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(71) Applicant: **ILLINOIS TOOL WORKS INC.** [—/US]; 155 Harlem Avenue, Glenview, Illinois 60025 (US).

(72) Inventors: **BUDAI, Michael B.**; c/o Illinois Tool Works Inc., 3600 West Lake Avenue, Glenview, Illinois 60026 (US). **GARDNER, Eric E.**; c/o Illinois Tool Works Inc., 3600 West Lake Avenue, Glenview, Illinois 60026 (US).

(74) Agent: **HAUPTMAN, Benjamin J.**; Lowe Hauptman & Ham, Llp, 2318 Mill Road, Suite 1400, Alexandria, Virginia 22314 (US).

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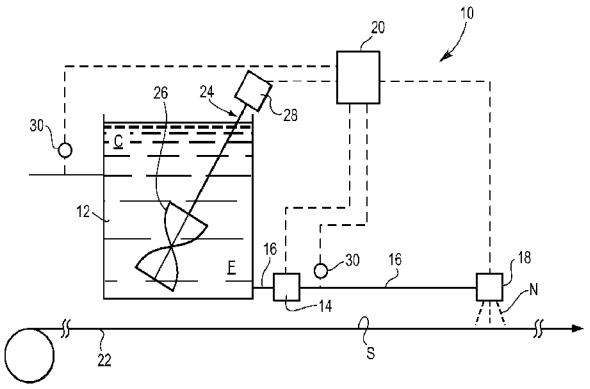
(54) Title: SYSTEM AND METHOD FOR APPLICATION OF NANOFIBRES TO A SUBSTRATE

Fig. 1



(57) Abstract: A system (10) for the application of nanofiber to a substrate (S) includes a tank (12) having an outlet, an agitator (24) disposed in the tank, a pump (14) located at the tank outlet and an applicator (18) disposed proximate to the substrate(S). One or more fluid conduits (16) extend from the tank to the pump and from the pump to the applicator. The fluid conduits are configured so as to minimize bends and interferences. The system includes a controller (20). A nanofiber formulation (N) in a fluid carrier in the tank is pumped from the tank to the applicator for application to the substrate at a predetermined flow rate. The pump (14) is controlled by the controller (20) to vary the output of the pump (14) to match the predetermined flow rate, and the nanofiber formulation is applied by the applicator head (18) at a predetermined coat weight on the substrate. A method for the application of nanofiber to a substrate is also disclosed.

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TITLE

SYSTEM AND METHOD FOR APPLICATION OF NANOFIBRES TO A SUBSTRATE

BACKGROUND

[0001] Nanofibers are generally defined as fibers having a diameter of less than about 1000 nm in diameter and may have lengths from a few centimeters to less than one millimeter . Such fibers have come into use in various fields, including medical applications, protective materials, general textiles and filtration media.

[0002] Current processes for the commercial manufacture of nanofibers include electrospinning and meltblowing. In electrospinning, a high voltage is applied to a liquid droplet, charging the droplet. Electrostatic repulsion counteracts the surface tension of the liquid and, as the droplet is stretched, a stream of liquid erupts from the surface of the liquid as a liquid jet. As the jet dries, it forms the fiber, which is deposited on a collector.

[0003] In meltblowing, a liquid, such as a polymer, is forced through a die having very narrow slots at high temperatures, with a stream of hot gas, such as air. Thread or fibers are formed which are dried and collected on a collector by use of a vacuum applied through the collector.

[0004] Both of these processes are mechanically harsh on the fibers formed. In addition, these processes consume a significant amount of energy with low output, resulting in high cost per unit output. Moreover, there is significant capital required for the equipment to manufacture nanofibers using these known techniques.

[0005] Accordingly, there is a need for a method and system for the manufacture of nanofibers. Desirably, such a method has lower energy requirements than known systems, requiring less heat input to form such nanofibers. Desirably such a system and method produce nanofibers on a commercial scale that is less capital intensive than known systems and produces a higher output as well as a higher throughput than known systems.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 is a schematic illustration of an exemplary system for the manufacture of nanofibers.

DETAILED DESCRIPTION

[0007] While the present disclosure is susceptible of embodiment in various forms, there is shown in the drawings and will hereinafter be described one or more embodiments with the understanding that the present disclosure is to be considered illustrative only and is not intended to limit the disclosure to any specific embodiment described or illustrated.

[0008] Referring to the figures and in particular to FIG. 1, there is shown a schematic illustration of an exemplary system 10 for the application of nanofibers N onto a substrate S. The system 10 includes a feed tank 12 for storing a fluid, such as a liquid polymeric feed solution F, an outlet pump 14, fluid conduits 16, such as piping, hoses or the like, and an applicator head 18. A control system or controller 20 monitors and controls the overall operation of the system 10. A conveyor 22 can be used to move the substrate S along a path P relative to the applicator system 10 and head 18.

[0009] The tank 12 can be formed of any material suitable and/or compatible with the feed solution F. Such materials include, but are not limited to stainless steel, polypropylene or the like.

[0010] The system 10 is configured to apply the nanofiber N solution to a substrate S. The nanofiber N can be applied to, for example, a coarse web, a fine web, a non-woven material or essentially any type or construction of suitable substrate.

[0011] An agitator 24 is positioned in the tank 12 to maintain the nanofibers in solution. One agitator 24 is a multi-blade rotary agitator, preferably powered by a variable speed drive 28. A variable speed drive 28 allows for controlling the consistency of the solution– that is maintaining the nanofiber evenly distributed and suspended in the solution, while minimizing over-working or over-agitating the solution and controlling the power consumption of the agitator 24. Those skilled in the art will recognize other types of agitators that can be used to maintain the nanofibers in solution.

[0012] The outlet pump 14 provides a metered or precise fluid flow to the applicator head 18. One type of pump 14 is a metering pump (or multiple metering pumps) to provide precise flow to the applicator head 18.

[0013] The fluid conduits 16 extending between the tank 12 and the pump 14 and the pump 14 and the applicator head 18 are configured to maintain the fiber in solution and to

prevent the nanofibers from falling out of solution or settling in the piping or hoses 16. For example, the piping or hoses 16 between the various system components can be designed having straight runs to reduce or eliminate bends, or where necessary an increased the radius of curvature of bends. Conduits 16 having smooth internal surfaces to minimize flow resistance and interferences, cavities (or flow dead spots) and the like, can be used maintain a desired flow rate and /or velocity through the conduits 16. One or more flow meters 30 properly positioned within the system 10 provide for monitoring the inlet of carrier fluid C (e.g., water) to the tank 12 and the flow of the nanofibers in solution N from the tank 12. It will be understood that the materials of the conduits 16 and other process equipment are selected to be suitable and/or compatible with the nanofiber formulation.

[0014] The applicator head 18 is configured as a building block-type expandable design in which sections can be added or removed depending on the width of the substrate S. The applicator head 18 sections can be made up of a variety of nozzle designs depending on the specific formulation and the intended coat weight of nanofibers on the substrate S. Where desired, the applicator head 18 can atomize the formulation through pressure generated from the pump 14 at the outlet side of the tank 12. Exemplary of such applicators are those described in Budai, U.S. Patent Application Serial No. 13/547,685, which application is commonly assigned with the present application and is incorporated herein by reference in its entirety.

[0015] The system 10 is controlled by the controller 20. The controller 20 can, for example, monitor the line speed of the substrate S and vary the nanofiber formulation output flow based on the line speed of the substrate S, the density at which the nanofiber formulation is applied to substrate S (coating weight), the pump 14 outputs and inputs, and like process parameters. The controller 20 can also monitor and control the agitator 24, process temperatures and the like. It is anticipated that the controller 20 will be of a menu driven type.

[0016] The present system 10 is configured to apply nanofiber to a wide variety of substrates S. Exemplary nanofiber is that formulated from cellulose acetate, polypropylene, polyethylene, polyester, nylon, polyphthalamide (PPA), polymethyl methacrylate (PMMA), polyactic acid, poly aniline, poly vinyl alcohol, poly acrylonitrile and the like. Other suitable polymers will be appreciated by those skilled in the art. The polymer can be carried in a wide variety of suitable liquid carriers C, such as water. Other additives may be used to create a desired viscosity or nanofiber suspension, including for example, surfactants such as glycerin.

[0017] A method of applying nanofibers to a substrate S includes providing a substrate and a system 10 for applying the nanofiber solution to the substrate and moving the substrate S and system 10 relative to one another. It is anticipated that the substrate S will move relative to the applicator head 18. The method further includes conveying, from a storage vessel such as a tank 12, a liquid formulation of nanofibers N in suspension, through one or more fluid conduits 16, to the applicator head 18.

[0018] The fluid flow is carefully controlled and monitored. As such the flow can be measured, as by one or more flow meters 30 or like device, at the tank 12 outlet (e.g., the pumped fluid) and the flow rate monitored to ensure that a desired flow rate is maintained. To assure that the formulation in the tank 12 is maintained (e.g., the concentration of nanofibers in the solution), the carrier C inlet to the tank 12 can also be monitored.

[0019] In a preferred method, the liquid formulation of nanofibers in suspension is transported through a system that reduces the number of bends or other interferences in flow. The method further includes applying the formulation to a substrate through an applicator head 18 such as that described above. The nanofiber formulation will be applied at a predetermined coat weight and may depend upon the specific formulation used and the intended use of the resultant coated substrate. It is anticipated that the formulation may be applied by spray, atomization (effected by pump pressure) or like methods.

[0020] It will be appreciated that the present system 10 and method can greatly reduce the energy requirements for applying nanofibers N to substrates S. It is expected that the overall cost of nanofiber production can be reduced by as much as fifty percent with production yields being twenty times greater than known methods such as electrospinning. The present process can be carried out at or about room temperature, thus greatly reducing the energy costs over known systems and methods. In addition, functional composites can be made by selectively incorporating materials such as silica, clay, silver particles, titanium and aluminum-based materials and the like.

[0021] Using the present system and method, nanofibers can be produced for use in the medical, energy, filtration and lighting industries, as well as for use in general textiles.

[0022] It should also be understood that various changes and modifications to the presently disclosed embodiments will be apparent to those skilled in the art. Such changes and modifications can be made without departing from the spirit and scope of the present disclosure

and without diminishing its intended advantages. It is therefore intended that such changes and modifications be covered by the appended claims.

CLAIMS

1. A system for the application of nanofibers to a substrate, comprising:

a tank having an outlet;

an agitator disposed in the tank;

a pump located at the tank outlet;

an applicator disposed proximate to the substrate; and

one or more fluid conduits extending from the tank to the pump and from the pump to the applicator, the fluid conduits configured so as to minimize bends and interferences; and

a controller,

wherein a nanofiber formulation in a fluid carrier in the tank is pumped from the tank to the applicator for application to the substrate at a predetermined flow rate, the pump being controlled by the controller to vary the output of the pump to match the predetermined flow rate, and wherein the nanofiber formulation is applied by the applicator head at a predetermined coat weight on the substrate.

2. The system of claim 1 including one or more flow monitors to monitor the flow of the fluid carrier into the tank and/or the flow of the nanofiber formulation from the tank and/or the flow of nanofiber formulation at a discharge of the pump.

3. The system of claim 1 wherein the agitator is a variable speed agitator and wherein the controller controls the speed of the pump.

4. The system of claim 1 wherein the applicator includes one or more nozzles for application of the nanofiber formulation to the substrate.

5. The system of claim 4 wherein the nozzles are configured to spray the nanofiber formulation onto the substrate.

6. The system of claim 4 wherein the nozzles are configured to atomize the nanofiber formulation for application to the substrate.

7. The system of claim 1 including a conveyor for moving the substrate relative to the applicator.

8. The system of claim 7 wherein the controller controls movement of the conveyor.

9. A method for the application of nanofiber to a substrate comprising the steps of:

providing nanofiber in a carrier to form a nanofiber formulation, the nanofiber formulation stored in a storage tank;

agitating the nanofiber formulation in the storage tank;

pumping the nanofiber formulation from the storage tank to an applicator; and

discharging the nanofiber formulation from the applicator onto the substrate at a desired rate.

10. The method of claim 10 including the step of controlling a rate of discharge from the pump to the applicator.

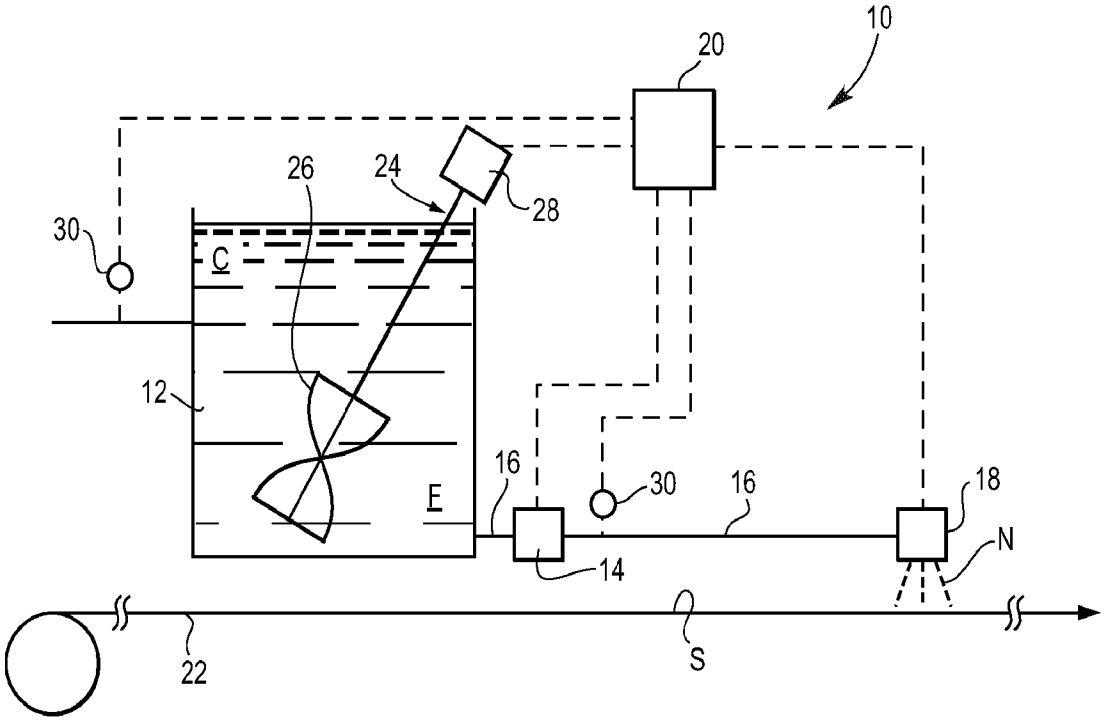
11. The method of claim 9 wherein the nanofiber formulation is discharged as a spray onto the substrate.

12. The method of claim 9 wherein the nanofiber formulation is atomized for application onto the substrate.

13. The method of claim 9 including the step of conveying a substrate past the applicator, and controlling a speed of conveyance of the substrate.

14. The method of claim 13including the step of controlling a rate of discharge from the pump to the applicator.

Fig. 1



INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER
INV. B05B15/00 B05B9/03 B05B7/14
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B05B B05C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	CN 100 500 304 C (INST OF MECHANICS CAS [CN]) 17 June 2009 (2009-06-17) abstract; figure 1	1-14
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X	JP S63 158149 A (NEC CORP) 1 July 1988 (1988-07-01)	9-14
A	abstract; figure	1-8

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
29 January 2014	06/02/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Daintith, Edward

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/066851

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CA 2 520 691 A1 (GALVATECH 2000 [CA]) 22 March 2007 (2007-03-22) paragraph [00024] - paragraph [00027]; figures -----	1-14
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2013/066851

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