with time.

Applications:

- Endoscopic imaging allowing simultaneous morphology of organs and blood flow velocity measurements
- Used in multiple environments were access to specimens or items to be imaged may be limited
- In-vivo, high resolution imaging of biomedical samples

Benefits:

- Significant decrease in the time interval required between successive scans
- 1000x faster OCT imaging speed than current technology
- Increased flow velocity detection capability
- Essential real-time image feedback
- Easy to integrate with existing technologies

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Patent Status: A patent application has been filed

Licensing Status: This technology is available for licensing

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Related publications:

"An Approach for Megahertz OCT: Streak Mode Fourier Domain Optical Coherence Tomography", Proc. SPIE, March 8, 2011. http://proceedings.spiedigitallibrary.org/proceeding.aspx?articleid=1348518

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