



Tunable Microwave-Assisted Surface Functionalization of Biocompatible Magnesium Silicate Nanotubes for Advanced Nanomedicine Applications

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Abstract:

Magnesium silicate nanotubes (NTs) have recently emerged as a versatile class of biocompatible inorganic nanomaterials for biomedical applications, owing to their unique tubular morphology, high surface area, and ability to accommodate multiple functionalities. Developing reliable strategies for controlled surface modification is therefore essential to expand their potential as multifunctional platforms for diagnostics and therapy^[1]. Here, we present a rapid and tunable microwave-assisted silanization protocol for the covalent functionalization of synthetic NTs using 3-aminopropyltrimethoxysilane (3-APTMS). Microwave irradiation enables efficient functionalization under mild conditions (70 °C, 1 h), significantly reducing reaction times compared with conventional approaches. By systematically varying the silane concentration and reaction time, surface coverage can be finely tuned, providing a versatile platform for the subsequent covalent attachment of functional molecules, including photosensitizers, targeting ligands, imaging probes, and therapeutic agents. The structural integrity of the NTs after functionalization was confirmed by complementary characterization techniques, including TEM, powder XRD, Raman spectroscopy, XPS, solid-state NMR, elemental analysis, TGA, and ninhydrin assays. These analyses reveal that silanization proceeds through surface silanol groups, forming predominantly bi- and tri-dentate Si-O-Si linkages and achieving nearly complete surface coverage while preserving the NTs morphology and crystalline structure. Overall, these results establish microwave-assisted silanization as a robust and reproducible strategy for engineering magnesium silicate NTs, paving the way for their integration into next-generation nanomedicine platforms.

[1] Secchi V, et al. *Nanoscale* 17(35):20259-20268. (2025)