Spring 2020

Magnesium Contained Nano-fibrous Mesh Scaffolds for Biomedical Applications

Sheikh Saudi
North Carolina Agricultural and Technical State University

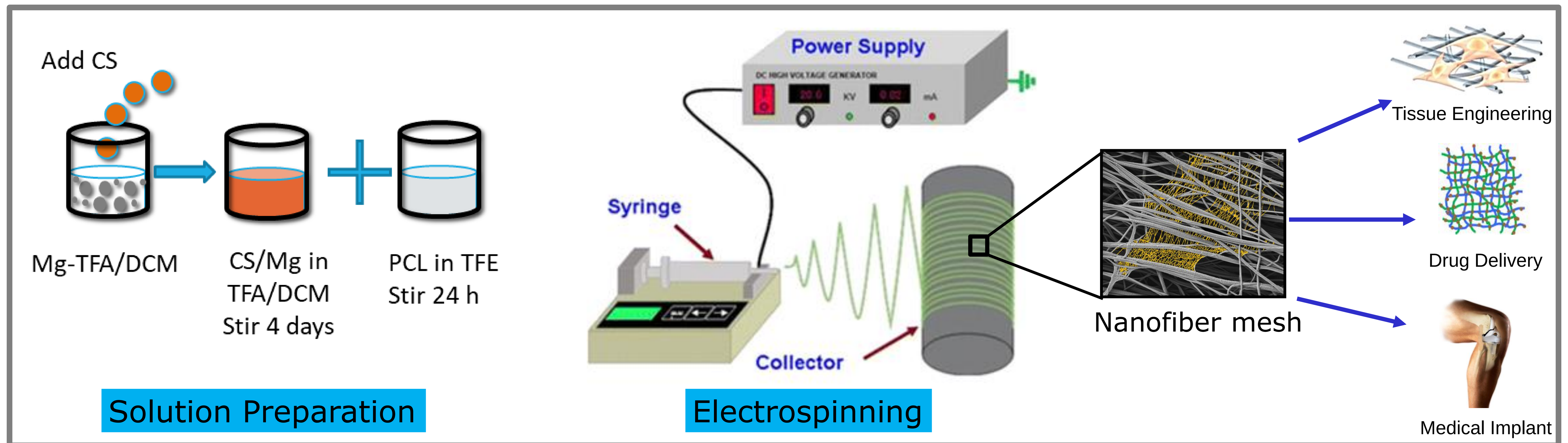
Magnesium Contained Nano-fibrous Mesh Scaffolds for Biomedical Applications

Student: Sheikh Saudi, Program: Nanoengineering (PhD),
Research Advisor : Dr. Narayan Bhattarai

Magnesium (Mg): Mg-based implant has drawn tremendous attraction to the researchers in the health sector, especially in orthopaedics and cardiovascular, due to its superior properties, *mechanical, biocompatibility, and biodegradability*, compared to it nondegradable counter parts such as Stainless Steel. Mg, when it corrodes in body, releases beneficial hydrogen gas (H_2) and Mg ions (Mg^{2+}) which is directly related to various biological functions. Mg ions are also found anti-inflammatory and neuroprotective in the body.

Problem Stated: Mg is highly chemically active substance when exposed to air or an aqueous environmental which results in the formation of an oxide layer/hydroxide, and, create gas-filled cavities that can put pressure on and damage adjacent tissues when a rapid rate of Mg degradation occurs.

Research Strategy and Hypothesis: In order to remediate this problem, we propose to coat the Mg particles completely with a polymeric scaffold to prevent the oxidation and control release over time. We synthesize electrospun nanofiber meshes of synthetic (Poly(ε-caprolactone) (PCL)) and natural polymer (Chitosan (CH)) embedded with laboratory-developed Mg metal nanoparticles. Model drug (Diclofenac Sodium) and commercially available nanoparticle will be loaded and tested with the composite fiber mesh to optimize the loading and release characteristics studied. We hypothesize that Mg-containing nanofiber meshes would have more useful biological properties than control meshes containing PCL or PCL/CH nanofibers alone. These properties will lead to future exploration of the scaffold materials for use in clinically relevant translational tissue engineering applications.



1. Synthesis of Mg nanoparticle

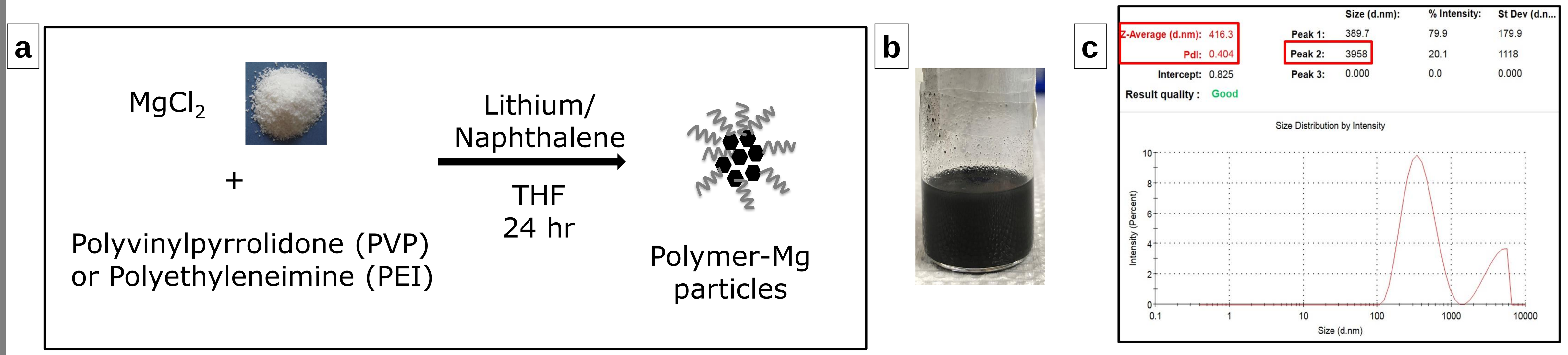
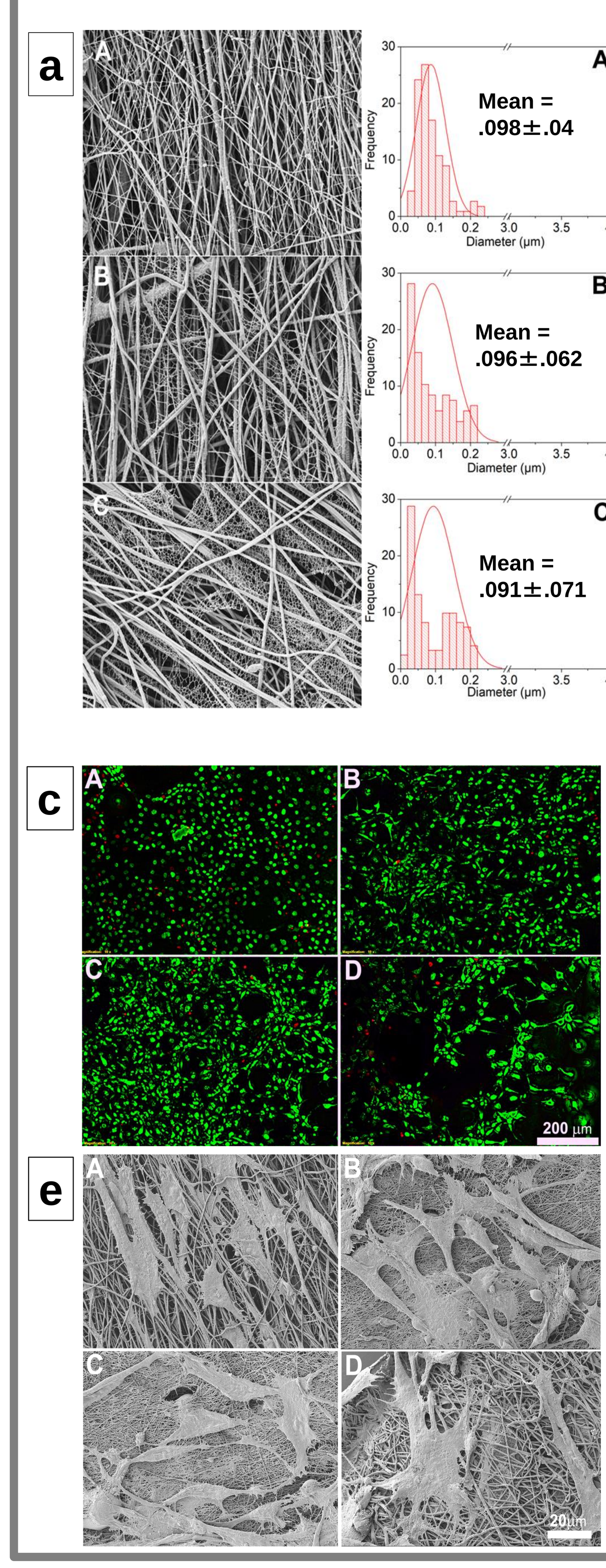


Figure. (a) Reduction reaction of Mg salt under inert condition. **(b)** Polymer-Mg solution. **(c)** Mg particle characterization in Dynamic Light Scattering (DLS). Polydispersity (PDI) was found 0.404. Particle average size was 416.3 nm with st dev. ~180 nm.

Sample	Mg	Li
Mg-PVP	6.77	2.24
Mg-PEI	5.28	4.09

Table 1. Concentration of elements in wt% detected by Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

2. Drug loaded PCL/CH fiber mesh



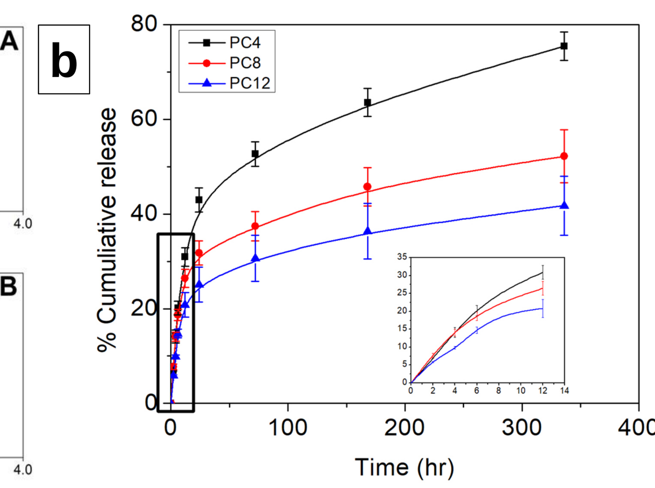


Figure. (a) Morphology and Frequency Distribution of PCL/CH-DS nanofiber. A–PC4, B–PC8, and C–PC12. Scale bar represents 1μm. **(b)** Drug release profile from the corresponding fiber.

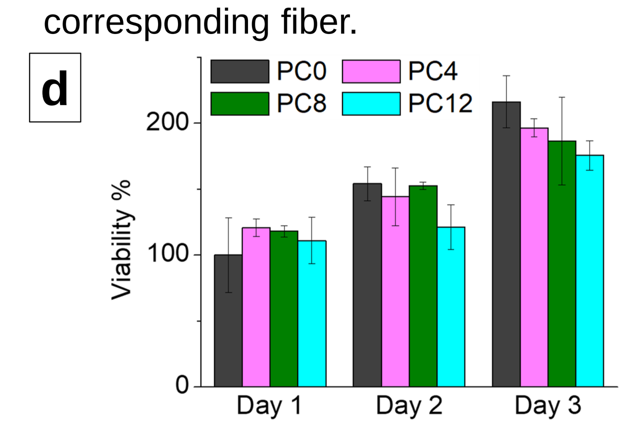


Figure. (c) Fluorescent Microscopy Images A to D represent live (stained green) and dead (stained red) 3T3 fibroblasts cell cultured for 3 days on meshes PC0, PC4, PC8 and PC12, respectively. **(d)** Cell proliferation data. **(e)** SEM Images A to D represent the morphology and attachments of 3T3 fibroblasts cultured for 3 days.

3. Zn loaded PCL fiber mesh

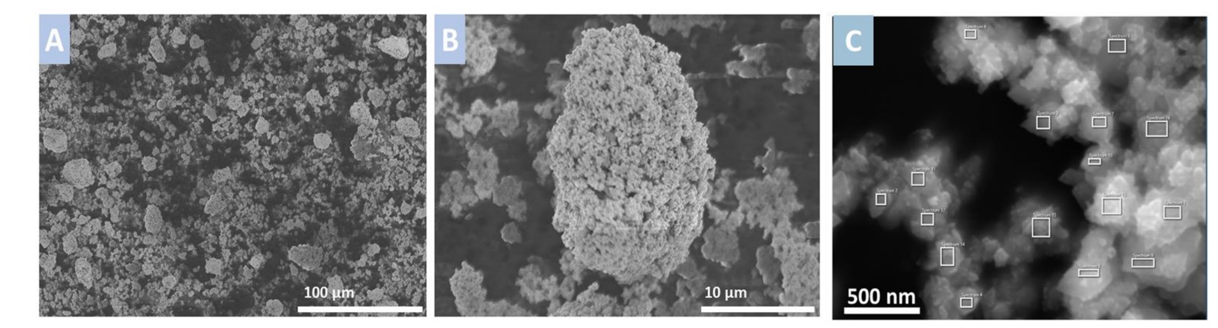
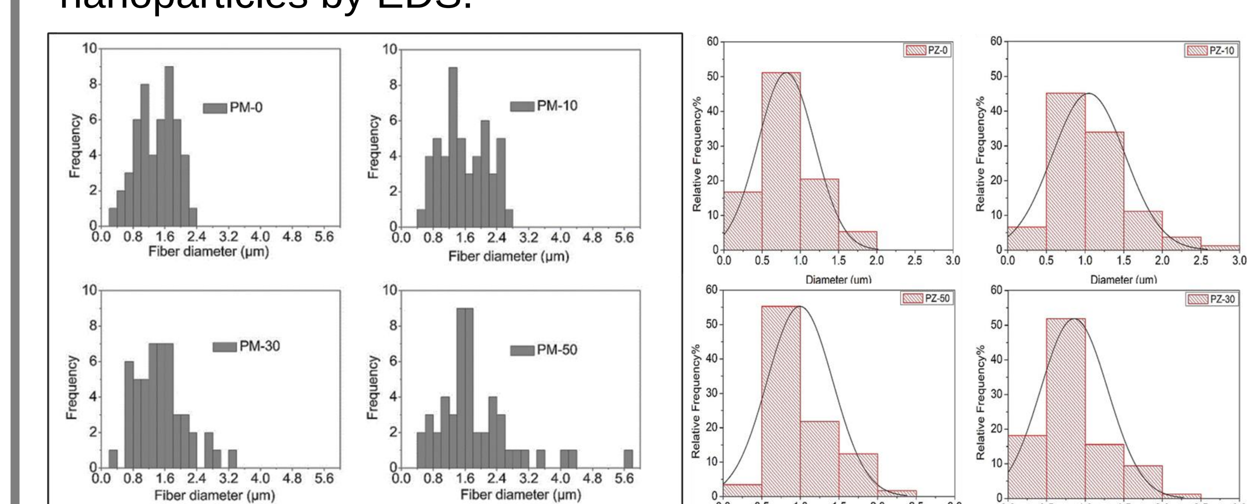


Figure. SEM images (A and B) of commercial Zn nanoparticles. SEM images for EDS shown in (C). As interpreted from the images, these nanoparticles are agglomerated. The average size of these agglomerates was found to be 3.307± 0.19 μm; agglomerates size was found as large as 18 μm.

Elements	O	Ni	Zn
Amount (wt%)	11.95 ± 2.51	3.62 ± 0.43	84.43 ± 2.40

Table 2. Semi-quantitative elemental analysis of Zn nanoparticles by EDS.



Mg particle size ~44 μm, fiber distribution with rang 200 – 5600 nm	Zn particle size <100 nm, fiber distribution with rang 200–2800 nm

Figure. Comparison of FD of Mg/PCL and Zn/PCL nanofiber.

Conclusion and Future work :

- PCL/CH based composite nanofiber mesh with different composition was successfully produced by using laboratory designed electrospinning set up. Several physio-chemical properties of the mesh characterized and identified a best composition for next level of experiments.
- Several experimental process have been performed to synthesize Mg nanoparticle and we are in progress to synthesized Mg particle in desired size.
- Composite nanofiber mesh have been further advanced by encapsulating drug (e.g. diclofenac sodium) and Zn nanoparticles.
- Release profile of drug reflects fiber composition are capable to entrap the drug molecule and sustained release profile has been obtained.
- Fibrous mesh has been tested with NIH 3T3 fibroblast cell. Toxicity of the fiber has been performed and our finding shows that samples were nontoxic to the cell.

Acknowledgment: This work is supported by the NSF, through the Engineering Research Center for Revolutionizing Metallic Biomaterials (ERC-RMB, EEC-0812348). Characterization of meshes was performed in part at the Joint School of Nanoscience and Nanoengineering.

References: 1. Song, M. R., Chen, M., & Zhang, Z. J. (2008). Materials Characterization, 59(5), 514-518. 2.U. Adhikari et al. / Acta Biomaterialia 98 (2019) 215–234