Portfolio Summary: Hydroxyapatite, HAp, chemical formula Ca_{10}(PO_4)_6(OH)_2 has attracted the attention of researchers over the past thirty years as an implant material because of its excellent biocompatibility and bioactivity. HAp has been used extensively in medicine for implant fabrication. It is commonly the material of choice for fabricating dense and porous bioceramics. Its general uses include biocompatible phase-reinforcement in composites, coatings on metal implants and granular all for direct incorporation into human tissue. Other potential non-medical applications include a packing material/support for column chromatography, gas sensors and catalysts, as a host material for lasers, and as a plant growth substrate.

Market Applications:
• Biocompatible phase-reinforcement in composites
• Coatings on metal implants
• Non-medical applications
  - Packing material/support for column chromatography,
  - Gas sensors and catalysts,
  - Host material for lasers,
  - Plant growth substrate

RU 2000-0132: Magnesium-Substituted Hydroxyapatite Powder

Invention Summary: Rutgers Researchers have discovered that hybrid mechanochemical-hydrothermal synthesis techniques may be employed to produce magnesium substituted Hap. Additionally they were able to incorporate levels of magnesium into the HAp lattice structure that was not believed possible until now. Mechanochemical powder synthesis is a solid-state synthesis method that takes advantage of the perturbation of surface-bonded species by pressure to enhance thermodynamic and kinetic reactions between solids. Pressure can be applied at room temperature by milling equipment ranging from low-energy ball mills to high-energy stirred mills.

The mechanochemical-hydrothermal route produces comparable amounts of HAp powder as the hydrothermal processing but it requires lower temperature, i.e., room temperature, as compared to typically 90-200° C. for the hydrothermal processing and it can be done at a low cost. An additional advantage of the processing is that there is no need for a pressure vessel and no need to heat the reaction mixture.

Advantages:
• Simplicity
• Low cost
• Lower temperature (i.e., room temperature)
• No need for pressure vessel
• No need to heat reaction mixture

Intellectual Property & Development Status:
RU 2006-038: Biomimetic Hydroxyapatite Synthesis

Invention Summary: Hydroxyapatite is synthesized with high yield at room temperature in as little as 1 hour. The system uses two chemical components (Calcium Acetate and Potassium Phosphate) plus water and does not employ additional pH controlling agents. The pH of the system can be controlled using different ratios of the components. The range studied in this research is a Ca/P ratio 1.25-2.5 which encompasses the pH ranges 6-14 as the final pH of the system. This provides for the possibility of creating a composite at cell and polymer friendly conditions at room temperature. Size can be controlled using reaction time, kinetic stirring conditions and the employment of seeds. Smaller nanoscale particles (under 10nm) are formed instantly with the absence of stirring and the absence of seeds. SEM data indicates larger hexagonal particles are produced at 2 hours. The ions produced are also found in vivo, so minimal washing is needed to obtain usable product.

Advantages:
• Conducted at room temperature
• Final pH is neutral or can be inherently buffered
• High yielding reaction
• Short reaction time
• Minimal washing
• Future prospects in composites with natural and manmade substrates
• Nanoscale powder technology may be applicable for drug delivery

Intellectual Property and Development Status:
Issued, 8,287,914 B2; Various Published PCT applications.

RU 2008-011: Room Temperature Hydroxyapatite Synthesis via Calcium and Tribasic Phosphate

Invention Summary: The previous technology relied on the assumption that calcium acetate was needed to produce nanoscale hydroxyapatite powder at room temperature when potassium phosphate tribasic was used with the calcium source. This technology utilizes the approach that any room temperature water soluble calcium source (calcium nitrate, calcium chloride, calcium fluoride etc) can be used with a tribasic phosphate source (potassium phosphate tribasic, sodium phosphate tribasic, ammonium phosphate tribasic) to produce hydroxyapatite at room temperature. Similarly to the previous invention, a gel phase was present when acetic acid was not present, but agitation in both cases yielded white slurry indistinguishable from the previous invention utilizing calcium acetate. It may be extrapolated that the size, phase, and surface area of this powder is similar to that of the previous invention.

Advantages:
• Can use any water soluble calcium source
• Can be used with a tribasic phosphate source
• Room temperature production of hydroxyapatite

Intellectual Property and Development Status:
PCT filed.
RU 2008-030: Hydrothermal Liquid Phase Sintering of Porous Ceramics with Interconnected Porosity

Invention Summary: Researchers at Rutgers University have developed a hydrothermal process for sintering conventionally shaped and compacted porous solid matrices, which can be derived from various materials including metal oxide powders. More specifically, they have developed a hydrothermal liquid phase sintering (HLPS) process in which a compacted porous ceramic matrix is infiltrated with a liquid medium. A hydrothermal chemical process is then initiated between the medium and the microstructure of the solid matrix, under conditions of temperature and pressure that are considerably milder in comparison with those employed in conventional oven-fired high-temperature sintering methods.

By manipulating the components of the ceramic matrix and the infiltrating medium of the developed method, a sintered, multi-component ceramic product that retains the same size and shape as the original compacted solid can be obtained.

Advantages:
- Sintering process can be performed at relatively mild conditions of temperature and pressure
- Minimizes energy consumption.
- Accommodate a wide variety of starting materials, reagents, and shapes and sizes of the desired product.
- Low temperatures leads to an interconnected open porosity.
- Sintered products obtained have a very homogeneous and fine microstructure.


RU 2010-053: Hydroxyapatite with Controllable Size and Morphology

Invention Summary: Current methods for HAp synthesis have many drawbacks. Usually a high temperature process is used which lacks the ability to control particle size and morphology, or the process does not produce a phase pure crystalline product and produces large agglomerates.

An esteemed Rutgers Materials Science professor has developed a technology that meets the need for phase-pure hydroxyapatite having a controllable size and morphology, a method for producing uniform hydroxyapatite films and coatings, and a method for deposition of the coatings with an intermediate bonding layer over a substrate surface. This invention allows a range of particle size to be isolated through specific conditions. Both the ceramic powder and film formation involves the appropriate mixture of reagents heated to a specific time and low temperature with a controlled stirring speed. The products are then isolated in a very simple manner.

Advantages:
- Specific particle size and morphologies
- Controlled particle sizes from 50 nm to 5 μm with aspect ratios of 0.5 to 5.0.
- Low temperature coating process.
- Uniform film/coating with consistent particle morphology and controlled film thickness.
- Intermediate bonding layer for better substrate adhesion.

Intellectual Property and Development Status: PCT filed.