SILICON NITRIDE – A PROMISING CANDIDATE FOR THE BIOACTIVE COMPOSITE IMPLANTS

Miroslav Hnatko [1] *– Pavol Šajgalík* [1] *– Martina Labudová* [2]

[1] Institute of Inorganic Chemistry, SAS, Bratislava, Slovakia, e-mail: uachmiho@savba.sk; sajgalik@savba.sk
[2] Biomedical Centre, Institute of Virology, SAS, Bratislava, Slovakia, e-mail: virulama@savba.sk

Keywords: biomaterial, bioinert, bioactive, silicon nitride

Silicon nitride-based ceramics are characterized especially by high chemical resistance, superior combination of fracture toughness, hardness, and thermal shock and wear resistance. Recently also silicon nitride attracts interest for bio-applications in the human body as bio inert material. Silicon nitride based biomaterials have a potential to be used as total hip-joint replacements, mini-osteofixation systems, multiwall drug-release devices, intervertebral spacers and spinal surgery or implantations in otorhinolaryngology and traumatology. However, the biological applications often require additional properties, e.g. bioactivity enabling stronger bonding to the host tissue and moreover ceramic bio-implants are of different size, shape or form with foreseen mechanical, physical or chemical properties. In this work porous or dense silicon nitride based substrate in the form of bulk or granules/microspheres were prepared and subsequently covered by the hydroxyapatite/ calcium phosphate phase thin layer in order to change the substrate from bio-inert to bio-active. Four different silicon nitride based bio-active materials will be presented with the aim to show a potential of silicon nitride in bio applications:
1.) Porous silicon nitride with bone-like pore structure prepared by replica method and
2.) porous spheres of size about one millimeter (or more) on average prepared by water silicon nitride suspension by freeze drying. Silicon nitride–hydroxyapatite composites were prepared by infiltration of hydroxyapatite precursor sol into the silicon nitride based porous ceramics (porosity up 80%). Cytotoxicity and in vitro bioactivity of Si_3N_4–HA composites were tested in order to verify the effect of hydroxyapatite addition on the biological properties of composite. After immersion of porous composite into simulated body fluid (SBF) for 21 days, calcium phosphate (CP) layer was formed on the surface of silicon nitride–hydroxyapatite composites, indicating their bioactivity.
3.) Surface modification of dense silicon nitride body using an oxyacetylene torch at high temperatures and the formation of a thin (2-5 μm) and porous bioactive layer based on the grain boundary composition with chemical adhesion to substrate.
4.) Porous silicon nitride microspheres of size about 10-100μm prepared by flame synthesis.
The formation of thin layer utilizing of high temperature oxidation of dense silicon nitride with different grain boundary phase (SiO_2 or $Ca_3(PO_4)_2$) by oxyacetylene torch was studied. After short dwell time (30 – 60sec.) at high temperature (aprox. 1480-1500°C) two processes were started – formation of a thin layer of glassy phase on the surface and decomposition of silicon nitride (acting as a pore forming agent). This method of surface modification seems to be a promising route for the bio-active layer formation. Finally, porous silicon nitride microspheres with different ratio of $S_3N_4/Ca_3(PO_4)_2$ within starting mixture were prepared by flame synthesis method. The influence of feed rate on the size distribution and porosity of microspheres were studied.