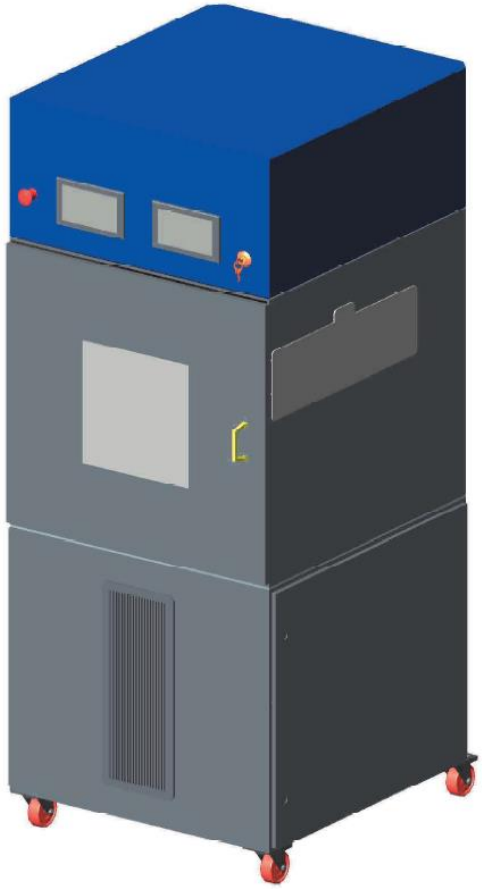
State of Art Electrospinning

The E-SPINNE PH 100 serves as an invaluable tool for conducting proof-of-concept and feasibility studies concerning novel materials and formulations. Designed to accommodate compact laboratory environments, its ergonomic configuration and user-friendly interface facilitate seamless workflow operations. Boasting a diverse array of functionalities and unparalleled reliability, this apparatus empowers customers to prototype and refine their concepts with precision and reproducibility. Its primary functions encompass the electrospinning of fibers and the electro-spraying of particles. Additionally, it offers compatibility with an optional air conditioning unit, enabling precise control over temperature and relative humidity parameters.

The **E-Spinne machine** comes as standard with the following features and can be upgraded with optional extras as described in the next section.

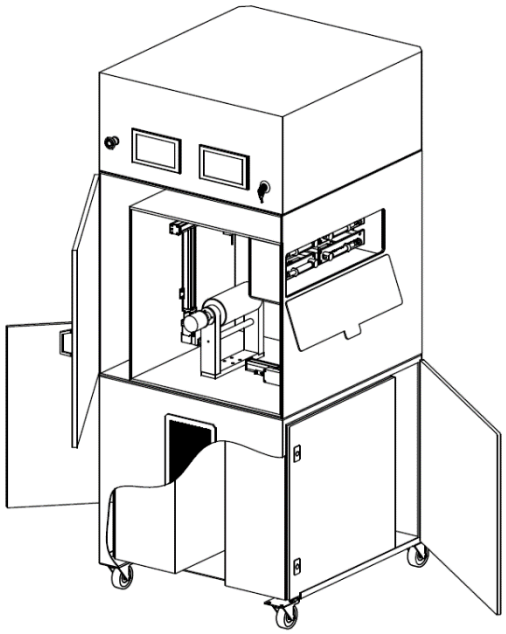
a) Stainless steel, aluminum, and glass comprise the frame and enclosures of the unit. This construction renders the cabinet highly resistant to organic solvents, facilitating effective solvent cleaning procedures. Emphasizing the establishment of sterile conditions, the design ensures chemically resistant properties. Transparency is incorporated into the front door, top ceiling, and rear panel, allowing for easy visualization of processes. Furthermore, the cabinet is hermetically sealed and thermally insulated, promoting rapid chamber conditioning. For precise temperature and relative humidity (T & RH) control, acquisition of climate conditioning equipment is recommended.



b) Equipped with special safety-encapsulated diffuse LED lighting, ensuring optimal visualization of the process while maintaining safety standards.

c) Operated via a **Siemens** touch screen interface, the tool provides users with intuitive software control

over all parameters and functionalities, enhancing user interaction and ease of operation.



d) The primary **SPELLMANN** high voltage (HV) power supply, adjustable from 0kV to 30kV, serves to polarize the emitter. It features full arc and short circuit protection, ensuring safety during operation. With voltage regulation of Line <0.01% and Load <0.01%, as well as stability rates of 0.01% per 8 hours and 0.02% per day, it maintains precise voltage output over time. Accuracy is rated at 2% of full scale, with a maximum output current of 0.133mA.

e) An additional adjustable HV power supply (-10kV) linked to the collector enhances the collection efficiency of atomized particles/fibers. Like the primary supply, it is fully arc and short circuit protected. It boasts voltage regulation rates of Line <0.01% and Load <0.01%, with stability levels of 0.01% per 8 hours and 0.02% per day. Accuracy remains at 2% of full scale, with a maximum output current of 0.75mA.

Accurate Injection

The **SPETEC** syringe pump is provided for precise control of liquid infusion processes.

Featuring a minimal dead volume, ensuring minimal waste (< 0.1 mL), it accommodates syringe volumes of up to 140 mL. The pump supports a wide range of flow rates, from 0.1 µL/h to 6000 mL/h, varying based on the syringe size employed. For instance, with a 5 mL BD plastic syringe, flow rates range from 9.5 µL/h to 1,240 mL/h. Linear force exerted by the pump falls within the range of 100-200N, ensuring consistent and accurate liquid dispensing.

f) The spinning head features a single-phase emitter, facilitating easy removal and replacement of the capillary needle. It accommodates a wide range of needle dimensions, with outer diameters ranging from 0.15 mm to 3.2 mm and inner diameters from 0.08 mm to 2.6 mm.

g) The flat plate collector is designed for tool-free removal from the spinning chamber, offering both vertical and horizontal orientation options. It includes an interchangeable flat stainless-steel plate collector measuring 150 mm x 200 mm.

h) Manual regulation allows for adjustment of the distance between the spinning head and the collector, with a range of 0-200 mm.

i) Real-time environmental conditions within the spinning chamber, including temperature and relative humidity (RH), are displayed on the control panel via built-in sensors.

j) An integrated passive exhaust system features a ventilation fan to effectively remove evaporated solvents. The equipment is equipped with a rear port for connection to external ventilation via an 80mm ID hose.

k) A sealed cable pass-through enables easy wiring of tubing, power, and control wires from the chamber, facilitating enhanced flexibility for experimental setup adjustments or installation of additional accessories, systems, or apparatuses inside the experimental chamber.

l) Ethernet connectivity enables remote diagnostics and software upgrading, allowing for seamless maintenance and updates to the system.

m) The system incorporates safety features ensuring compliance with CE standards, meeting the requirements of relevant EU Directives (2006/42/EC, 2004/108/EC, 2006/95/EC). Compliance is independently verified by a third party.

n) **Dimensions**: External dimensions: 850mm width x 570mm depth x 1,850mm height.

Internal dimensions of the experimental chamber: 685mm width x 510mm depth x 720mm height.

o) **Weights (approximate):**

E-Spinne: 85 kg

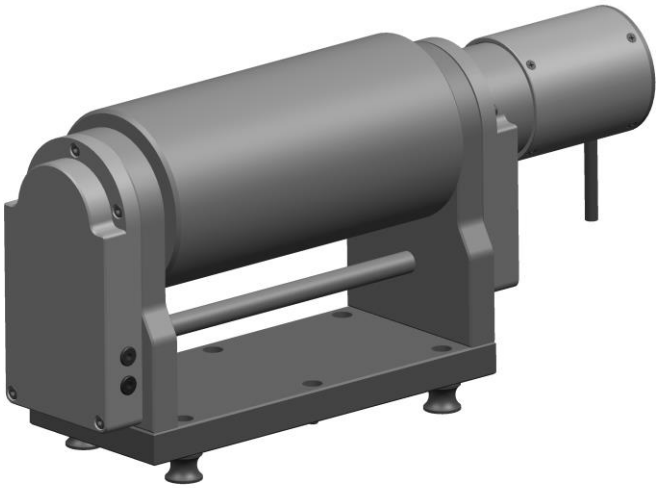
With HVAC: 190 kg

Second Injection System:

The EPCOTEC system offers the option of integrating a second injection system, providing independent control of a secondary solution flow. This configuration enables single-phase or co-axial electrospinning/electrospraying processes. Featuring minimal dead volume (< 0.1 mL) and accommodating syringe volumes of up to 140 mL, it supports flow rates ranging from 0.1 to 1000 mL/h. The coaxial emitter facilitates the spinning of core-shell fibers or particles and prevents tip blockages when using highly volatile solvents by continuously flowing liquid solvent through the outer needle. Capillary needles can be easily replaced and interchanged, accommodating a wide range of dimensions (outer diameter: 0.15 – 3.2 mm; inner diameter: 0.08 – 2.6 mm). Custom emitter geometries are also available upon request.

High-Speed Rotation Collector:

This optional upgrade features a rotating drum with dimensions of 200 mm in length and 100 mm in diameter. It offers adjustable rotation speeds from 0 rpm to 3000 rpm (resulting in approximately 10 m/s linear speed with a 100 mm diameter drum), facilitating the collection of randomly or circumferentially aligned fibers. The cylindrical collector is constructed from anodized aluminum or stainless steel and mounts into the universal rotating collector platform. The standard drum size provided is 100 mm in diameter and 200 mm in length, with other diameters available upon request. When combined with scanning emitter motion, this configuration enables the fabrication of uniform coatings or sheets of electro spun fiber (up to 200 mm x 310 mm).



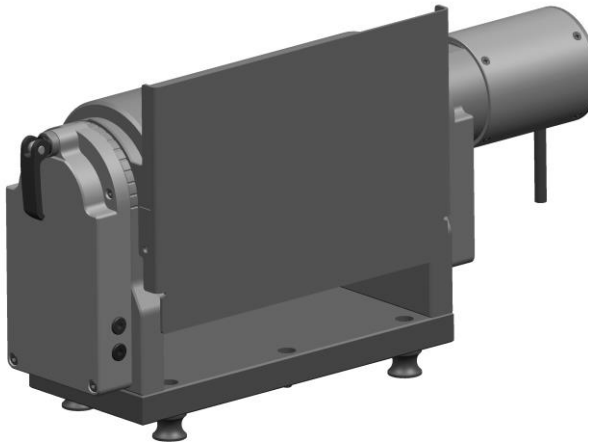
Mandrel and wire Collector:

The EPCOTEC system offers an anodized aluminum rod collector as an optional accessory for mounting into the universal rotating collector platform (Item 3). This collector allows for the fabrication of nanofiber-walled tubular structures. Multiple diameters ranging from 1 mm to 15 mm are available, with a maximum length of 200 mm. Alternatively, a stainless-steel mandrel is also available upon request.

Plate collector

Sharp-edged anodized aluminum plate collector is offered as an optional accessory for installation into the universal rotating collector platform (Item 3). Designed for the collection of aligned fiber

bundles, it features a maximum width of 150 mm. Additionally, a stainless-steel plate option is available upon request.



Scanning emitter motion stand

The system offers linear automated motion of the spinning head, facilitating the creation of wider and more homogeneous samples. When combined with the rotating drum collector, this functionality enables the fabrication of homogeneous nano/micro-fibrous sheets or coatings with dimensions of up to 200 mm x 310 mm. The linear motion stage features adjustable stroke length and speed, ranging from 0 to 200 mm and 0 to 100 mm/s, respectively. It can be positioned vertically or horizontally within the chamber. Additionally, the chamber can accommodate two stands for simultaneous deposition of two materials, further enhancing versatility and efficiency in experimental setups.

Extra Nozzle system

An additional scanning emitter motion stand is available with a second positive high voltage (HV) power supply, facilitating the simultaneous spinning of two solutions in both horizontal and vertical configurations. This setup is fully arc and short circuit protected, ensuring safety during operation. The power supply features precise voltage regulation with Line <0.01% and Load <0.01%, as well as stability rates of 0.01% per 8 hours and 0.02% per day, maintaining consistent voltage output over time. Accuracy is rated at 2% of full scale, with a maximum output current of 0.133mA..

Powerful ventilation

The ventilation module is designed to effectively remove evaporated solvents from the experimental chamber. Pressure sensors installed at the inlet and exhaust continuously monitor the air pressure differential, ensuring optimal ventilation. Additionally, the system maintains a slight negative pressure within the chamber to enhance operator safety.

In the event of ventilation interruption, the system initiates a safe shutdown procedure to prevent the accumulation of hazardous vapor. This actively regulated exhaust system is essential for use with optional air conditioning modules to ensure balanced airflow throughout the system.

Environmental Electrospinning

Climate electrospinning machines are used to simulate standard climates and extreme environmental conditions from dry heat, high humidity to frost. In addition to continuously adjustable heating for a homogeneous spatial temperature distribution, EPCOTEC climate cabinet also have low-noise, powerful and environmentally friendly compressor technology with predominantly natural refrigerants. The environmental parameter humidity is achieved using low-energy, fast-reacting ultrasonic humidification. With the intuitive Control touch, program sequences can be easily controlled and documented.

Gas insertion system

The system features a specially designed emitter and gas flow controller tailored for gas-assisted spinning applications. This innovative setup combines electrostatic stretching with conventional blow spinning techniques, offering enhanced control over the spinning jet and enabling higher flow rates compared to stretching alone. It operates by utilizing compressed dry air or alternative gases, providing flexibility based on user preferences and requirements.

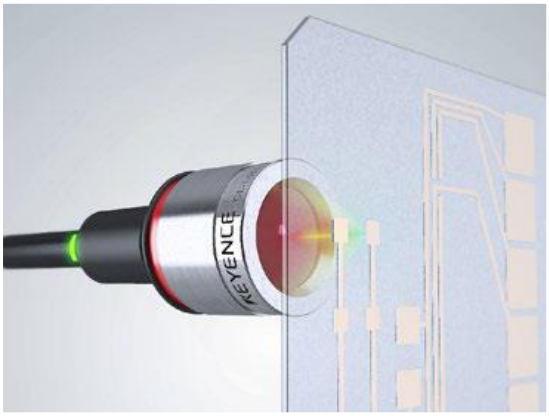
Multi Parallel Electrospinning

The multi-emitter spinning head comprises six parallel emitters, all supplied from a single syringe, aimed at boosting production rates. Compatible with single-phase emitters featuring outer diameters ranging from 0.15 mm to 3.2 mm and inner diameters from 0.08 mm to 2.6 mm, this configuration offers versatility and efficiency in electrospinning applications.

Taylor Cone camera

The system incorporates an endoscopic connected camera with a lens, facilitating close monitoring of the Taylor Cone and spinning jet. This feature is particularly recommended for use with coaxial setups,

aiding in the optimization of spinning parameters by providing real-time visual feedback..

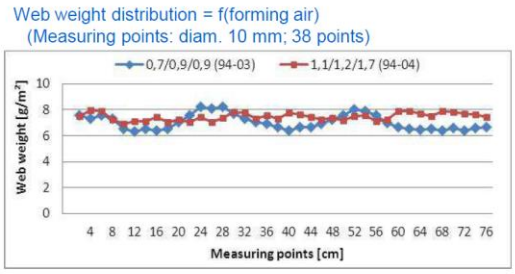


security access to database

The system provides various levels of operator access, ensuring that only authorized personnel can modify processing parameters. Basic operator login permits access solely to pre-set "recipes" of parameter set-ups, which can be saved into a database of optimized recipes linked to the processing of specific materials. This approach enhances standardization and streamlines the workflow for recurring processing tasks.

Data tracing system

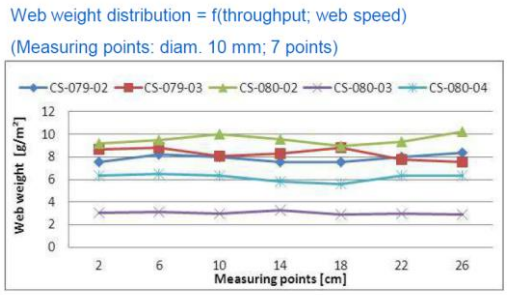
All processing parameters and spinning conditions are automatically recorded and can be exported for further analysis and documentation. This capability streamlines data management and ensures comprehensive records of experimentation for analysis and future reference.



Var.-coeff.: 94-03: 26%; 94-04: 14%

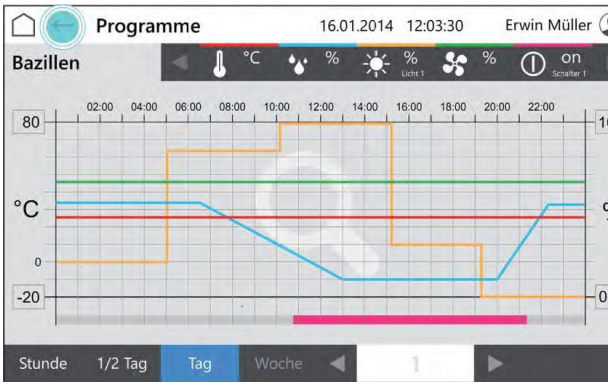
15. Strong Programming

The system allows for the programming and automation of processing parameters, such as voltage, distance, flow rate, drum rotation speed, and more, as a function of time.



→ Var.-coeff.: < 15%

Users can create, save, and load sequential programs via the touch-screen interface. This capability enables precise control and automation of experimental processes, enhancing efficiency and reproducibility..



Application Area

Nano Electrospinning: Nano Electrospinning involves the creation of ultra-fine fibers at the nanometer scale using electrostatic forces. The E-Spinne system facilitates this process by precisely controlling parameters such as voltage, distance, and flow rate to produce nanofibers with tailored properties. These nanofibers find applications in various fields:

Filtration: Nanofibrous membranes can be used for air and water filtration applications, offering high efficiency and capacity for capturing particles and pollutants.

Protective Clothing: Nanofiber-based fabrics provide enhanced protection against contaminants, pathogens, and chemical agents, making them ideal for use in protective clothing and personal protective equipment (PPE).

Medical Technology: Nanofiber scaffolds are used in tissue engineering and regenerative medicine for applications such as wound healing, drug delivery, and tissue regeneration.

Biologic Processes:Nano Electrospinning enables the fabrication of biomimetic scaffolds for cell culture studies, organ-on-chip devices, and biomedical implants.

Electro spraying: Electro spraying involves the generation of charged droplets from a liquid solution under the influence of an electric field. The E-Spinne system can perform electro spraying processes alongside electrospinning, expanding its versatility. Applications of electro spraying include:

Buty Industries: Electro sprayed coatings are used in various industries for surface modification, corrosion protection, and functionalization of materials.

Cleaning Devices: Electro spraying technology is employed in the development of spray cleaners, disinfectants, and surface sanitizers for household and industrial use.

Solar and Battery Technology: Electro sprayed coatings are utilized in the fabrication of electrodes and electrolytes for solar cells, batteries, and energy storage devices, enhancing their performance and durability.

Mineral Organic Materials: Electro spraying can be applied in the synthesis of nanoparticles, composite materials, and functional coatings for mineral processing, catalysis, and environmental remediation.

In summary, **the E-Spinne** system serves as a versatile platform for advanced nanomaterial fabrication, offering precise control over electrospinning and electro spraying processes. Its wide-ranging applications span across industries, contributing to advancements in materials science, biotechnology, energy, and environmental sustainability.

Material Varieties

Electrospinning is a highly versatile technique that can process a wide range of materials, including various polymers and other compounds. Here's a breakdown of some common materials that can be processed using electrospinning:

1. **Polymers:**
    - Polyurethane (PUR)
    - Cellulose acetate
    - Polyimide (PI)
    - Polyacrylonitrile (PAN)
    - Polyvinyl alcohol (PVA)
    - Polyethylene oxide (PEO)
    - Polylactic acid (PLA)
    - Polystyrene (PS)
    - Polyamide (PA)
    - Polycarbonate (PC)
    - Polycaprolactone
    - Collagen
    - Peptides
2. **Inorganic Compounds in Solution:**
    - Inorganic compounds dissolved in appropriate solvents can also be processed using electrospinning, allowing for the fabrication of composite materials.