*DISCIPLINE PLAN*

Name of the discipline: **CRYSTAL GROWTH:**
**Low-dimensional crystal materials**

**Recommended for training programme:**

**020700 «Geology», Specialization – «Geochemistry»**

Qualification (degree) **– Master**

**1. Goals and objectives of study:**

The discipline “CRYSTAL GROWTH: Low-dimensional crystal materials” ***is aimed*** at teaching fundamentals in the field of crystallogenesis and practical crystal growth for students-crystallographers.

This course pursues the following ***objectives/topics***:

- overview of microcrystallisation conditions in different media and criteria for choice of crystal growth method;
- analysis of physico-chemical characteristics regarding to growth of highly efficient low-dimensional single crystals for modern sciense and technogy/engineering;
- current aspects of micro- and nano-crystallization in laboratory and mineral-forming natural systems;
- teaching basic methods of micro- and nano-crystallization.

**2. Discipline as part of the curriculum**:

Course "CRYSTAL GROWTH:Low-dimensional crystal materials" resides in a block of professional disciplines within optional section of the Master carriculum as part of the "Crystallography" module.

It is based on fundamental preceding courses belonging to the modules "Physics" and "Chemistry", and on the professional disciplines of optional part, such as "Crystallography", "Crystallochemistry ", "X-ray Strucrural Analysis", and “Mineralogy”.

**3. Discipline requirements:**

The studying this discipline is focused on the formation of the following competences:

It implies that each student will be able to perform independently research in the field of growth of low-dimensional single crystals, and to use this knowledge in his further practical work, pilot and commercial productions of low-dimensional crystals, epitaxial films and nano-structures.

As a result of studying this crystal growth course, the student must:

- ***know*** the fundamentals of low-dimensional crystallization in multicomponent systems;
- ***be able*** to use professional theoretical and practical knowledge to curry out basic and applied research,
- ***be familiar*** with equipments for crystallization of nano-materials and their initial characterization;
- ***grasp*** advanced methods to examine the experimental results obtained, as well as to use them freely and creatively, in order to solve scientific and practical problems.

**4. The structure and content of the discipline**:

This crystal growth course consists of 6 credit units, i.e. 216 academic hours, including 62 hours of lectures, 4 hours of seminars, 150 hours of extracurricular self-study master students’ works.

***Discipline structure:***

| № | Module name | Semester | Week of semester | Types of work including self-study (hours) | | | | Control mode *(by weeks of semester)* |
|---|---|---|---|---|---|---|---|---|
| | | | | Lec-tures | Semi nars | Lab. works | Self-study | |
| 1 | Growth of low-dimensional single crystals and films | 9 | 1-14 | 38 | 2 | | 70 | Selective oral recitation, marked reports |
| 2 | Formation of nano-structures | 10 | 1-12 | 24 | 2 | | 80 | Selective oral recitation, marked reports |
| The interim assessment by semester and final assessment of the course | | | | | | | | Oral questioning (semester 9); Written Exam (semester 10) |
| Total hours: 252 | | | | 62 | 4 | | 150 | |

***Discipline content:***

***Section I.*** **LOW-DIMENSIONAL "BULK" SINGLE CRYSTALS**

**Technique, engineering and processing methods**

Growth of low-dimensional single crystals from melts
- *Advanced heating sourses*
- *Tools for crystallization of fibers and whiskers*

Flux growth
- *Classical fluxed melts*
- *Self-fluxed (non- stoichiometric) melts*
- *Technical modifications and development prospects*

Hydrothermal synthesis
- *Phase diagrams*
- *Mineralizers*
- *Filling coefficients of autoclaves*

**Typical examples of low-dimensional single crystal growth technologies**

High-temperature borates
- *Laser and non-linear optical rare earth orthoborates*
- *Non-linear optical meta- and polyborates*

HTSC- cuprates
- *Rare earth cuprates: structural type 123*
- *Bi-based HTSC: structural types 2212 u 2223*
- *Incommensurate-type phases*

Vanadates and tungstates
- *Laser rare earth ortho-vanadates*

- *Magnetic vanadates with layered structure*
- *Laser rare earth tungstates*

Manganites

***Section II.*** **MICRO-DIMENSIONAL SINGLE CRYSTAL LAYERS**

**Typical growth methods**

Liquid phase epitaxy: fluxed melts and hydrothermal growth
Crystallization from vapor/gaseous phase

**Preparation of monolayered films**

Zinc oxide (zincite)
Niobates and tantalates
Borates
Tungstates and vanadates
Manganites
HTSC cuprates

**Formation of multicomponent heterostructures**

Compounds II-VI
Compounds III-V

***Section III.*** **1- AND 0-DIMENSIANAL NANO-STRUCTURES**

**Basic terms, notations and types of nano-structures**

Fibers and Whiskers
Qantum dots
Glass ceramic composites

**Features of formation**

Sol-gel method
VLC method
Related technologies
Treatment of agates

**Characterization of nano-structures**

Electron microscopy
Atomic force microscopy (AFM)
X-ray and spectroscopic characterization

**Mineralogical examples**

**Biocrystallization**

**5. Recommended methodology:**

Presentations, reports, interactive classes and other modern approaches expect to be used as educational methods for teaching this course. As a result of self-study research related literature sources, Internet resources and databases, students, under guidance of the teacher, perform their home-works and do their presentations at seminars and colloquia. They also will abstract some sections of the course for discussing their self-prepared abstracts at seminars.

## 6. Marking for current performance control and interim assessment during and at the end of the course:

Oral recitations, defence of self-prepared abstracts and marked reports are planned at seminars for current performance control and interim assessment during the course. Examples of typical questions for current control are the followings:

1. What methods can be used for crystal growth of low-dimensional "bulk"materials?
2. What most popular methods are known for growth of thin single crystal layers?
3. What is liquid phase epitaxy?
4. What are multicomponent heterostructures, and what techniques are known for their processing?
5. What are nano-materials? What types of nano-structures are known?

The interim assessment by semester and final assessment of the course are oral questioning and written exam, respectively.

## 7. Methodological and informational support:

Primary list of textbooks (bibliography):


1. *L.S. Palatnik, I.I. Papirov.* Epitaxial films. «Nauka» Pbl, Moacow, 1971, 480 p. (in Russian).
2. *N.I Leonyuk, E.V. Koporulina, E.A. Volkova, V.V.Maltsev*. Nucleation, growth and morphology of grystals. «MAKS Press» Pbl., Moscow, 2010, 143 p. (in Russian).
3. *N.I. Krasnova, T.G. Petrov.* Genesis of minerals and aggretates. «Nevsky Kurier» Pbl., St-Petersburg, 1997, 228 p. (in Russian).
4. *Modern Crystallography.* Vol. 3: *Formation of Crystals*, by A.A.Chernov, E.I.Givargizov, Kh.S. Bagdasarov, V.A.Kuznetsov, L.N.Demianets and A.N.Lobachev, «Nauka» Pbl., Moscow, 1980, 430 p. (in Russian).


Secondary list of books (bibliography):


1. *Handbook of Crystal Growth* (in 3 Volumes). Edited by D.T.J. Hurle. North- Holland Publ., Amsterdam- London - New York – Tokyo, 1993-1995.
2. *Journal of crystal growth*. "Elsevier" Pbl, Amsterdam.
3. *Physica E: Low-dimensional Systems and Nanostructures*. "Elsevier" Pbl, Amsterdam.


Software and Internet-resources:

1. http://database.iem.ac.ru/mincryst/
2. http://www.shapesoftware.com/

## 8. Necessary facilities and equipment:

Lectures, presentations of self-prepared abstracts and home-works will be equiped with a LCD projector. For students' self-study works, there are a scientific library of Geological Faculty, Moscow State University, a computer classroom with Internet access, software for visualization of crystal morphology and crystal structures, samples of natural and synthetic crystals from the collection of the Department of Crystallography and Crystal Chemistry.

## 9. Discipline content (annotation):

The proposed course is focused on the most important recent advances in crystallization of low-dimensional materials such as highly efficient "bulk" single

crystals, thin films, fibers, whiskers and other nanostructures , as well as on the role and location of mineralogical investigations in this connection. The discipline structure is based on a logical teaching modern approaches in this rapidly developing field of science. Considerable attention is paid to crystalline heterostructures and functional ceramic materials.

**10. Educational and methodological recommendations for self-study:**

***Abstract topics:***

1. Comparative characterization of growth techniques of "bulk" low-dimensional non-linear optical and laser single crystals.
2. Liquid phase epitaxy.
3. Growth methods of single crystal thin layers and multicomponent heterostructures.
4. Nano-minerals.
5. Fibers and Whiskers.
6. Glass-ceramic composites.

***Topics of Master final works*** will be suggested at the beginning of each school year as soon as new challenges research projects are available.

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**Experts**:

1. Professor E.M. Spiridonov, Department of Mineralogy, Geological Faculty, Lomonosov Moscow State University.
2. Dr. Grebenev, Senior Scientist, Shubnikov Institute of Crystallography, RAS.

The program has been approved by Academic Council of Geological Faculty, MSU.