'Greening' biomaterials and scaffolds used in regenerative medicine

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Green manufacturing is becoming an increasingly critical process across industries, propelled by a growing awareness of the negative environmental and health impacts associated with traditional practices. In the biomaterials industry, electrospinning is a universal fabrication method used around the world to produce nano- to microscale fibrous meshes that closely resemble native tissue architecture. The process, however, has traditionally used solvents that not only are environmentally hazardous but also pose a significant barrier to industrial scale-up, clinical translation, and, ultimately, widespread use.

Researchers at Columbia Engineering report that they have developed a "green electrospinning" process that addresses many of the challenges to scaling up this fabrication method, from managing the environmental risks of volatile solvent storage and disposal at large volumes to meeting health and safety standards during both fabrication and implementation. The team's new study, published June 28, 2021, by *Biofabrication*, details how they have modernized the nanofiber fabrication of widely utilized biological and synthetic polymers (e.g. poly-α-hydroxyesters, collagen), polymer blends, and polymer-ceramic composites.

The study also underscores the superiority of green manufacturing. The group's "green" fibers exhibited exceptional mechanical properties and preserved growth factor bioactivity relative to traditional fiber counterparts, which is essential for drug delivery and tissue engineering applications.

Regenerative medicine is a $156 billion global industry, one that is growing exponentially. The team of researchers, led by Helen H. Lu, Percy K. and Vida L.W. Hudson Professor of Biomedical Engineering, wanted to address the challenge of establishing scalable green manufacturing practices for biomimetic biomaterials and scaffolds used in regenerative medicine.

"We think this is a paradigm shift in biofabrication, and will accelerate the translation of scalable biomaterials and biomimetic scaffolds for tissue engineering and regenerative medicine," said Lu, a leader in research on tissue interfaces, particularly the design of biomaterials and therapeutic strategies for recreating the body's natural synchrony between tissues. "Green electrospinning not only preserves the composition, chemistry, architecture, and biocompatibility of traditionally electrospun fibers, but it also improves their mechanical properties by doubling the ductility of traditional fibers without compromising yield or ultimate tensile strength. Our work provides both a more biocompatible and sustainable solution for scalable nanomaterial fabrication."

The team, which included several BME doctoral students from Lu's group, Christopher Mosher Ph.D.'20 and Philip Brudnicki, as well as Theanne Schiros, an expert in eco-conscious textile synthesis who is also a research scientist at Columbia MRSEC and assistant professor at FIT, applied sustainability principles to biomaterial production, and developed a green electrospinning process by systematically testing what the FDA considers as biologically benign solvents (Q3C Class 3).

They identified acetic acid as a green solvent that exhibits low ecological impact (Sustainable Minds Life Cycle Assessment) and supports a stable electrospinning jet under routine fabrication conditions. By tuning electrospinning parameters, such as needle-plate distance and flow rate, the researchers were able to ameliorate the fabrication of research and industry-standard biomedical polymers, cutting the detrimental manufacturing impacts of the electrospinning process by three to six times.

Green electrospun materials can be used in a broad range of applications. Lu's team is currently working on further innovating these materials for orthopaedic and dental applications, and expanding this eco-conscious fabrication process for scalable production of regenerative materials.

"Biofabrication has been referred to as the 'fourth industrial revolution' following steam engines, electrical power, and the digital age for automating mass production," noted Mosher, the study's first author. "This work is an important step towards developing sustainable practices in the next generation of biomaterials manufacturing, which has become paramount amidst the global climate crisis."

More information: Christopher Z Mosher et al, Green electrospinning for biomaterials and biofabrication, *Biofabrication* (2021). DOI: 10.1088/1758-5090/ac0964

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