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Editors

Jiri Orava

University of Cambridge
Department of Materials Science and Metallurgy
27 Charles Babbage Road
CB3 0FS Cambridge
United Kingdom

Tohoku University
WPI-Advanced Institute for Materials Research
(WPI-AIMR)
2-1-1 Katahira, Aoba-ku
980-8577 Sendai
Japan

Tomas Kohoutek

Involved Ltd.
Siroka 1
537 01 Chrudim
Czech Republic

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Introduction of new laboratory device 4SPIN® for nanotechnologies

M. Pokorny,* J. Rebicek, J. Klemes and V. Velebny

Contipro Biotech s.r.o., R&D Department, 561 02 Dolni Dobrouc, Czech Republic, www.contipro.com, Phone: +420 467 070 339

*Electronic mail: marek.pokorny@contipro.com

The 4SPIN® desktop laboratory device has been developed for the deposition of nanomaterials dedicated not only to medical applications, but also to other fields such as nanoelectronics, optics, filtration, etc. The apparatus integrates various methods to enable the preparation of nanostructured materials according to researching demands. Nine principally different emitters (most of them are usable in the method called electroblowing) and four different collectors enable to perform various types of experiments. This allowed nanofibrous materials with different microscopic and macroscopic structures to be successfully prepared. Almost twenty different solutions (including hyaluronic acid and its derivatives), their blends and composites have been processed so far. It is possible to repeatedly produce nanomaterials with identical properties by implementing precisely regulated process parameters. Its central system simplifies control and also improves productivity and operator safety. The 4SPIN® laboratory device was developed at Contipro Biotech s.r.o. and seven principles used were patented. The device has been certified for electrical safety by CE mark and has been marketed since January 2013.

Today, electrospinning equipment and technological solutions as well as electrospun materials are moving towards commercialization. Hence there is a higher demand for laboratory and production devices. Laboratory equipment must meet the following requirements: i) multifunctional setup (all-in-one device), ii) compactness (limited lab space), iii) accuracy and reproducibility of the material produced, iv) safe and easy handling, and v) affordable price for academia [1].

The 4SPIN® device offers several benefits that differentiate it from devices offered by competition. Generally it can be used for the electrospinning and electroblowing methods [2].

Precisely aligned nanofibers with anisotropic properties have been collected by advanced electrospinning, e.g. on static patterned and rotated collectors. Small spherical structures have been prepared using the electrospraying mode. Morphological properties were well controlled by the electroblowing process parameters. For example a reduction of fiber diameter down to 50 % was achieved.

Detailed studies focusing on the stability of the process were carried out using a solution with optimal parameters. Fourteen nanofibrous samples made of a 6% HA/PEO (80:20) solution dissolved in distilled water were prepared under the same conditions. The average fiber diameter of all samples is (154 ± 58) nm. The average weight is (81 ± 7) mg. Their homogeneity determined on the basis of local weight is less than 10 %. The homogeneity of the two components in the final product is about 2 %. The presented results illustrate the preparation of nanofibrous layers with almost identical properties.

The most important features and capabilities of the new 4SPIN® technologies are presented in this work. The results show the advantages and benefits of using our laboratory equipment.

Automatic regulation of all process parameters makes it possible to achieve constant material properties in the fabrication of nanofibers. Therefore fiber diameter does not change throughout the sample volume. Reproducible materials, i.e. products with identical properties,

Figure 1. Laboratory device 4SPIN® C4S LAB1.

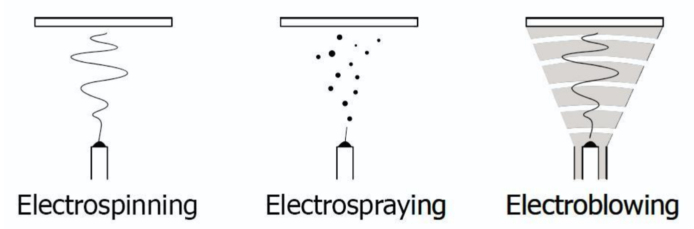

Figure 2. Schematic diagram of the three implemented methods.

can be prepared by applying precise regulation of process parameters (individual procedures can be saved and used again at any time). Various fibrous and spherical forms with macroscopic arrangement can be easily produced.

Thanks to its experimental versatility, safety components, easy handling, intuitive device control and other benefits the 4SPIN® apparatus significantly contributes to research progress in the nanofiber application field.

Although the device is intended and highly suitable for laboratory experiments, the newly developed needle-free emitter E5 is able to achieve high throughput. The results of this new patented technology will be used to upgrade the equipment, which will result in a considerably easier and cheaper transition from the development of new products to their production.

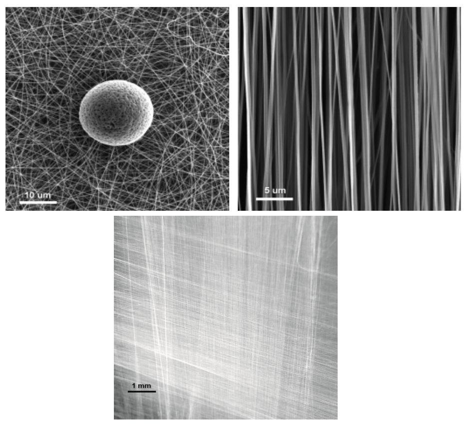

Figure 3. Example of a variety of micro and nano structures.

MATERIALS AND METHODS

Materials: The functionality of the device was verified by spinning a wide range of natural and synthetic polymers. Only the most important ones are listed: hyaluronic acid (HA) and its derivatives, gelatin, collagen, chitosan, polyacrylonitrile (PAN), polyvinylalcohol (PVA), polyamide (PA 6 and 66), polyethylene oxide (PEO), polycaprolactone (PCL), polyurethane (PU), poly (L-lactic acid) (PLLA), polyvinylpyrrolidone (PVP), and also inorganic glass. The polymers are dissolved into a solution in the required concentration by using any of the following solvents: distilled water, acetic acid, chloroform, ethanol, isopropyl alcohol, dimethylformamide or tetrahydrofuran.

Methods: Nanofibrous materials were first prepared on the 4SPIN® C4S LAB1 device, then analyzed on a scanning electron microscope (ZEISS Ultra) and an in-house developed confocal Raman spectroscope. All values of the process parameters were recorded and viewed in real time on a PC screen. Device settings were saved and recalled before subsequent depositions.

We have proven the ability of the device to repeatedly produce nanomaterials with identical properties by using repetitive production. The study was carried out in a few steps in order to obtain the necessary data for evaluation: a) consistent microscopic properties during the deposition by measuring average fiber diameters, b) throughput uniformity by the weight of all samples, and c) homogeneity of layers by two processes from the perspective of the distribution of local weights and chemical composition.

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