ME – PhD Thesis Defense

Multifunctional Biomaterials based on Polyacrylamide/Hydroxyapatite for magnetic biosensing and Musculoskeletal Repair.

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ABSTRACT

The development of advanced nanocomposites for musculoskeletal repair represents a significant leap in biomedical engineering. These nanocomposites leverage the properties of hydrogels and hydroxyapatite (HAP) to address key challenges in tissue repair and regeneration. Hydrogels, with their high biocompatibility and water-holding capacity, offer flexibility and adaptability for various applications, including cartilage repair. Similarly, HAP composites are gaining traction for bone replacement due to their similarity to natural bone mineral. Integrating nanoparticles into these materials can significantly enhance their mechanical properties, bioactivity, and overall effectiveness in musculoskeletal repair.

Hydrogels are flexible polymers known for their biocompatibility and high water-holding capacity due to their three-dimensional network. These hydrogels can be modified by using various monomers and crosslinkers to enhance their properties. Research has explored infusing hydrogels with nanoparticles, such as magnetic particles, to create ferrogels with applications in magnetic biosensing and drug delivery. Incorporating carbon nanotubes (CNTs) into polyacrylamide (PAM) hydrogels embedded with nickel nanoparticles significantly improved magnetic sensitivity, strength, and wear resistance. CNTs increased the magnetic moment by 85%, enhanced magnetism, and reduced wear by 40% due to their lubricity and synergistic effects with nickel nanoparticles.

However, traditional PAM hydrogels face challenges in mechanical strength and puncture resistance. To address this, the strength of PAM hydrogels was improved using titanium oxide (TiO_2) and CNTs separately, and in combination. The PAM-TiO_2-CNT composite exhibited enhanced compressive strength, elastic modulus, and puncture resistance. It also demonstrated self-healing properties, bioactivity, and high cytocompatibility, with a cell viability of about 99%.

Additionally, hydroxyapatite (HAP) composite coatings were developed for orthopaedic applications. Three HAP composites (HAP + CNT, HAP + GRO, and HAP+ hBN) were fabricated and characterized for wear resistance, mechanical strength, hydrophilicity, and cytotoxicity. Among these, the HAP + hBN composite exhibited the best properties for bone implants, with improved wear resistance, mechanical strength, and hydrophilicity due to the synergistic effects of hBN.

Overall, the incorporation of nanoparticles like CNTs and TiO_2 into hydrogels and HAP composites represents a significant advancement in material properties for biomedical applications, including cartilage repair and bone implants. These musculoskeletal repair nanocomposites provide enhanced performance and durability, paving the way for improved clinical outcomes in tissue regeneration and orthopaedic repairs.

ABOUT THE SPEAKER

Jeet Kumar gaur is an integrated PhD student, working in Prof. M S Bobji's (FM) lab, in Mechanical engineering dept of IISc. In his PhD work, he synthesized and studied nanocomposite materials with base as organic polymer (Polyacrylamide) and ceramic (Hydroxyapatite) for magnetic biosensing and musculoskeletal repair applications. The various techniques employed for characterization vary from magnetic hysteresis plot obtained from VSM (Vibrating Sample Magnetometry) to wear rate calculation on a tribometer. While polyacrylamide nanocomposites are viable for soft tissue (like cartilage) replacement, the Hydroxyapatite based nanocomposites are viable for hard tissue like bone-replacement coating material.