# DEVELOPMENT AND TESTING OF NOVEL ANTIMICROBIAL MATERIALS FOR ADDITIVE MANUFACTURING WITH APPLICATION IN SPACE

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**PURPOSE:** The purpose of the study was twofold: (i) develop and test the antimicrobial properties of a polylactic acid- and a polyurethane-based filament, and (ii) use these filaments to manufacture a socket-based prosthesis to verify printability and longevity of the antimicrobial properties. It was hypothesized that the formulation of a novel biocidal copper-based nanocomposite with a biocompatible 3D printing polymer/copolymer can be used for the development of antimicrobial medical devices to mitigate microbial risks during long space flight missions [1, 2, 3].

**METHODS:** *Polylactic Acid-based Filament Development*-The development of a polylactic acid-based filament involved several processes, such as fermentation (corn to Lactic Acid), condensation (Lactide) and polymerization (Polylactic acid; PLA). The addition of copper antimicrobial nanocomposite additive to pellets at different concentrations facilitated the development of a multipurpose antimicrobial filament. The addition of a treated carbon fiber and natural fibers nanocomposites our team create a high strength polylactic acid-based filament (Zuniga, 2018). *Polyurethane-based Filament Development*-The current polyurethane-based filament is a versatile non-toxic biocompatible flexible filament with a wide variety of applications. To confer biocidal activity to this filament, the inorganic copper-based nanocomposite additive was immobilized physically by embedment in the polyurethane-based filament structure. The additive use zeolites as carriers. The metallic ions contained in zeolite are replaced by copper ions with biocidal properties through ionic exchange. The use of nanoparticles effectively increased the concentration of copper within the zeolites maximizing the antimicrobial behavior. The result was a polyurethane-based flexible filament with high biocidal activity, better action spectrum and longer duration. *Antimicrobial testing*-Antimicrobial effectiveness and longevity of the filaments was tested by an independent laboratory following standard procedures for ISO 22196 before and after a heat-based accelerating aging agent for a period of 1 month equivalent to 1 year period of aging (Situ Biosciences LLC, wheeling, IL, Chicago, USA). The antimicrobial longevity was tested using a heat-based accelerating aging agent (50°C) using a standard oven heat accelerated aging protocol for standard environmental conditions. Six flat test samples (5 cm x 5cm x 1cm) of each material was manufactured and tested. The ISO 22196 is designed to measure the antimicrobial properties of a solid plastic surface incubated with bacteria, such as two strains of Staphylococcus Aureus (Methicillin-resistant and standard strain) and Escherichia Coli.

**RESULTS:** The bacterial analysis showed that both, the acid- and polyurethane-based filaments with 1% antibacterial nanoparticles additives was up to 99.99% effective against two strains of Staphylococcus Aureus (Methicillin-resistant and standard strain) and Escherichia Coli. The materials showed a 98.99% reduction after one year of simulated aging. The printability of the device was similar o standard polylactic acid and thermoplastic polyurethane filaments. The extrusion process did not affect the antimicrobial properties of the filaments [2].

**CONCLUSIONS:** A recent study [3] found that 28 astronauts experienced an altered immune response during their six-month mission aboard the International Space Station [3]. The direct cause of this altered immune behavior has not been identified, but may be linked to radiation, microbes, stress, microgravity, altered sleep cycles and isolation 1. In a prolonged space mission, these factors could cause increased susceptibility to illness and, in turn, limitations to human space exploration [1, 3]. The unprecedented accessibility of additive manufacturing technology and the development of 3D printing "Active Materials" have several medical applications and have the potential to revolutionize the manufacturing of medical devices. Promising applications include developing medical devices in austere environments such as space (i.e., International Space Station and inflight medical conditions) as a preventive countermeasure to mitigate microbial risks during long space flight missions [1].

**REFERENCES:**

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