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Editorial corner – a personal view

Combination of nanofibers with 3D-printed or 4D-printed structures

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Nanofibrous nonwoven structures, especially electrospun webs, have hundreds of potential applications detailed in the literature. Quite many of these are introduced recently in Express Polymer Letters (https://doi.org/10.3144/expresspolymlett.2023.42, https://doi.org/10.3144/expresspolymlett.2023.36, https://doi.org/10.3144/expresspolymlett.2022.88). The bottleneck for their actual commercialization is that electrospun nanofiber veils are expensive to produce. Therefore, only a few of these are viable at higher technology readiness levels (TRLs). Applications which require a small amount of these textiles, or which may include high-value, multifunctional parts are feasible.
Additive manufacturing (AM) is a popular approach for producing such multifunctional polymeric parts. Many different AM methods have been invented, and 3D printing also has hundreds of potential or already realized applications. 3D printing is a type of AM that builds the structure layer-by-layer based on a CAD model, leading to a principal contradiction. For better dimensional accuracy, one needs to increase the number of layers. However, increasing the number of layers increases the cycle time. Due to this bottleneck, 3D printing may never offer a feasible alternative to mass-production polymer processing methods such as extrusion or injection molding. But, when speaking about high-cost, custom products, AM is unmatchable by means of reduced product development time and a wide range of potential functionalities. Small-size 3D printed repeating patterns can build auxetics, unique sportswear, or even robes with custom fit can be designed and printed (https://doi.org/10.3144/expresspolymlett.2022.50). Solid structures or ones with desired porosity and pore geometry can be built this way. There is tremendous flexibility in material design.
Besides the 'classic' 3D printing, 4D printing – in which the 4th dimension is time – has also emerged. Shape memory, self-assembling, self-healing 4D-printed structures can be constructed at moderate costs (https://doi.org/10.3144/expresspolymlett.2023.82). Other functions, such as drug delivery, piezoelectricity, and unique optical effects, can also be implemented.
Both 3D printing and electrospinning are about creating thin layers. They have similar potentials and limitations. Both techniques can create porous layers but with very different pore sizes. While electrospinning operates in the hundred-nanometer range, AM is typically in the ten- and hundred-micron range by means of fiber/laid filament diameter and pore sizes. The thin nanofiber layers can be placed between the printed layers as interleaves (https://doi.org/10.18063/ijb.v6i4.278), and the desired 3D geometry can be generated this way. We can also integrate an electrospinning spinneret into the 3D printer itself, so the nanofibers are generated *in situ* (https://doi.org/10.1007/s00542-019-04730-7), making the process even more convenient. We can thus build porous,

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hierarchical structures layer-by-layer by the combination of the two techniques (https://doi.org/10.1016/j.addma.2021.102030). The continuous process can also be carried out using melt-blown fine fiber veils instead of nanofibers (https://doi.org/10.1016/j.addma.2022.103315).

Electrospun nanofibers might never have the desired precise geometry, high strength, or resistance to abrasion or tearing, but the 3D-printed layers have, and they protect the nanofibers at a macro-scale. 3D-printed layers do not have that small pore size or high specific surface area, but nanofibers do. With the combination of these techniques, we can bring the favorable properties of each method to the forefront. And besides, with the combination of these techniques, we can approach applications from an entirely different perspective (https://doi.org/10.1002/admt.202101309). These hierarchical structures might be used as scaffolds, drugdelivery systems, filters, sensors, piezoelectric devices, wearable electronics, and many more. In my opinion, these hierarchical structures offer a challenging research area; therefore, various new processing approaches and applications will arise in the near future.