From Inside the Body to Outer Space – Silicon Nitride

Silicon Nitride (Si_3N_4) is one of the strongest ceramics due to a unique grain structure which yields both high strength and high toughness. Dense silicon nitride is a very hard, abrasion-resistant and corrosion-resistant solid. Unlike familiar ceramics such as porcelain or glass, silicon nitride has very high strength, with the highest fracture resistance of any advanced ceramic.

Biomedical Grade Silicon Nitride

SINTX has developed a unique medical grade of Si_3N_4 that exhibits exceptional properties inside the body as orthopedic implants - that is implants for spine, knee, shoulder, etc. When used to make spinal fusion implants, silicon nitride has the flexibility of a dense, porous, or a combined architecture that can mimic the structure of bone. Silicon nitride is biocompatible, bioactive[1], and has shown bacterial resistance[2–5] and superb bone affinity[6–8]. Silicon nitride can be polished to a smooth and wear-resistant surface for articulating applications, such as bearings for hip and knee replacements.

The Ideal Biomaterial

- ***Strength and fracture toughness****: Interlocking anisotropic grains deflect and bridge cracks.*
- ***Wear resistance****: High hardness, strength, and fracture toughness prevent wear.*
- ***Material phase stability:*** *No spontaneous phase transformation or associated weakening.*
- ***Hydrophilicity****: Tunable through modification of surface topography and chemistry, from <10° up to ~70°.*
- ***Osseointegration****: Nanostructured topography combines with complex surface chemistry for optimal cell adhesion and bone growth.*
- ***Favorable imaging****: Low attenuation coefficient and magnetic susceptibility give a semi-radiolucent appearance in X-ray along with distortion-free CT and MRI scans*
- ***Bacterial resistance****: Surface chemistry, nanotexture, and charge inhibit biofilm formation*

With an expanding, ageing and more active population, biomaterial innovations will lead to improved biomedical implant safety, high-performance, and lifetime durability. Already well-proven in diverse industrial applications and currently utilized as intervertebral spinal fusion cages, silicon nitride has the foundational evidence to be applied likewise across a range of biomedical applications.

Aerospace Grade Silicon Nitride

In addition to the properties and characteristics that make Si_3N_4 the ideal biomaterial, Si_3N_4 exhibits very high strength at high temperatures and a very high thermal shock resistance with a low density. These properties make it ideal for applications with high dynamic stresses at high temperature, and demanding reliability requirements. This unique combination of material properties provides advantages in severe-service applications such as components for turbine engines and radomes.

A radome is an aerodynamic structural part attached to the front of a missile that allows for transmission of electromagnetic signals with minimum attenuation and also protects the radar communication system. Thus, most radomes today are made of ceramics as they tend to exhibit the optimal combination of these requisite properties: low density, low dielectric constant

low loss tangent, high flexural strength, and high thermal shock resistance.

SINTX Si_3N_4 exhibits a flexural strength of greater than 1 GPa, with a high Weibull Modulus, making it one of the strongest silicon nitrides currently available. It meets the other requirements with respect to density, dielectric properties and thermal resistance.

SINTX Technologies

SINTX Technologies is located in Salt Lake City, Utah, where we operate an ISO 13485:2016 certified manufacturing facility. We are a commercial-stage company that develops silicon nitride and related ceramic technologies to address a wide range of medical and non-medical applications. Our spine implants are FDA-cleared, and sold in the U.S., and select markets in Europe and South America through our retail partner, i.e., CTL Amedica of Dallas, TX. Recent advancements in our R&D have opened up opportunities outside the biomedical space.

1. Pezzotti, G. *et al.* Human osteoblasts grow transitional Si/N apatite in quickly osteointegrated Si3N4 cervical insert. *Acta Biomater.* **64**, 411–420 (2017).
2. Gorth, D. J. *et al.* Decreased Bacteria Activity on Si3N4 Surfaces Compared with PEEK or Titanium. *Int. J. Nanomedicine* **7**, 4829–4840 (2012).
3. Webster, T. J., Patel, A. A., Rahaman, M. N. & Bal, B. S. Anti-infective and osteointegration properties of silicon nitride, poly(ether ether ketone), and titanium implants. *Acta Biomater.* **8**, 4447–4454 (2012).
4. Bock, R. M. *et al.* Bacteriostatic Behavior of Surface-Modulated Silicon Nitride in Comparison to Polyetheretherketone and Titanium. *J. Biomed. Mater. Res. Part A* **105**, 1521–1534 (2017).
5. Pezzotti, G. *et al.* Silicon Nitride Bioceramics Induce Chemically Driven Lysis in Porphyromonas gingivalis. *Langmuir* **32**, 3024–3035 (2016).
6. Ishikawa, M. *et al.* Surface topography of silicon nitride affects antimicrobial and osseointegrative properties of tibial implants in a murine model. *J. Biomed. Mater. Res. - Part A* **105**, 3413–3421 (2017).
7. Ball, H. T., McEntire, B. & Bal B, S. Accelerated Cervical Fusion of Silicon Nitride versus PEEK Spacers: A Comparative Clinical Study. *J. Spine* **06**, 1–6 (2017).
8. Pezzotti, G. *et al.* In Situ Spectroscopic Screening of Osteosarcoma Living Cells on Stoichiometry-Modulated Silicon Nitride Bioceramic Surfaces. *ACS Biomater. Sci. Eng.* **2**, 1121–1134 (2016).