**Name of the course: “Solid State Chemistry”**

**Department responsible for the course or equivalent:** Dpt of Chemistry

**Lecturer (name, academic title, e-mail): Dr.** V.B. Nalbandyan ([vbn@sfedu.ru](mailto:vbn@sfedu.ru)) , Dr. I. L. Shukaev ([ishukaev@mail.ru](mailto:ishukaev@mail.ru)).

**Semester when the course unit is delivered:** 1&2

**Teaching hours per week:** 3

**Level of course unit:** Master level.

**ECTS credits: 5**

**Admission requirements:** basic knowledge of chemistry, physics and mathematics (bachelor level); theory of symmetry, part of the parallel course “General Laws in Chemistry”; X-ray diffraction phase analysis, part of the parallel course “X-Ray Spectroscopy and X-Ray Diffraction”.

**Course objectives (aims):** In this course, after a brief account of a wide range of principles, materials, phenomena and methods, the attention will be focused on solid state ionics (solid electrolytes and electrode materials) and dielectrics (including ferroelectrics and multiferroics).

**Course contents: Module 1. Materials, phenomena and principles**

1.1. Defects in crystals. Points defects and dislocations. Composition-property relations in metallic solid solutions. Holes, electrons and ionic point defects in nonmetallic crystals. Diffusion in solids. Nernst-Einstein equation. Activation energy for diffusion and ionic conductivity. Quasichemical equilibria, dependences of defect concentrations, diffusion coefficients, ionic and electronic conductivities on the temperature, atmosphere and dopant concentration.

1.2. Overview of inorganic materials and applications

Crystal chemistry and basic properties of typical representatives of elemental metals, intermetallics, binary semiconductors, magnetic oxides, high-temperature superconductors, solid-state anion and cation conductors (including proton conductors), battery electrode materials, linear dielectrics, relaxors, ferroelectrics and multiferroics. Electrostriction. Domain structure of crystals. Electro-optical effects. Morphotropic phenomena in solid solutions. Piezoelectric ceramics, its poling and aging. Piezoelectric and magnetoelectric composites. Lithium ion batteries, emerging sodium ion batteries, sodium-sulphur batteries, low-temperature and high-temperature fuel cells, potentiometric and amperometric sensors, supercapacitors. Solid electrolytes in thermodynamic studies.

**Module 2. Experiments in solid state chemistry**

2.1. Preparative methods. Crystal growth, thin film technologies, solid-state synthesis, wet and semi-wet preparation methods, sintering and hot pressing, soft chemistry routes. Solvothermal and high-pressure techniques.

2.2. Methods of electrical measurements. Immitance spectroscopy, four-probe method, separation of bulk and electrode contributions using resistance vs. electrode separation plots, DC polarization, Tubandt and emf methods for determination of transference numbers, cyclic voltammetry and galvanostatic chronopotentiometry, Hall effect, dielectric permittivity, loss tangent and their dispersion, dielectric hysteresis, piezoelectric coefficients.

2.3. Optical microscopy in reflection and transmission mode. Metallographic studies and microhardness. Birefringence and domain structure of ferroelectric crystals.

**Learning outcomes:** It is expected that a student finally will be well informed in the current status, actual problems and trends in the solid state chemistry, including crystal chemistry, defect chemistry, experimental techniques and properties of a wide range of functional materials; It is expected that a student finally will obtain practical skills in sample preparation, electrical measurements, light microscopy and microhardness studies; It is expected that a student finally will be ready to solve problems and perform original investigations in the field of solid state chemistry.

**Planned learning activities and teaching methods –** lectures with a variety of examples and practice.

**Assessment methods and criteria:** set-off (1st semester) and examination (2nd semester)