Investigations of mechanism of no-additive sintering of metal nitride nanopowders – from synthesis to composite nanoceramics

Why nanocrystalline nitrides?

Man-made nitride materials including aluminum nitride AlN and gallium nitride GaN are modern „no-silicon"/„no-oxide" alternatives for key applications in electronics and ceramics. Also, some of the transition metal nitrides, *e.g.*, titanium nitride TiN, offer exiting combinations of properties unlike many of their traditional counterparts. One of the prime example is a wide bandgap semiconductor GaN (3.4 eV) that by forming solid solutions with such nitrides as AlN and InN yields semiconducting materials with the bandgap-of-choice in the range 1.8-6.2 eV (*cf.* Blu-Ray technology, energy efficient LEDs). Along this way, AlN is a chemically and mechanically robust electrical insulator with an outstanding thermal conductivity whereas extremely hard TiN is not a good heat conductor but its electrical resistivity resembles that of metals. All these nitrides can be made as nanopowders of which properties are crystallite size-dependent. Thus, such nitrides as AlN, GaN, and TiN in various composite subsystems, both as nanopowders and nanoceramics, can offer unique sets of properties. They are the subject of studies in this project. It needs to be underlined that sintering of the nitride nanopowders into robust nanoceramics is an attractive way for the nanopowders utilization, for instance, by substituting the difficult to make and expensive monocrystals.

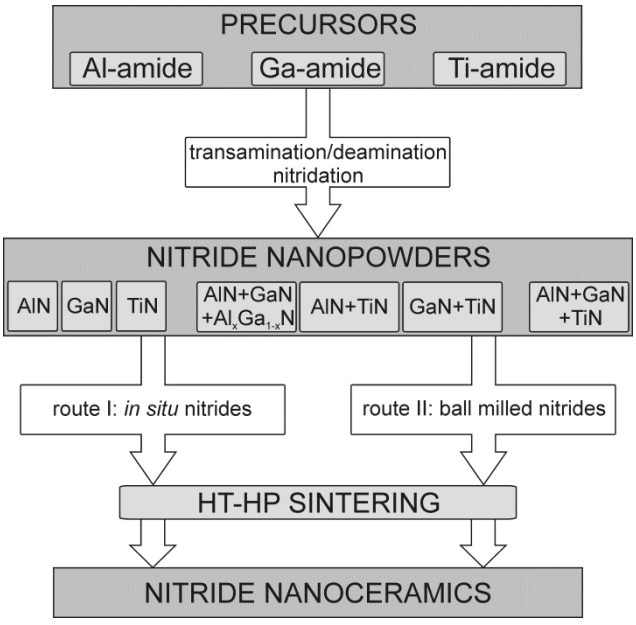
Investigations of the poorly known mechanism of no-additive sintering process in the composite systems of the nitride nanopowders will be concerned with determination of essential thermodynamic and kinetic factors of the process as well as with its control towards new composite nitride nanoceramics.

How to prepare nanopowders?

The synthesis and characterization of the individual nanopowders of AlN, GaN, and TiN as well as of their binary and ternary nanocomposites will be carried out using the original anaerobic synthesis method from the individual and/or suitably mixed metal dimethylamides. The final nitridation pyrolysis under ammonia at selected temperatures is expected to yield the *in situ* nanopowders of definite average crystallite size characteristics. A similar group of nanopowders with the analogous compositions whereas purposely amorphized/mechanically mixed will be derived by high energy ball milling of the *in situ* nanopowders.

How will nanopowders be sintered?

All nanopowders will be subjected to high temperature, 600-1000 °C, and high pressure, 4-10 GPa, sintering with no additives to afford new types of the composite nitride ceramics. The sintering process will be applied to both types of the nanopowders under conditions favoring preservation of the nanocrystalline nitride characteristics and the formation of nanostructured ceramics – nanoceramics. Below, the schematics of the major stages of the project is shown.



What materials characteristics will be determined?

Characterization of the materials will include the determination of their structural and chemical properties (powder XRD, ^{71}Ga MAS NMR, N analyses), microscopy examination and analysis (SEM/EDX, TEM), measurements of surface properties (BET specific surface area, helium density), and optical/spectroscopic data (UV-vis, micro-Raman, FT-IR); for the ceramics, the Vickers micro-hardness test will be done.