Characterizations of Biogenic Oxide Nanocomposites

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Marine diatoms are a class of micro-algae whose cell walls are composed of silica nanoparticles. These organisms actively assimilate silicic acid Si(OH)4 from seawater, polymerize silicic acid to silica nanoparticles by a protein-mediated precipitation process, and then assemble the silica nanoparticles into intricate patterns that constitute the cell wall micro-architecture of the diatom frustule. The biomineralization capacity of marine diatoms, Nitzschia, was harnessed to biologically manufacture silicon oxide/germanium oxide nanocomposite materials. Germanium was incorporated into living diatom cell mass in a two-stage cultivation process. In stage 1, the N. frustulum cell suspension was grown in silicic acid medium within a bubble-column photo-bioreactor. In stage 2, when all the soluble silicon had been consumed, $Ge(OH)_4$ or a mixture of $Ge(OH)_4$ and $Si(OH)_4$ were added to Si-starved cells. The cells assimilated soluble germanium by a surge uptake mechanism. The cell mass was thermally annealed in air at 800ºC for 6 hours to oxidize carbonaceous materials. The micro- and nanostructures of biogenic oxide nano-composite before and after post-processing were characterized using electron diffraction, HR-TEM with EDX, and XRD. The local molecular bonding was determined by FTIR. The thermally annealed cell biomass was characterized by TEM-EDS, FTIR, and XRD. These measurements confirmed the formation nanostructured Ge-Si nanocomposite composed of $CaSiO_3$ and Ca_3GeO_5. The measurements confirmed the biogenic formation of germanium oxide and germanium-silicon oxide alloys. This study demonstrates that the feasibility of biological production of oxide nanocomposite materials.