Engineering Materials Science

Subject title

Engineering Materials Science (Teknisk materialvetenskap)

Subject description and programme outcomes

Scientific field

Materials Science treats relationship between behaviour properties, structure and production of different materials. The research includes a large number of types of material, e.g. steel and aluminium alloys, hard metals, ceramics, and magnets and materials for information storing, carbon nanotubes and other types of nanomaterials. The current department of Materials Science and Engineering, created in 1993, is focused on engineering materials. It consists of 12 sections which are divided into three main fields of study: material function, material design and process design.

At the department of Materials Science and Engineering, there have been five third-cycle subject areas since its start in 1993. However, these have during the last decade increasingly been joined to form one single third-cycle subject area. At a study in December 2009 there were 143 active doctoral students with updated study plans and that had an activity of more than 20%. Here, it should be said that there is a large number of industry-based doctoral students, who are connected to the department. The reason is above all strong connections to the industry that supports the third-cycle education in order to increase the skills.

Description of possible specialisation

The subject has no specialisations.

Specification of how the programme outcomes are to be achieved

The general aim for the doctoral programme adheres to KTH's framework for doctoral programmes that is specified in the regulatory framework. Students graduating from the doctoral programme should, besides having solid subject knowledge within their own research domain, also be able to:

- formulate and initiate research projects and formulate scientific issues
- carry out research by applying scientific research methodology and place the results in a wider context
- utilise research results in technical applications and critically evaluate their own and others' research, and interact efficiently in interdisciplinary research teams through an open approach to other disciplinary domains
- present and discuss research results and research in an pedagogical way, within and outside the science community and in education, and apply a research-ethical approach
- lead research projects

Current research

The research is focused on three main fields of study: Material function, Material design and Process design.
Material function

Material function deals with issues that are of crucial importance for the use of material. It includes e.g. design and durability issues, including impact on the environment. To successfully develop new types of materials, these have to be precisely adapted and optimised for the current application. Not the least, this applies to advanced materials, the advantages of which must be fully utilised if they should become competitive. The scientific methods that are used are ab-initio and atomic calculations such as thermodynamic modelling for analysis and development.

Design of Materials

In this subject area, the material properties regarding electron structures are analysed, binding energies, crystal structures, grain boundaries and secondary phase particles and cracks in pores that can sometimes be observed by the naked eye. Without a hierarchical point of view the knowledge of materials becomes incomplete. To be able to design a material with the right properties and behaviours, one must be able to predict the phenomena along many different length and time scales. The aim is to create understanding of microstructure development in materials, with the aim of being able to control it, such that better and better materials can be produced.

Process design

Within Process design, research and development in the area of thermodynamics for the analysis of materials is carried out, in the phase of gas, in liquid phase and in solid form. Thermodynamic modelling is important to find development and applications of tools to calculate reactions in fluid materials and between different gas/liquid and gas/gas reactions. New unique calculation tools that dynamically connect kinetics and thermodynamics are developed within the centre for thermodynamic calculations (CCT). Research is carried out to study kinetic and thermodynamic phenomena in melts in melted metals, slags and gases, from some grams to a couple of kgs.

Programme structure

The education for third-cycle studies are carried out under the guidance of one principal supervisor together with one or two assistant supervisors, in accordance with an individual study plan. The education consists of a course module and an thesis module and assumes an active participation in the seminars of the department. The doctoral students normally also have departmental duties, see below.

The third-cycle education is carried out under the guidance of one principal supervisor together with one or two assistant supervisors. The principal supervisor should be a professor, a visiting professor or an adjunct professor, that is employed at KTH. If an adjunct professor is the principal supervisor, he/she should also be docent at KTH. Other individuals that are docent and have a permanent post (tenure) at KTH can also be appointed the principal supervisor.

Assistant supervisors are appointed partly to meet requirements of supplementary specialist competence that can be required for the research specialisation, partly to obtain a supplementary discussion partner for the doctoral student. The assistant supervisor should have a doctoral degree. Assisting supervisors from the industry without a Degree of Doctor, but with good skills can be appointed.

The supervisor is appointed by the Director of Third-Cycle Education at the ITM school after approval by the doctoral programme coordinator of the department. Doctoral students have the right to change supervisor on request, during the third-cycle studies, a decision which is taken in consultation with doctoral programme coordinator.

Each doctoral student should have an individual study plan that has been approved by the Director of Third-Cycle Education (FA) of the ITM school. The individual study plan should be adapted to the student's prior knowledge and to the specialisation of the thesis.

The individual study plan constitutes an important document for the planning of the research- the plan can be regarded as a contract between the department and the doctoral student. Creation and update of the study plan are done jointly by the doctoral student, the principal supervisor and the assistant supervisors and it should be updated once a year. In connection to the review of the individual study plan, the doctoral student's progress should be assessed.
The individual study plan should be concrete. This does not exclude that the plan can be incomplete initially, e.g. less specified regarding the latter parts of the education. The study plan should however be detailed for the work of the following year.

The individual study plan is established in connection with the admission to the postgraduate studies and should be delivered to the educational office of the ITM school no later than 6 months after admission. The individual study plan should be updated at least two times a year, preferably more often. An established/updated study plan should be registered in LADOK.

Two times a year, the doctoral student should submit a status report to the doctoral programme coordinator, for checking against the study plan.

Within the framework for third-cycle studies, departmental duties of 20% is normally included (counted over the entire Ph.D. study period), usually by participating in the department's first and second cycle education. Apart from being an important teaching resource, the departmental duties mean that the doctoral student becomes a natural member of the work staff. By participating in the teaching at the department, the doctoral student's pedagogical skills will also be trained.

Parts that may be included in the departmental duties include e.g.:

- Teaching/supervision/grading in courses that are given by the department
- Participation in course development
- supervision of degree projects, work with web pages, information materials, handling of computer tools, etc.
- research assignments that are enriching for the doctoral student

The departmental duties are planned in collaboration with the principal supervisor and the department management and should be documented in the individual study plan. The duties should be planned, so that it becomes a natural part of the third-cycle education. If possible, the departmental duties should be planned so that there are less duties during the final stage of the thesis.

In the third-cycle studies, an active participation is required in the research seminars at the department, both the department-specific Higher seminar and the seminar series that are run by different sections and research groups. The doctoral student should present his research at at least two official programme seminars for a Degree of Licentiate (research plan/thesis proposal seminar and final review seminar) and at at least three seminars for a Degree of Doctor (research plan/thesis proposal seminar, intermediate/licentiate seminar and final review seminar).

Participation in conferences constitutes a central element in all third-cycle education.

**Compulsory and recommended courses**

The third-cycle studies consist of a course module and a thesis module:

- For Degree of Licentiate, 120 credits are required, of which the course module should comprise at least 30 credits.
- For Degree of Doctor, 240 credits are required, of which the course module should comprise at least 60 credits.

It is recommended that the majority of the courses are taken during the first years of the third-cycle studies. It can however also be relevant to acquire specialist knowledge later.

By agreement with the principal supervisor can in the individual study plan credits be given for completed first and second cycle courses equivalent to a maximum of 15 credits for a Degree of Licentiate and no more than 30 credits for a Degree of Doctor. Courses from first and second cycle may only given credit for if they deal with subject areas relevant for the third-cycle studies, and only if they do not constitute entry requirements.
Third-cycle courses that are given at other higher education institutions, by national doctoral schools and by international networks should be utilised. All courses should be discussed with the supervisors and approved by the principal supervisor and the programme co-ordinator for the doctoral programme.

At credit transfers, regulations in KTH's Degree Ordinance for third-cycle degrees should be observed.

**Compulsory courses**

A combination of the following methodology and theoretical courses are compulsory, in all 14 credits of which 8 credits should be included in Degree of Licentiate.

F4H5900 Research planning and supervision 6 credits

Theory of science with special focus on the epistemology of engineering work and industrial activities; ITM general course, 5 credits

Epistemology within engineering, science and innovation; ITM general course, 2 credits

Scientific communication; 6 credits

**Recommended courses**

There is a high grade of flexibility at determination of the courses that should be included in the education. The principle is that the supervisors together with the doctoral student agree on the advanced courses that are most relevant to the doctoral student. These courses are registered in the study plan that is updated regularly following changes decided by the supervisor and the doctoral student. Examples of courses that will be given with regular intervals are:

F4H5202 Deformation mechanisms in metals, 6 credits

FMH3818 Material models at plastic forming

FMH3911 Oxide metallurgy, 6 credits

F4H5617 High Temperature Materials, 6 credits

F4H5622 Material optimisation, 6 credits

FMH3819 Industrial ceramics, 6 credits

F4H5101 Phase transformations, 6 credits

F4H5103 Advanced course in phase transformations, 6 credits

F4H5104 Alloy theory I, 6 credits

F4H5108 Simulation of diffusional transformations, 6 credits

FMH3111 Phase transformations in performance materials, 12 credits

F4H5301 Computer Calculations of Equilibria and Phase Diagrams, 6 credits

F4H5801 Nanomechanics- Methods, Models and Materials, 6 credits

F4H5804 Artificial materials, 6 credits

FMH3910 Quantum metallurgy, 6 credits

FMH3912 Introduction to the EMTO programs package I, 6 credits
FMH3913 Solid State Physics, modelling, 6 credits
FMH3914 Electron structure and atomic scale alloy theory, 6 credits
F4H5806 Nanoscale Materials Innovation Drives Frontiers in Technology, 6 credits
FMH3915 Physical properties of non-perfect crystals, 6 credits
FMH3916 Nanomagnetism, 6 credits
FMH3817 Modelling on atom scale level, 6 credits
F4H5916 Micro modelling in process metallurgy, 6 credits
F4H5923 Fundamental Basis for Modelling of Mass and Heat Transfer, 6 credits
F4H5902 Kinetics, 6 credits
F4H5911 Heat recovery, 3 credits
F4H5912 Modelling of Industrial Combustion Processes- theory, 7.5 credits
F4H5913 Modelling of Industrial Combustion Processes- applications, 6 credits
F4H5914 Combustion Engineering, 6 credits
F4H5905 Importance of Inclusions in the Processing of Steel Products, 6 credits
F4H5906 Macro Modelling of Metallurgical Processes I, 6 credits
F4H5907 Reactions with and within Liquid Phases, 6 credits
FMH3901 Application of thermodynamic calculation programs for metallurgical processes, 6 credits
F4H5901 Experimental Techniques in Metallurgy, 6 credits
F4H5904 Theoretical process metallurgy, 12 credits
FMH3253 Fluid Mechanics and heat transfer, 6 credits F4MH5302 the process technology of the Moulding, 6 credits
F4M5307 Solidification Processing I, 6 credits
FMH3820 Reactions in solid phase, 6 credits

Research skills courses

The following courses that give academic skills or understanding of significance for the research are strongly recommended to the doctoral students:

F9E5100 Writing scientific papers, 3 credits
FMH3900 Basic supervision of e.g. Bachelor theses, 4 credits

Examples of other courses are teaching and learning in higher education that is recommended for doctoral students that teach:

LH201V Teaching and learning in higher education, 5 credits
As said above, relevant courses can very well be taken at other schools of KTH and at national and international universities. Courses in teaching and learning in higher education are a requirement in the case of teaching in first and second cycle courses during the third-cycle studies.

**Thesis**

**Thesis**

The thesis is a compulsory part of the third-cycle education that aims at the doctoral student developing an ability to independently contribute to the research and the science community. The thesis can either be written as a monograph or as a compilation thesis. In the latter case, the thesis should include a specifically written summary (so-called summarising chapter). Irrespective of form, the thesis is assessed as a whole.

The doctoral thesis can be based on the licentiate thesis

The thesis should normally be written in English or Swedish (for Swedish-speaking theses, special permission from the ITM school is required).

**Quality assurance before the public defence of the doctoral thesis**

The application for the public defence of the doctoral thesis is made by the principal supervisor to the doctoral programme coordinator, no later than 10 weeks before the date of the defence of the thesis. In connection to this, proposals for faculty opponent and examination committee is also discussed. After that, the doctoral student hands in his supplement and a preliminary thesis to the doctoral programme coordinator, for internal review.

**Licentiate thesis**

A licentiate thesis should contain an application of existing scientific knowledge within a new field that the student has developed via theoretical or empirical research. It should also contain an overview of previous research within the chosen subject area and position the doctoral student's contribution in relation to previous research.

Whether the licentiate thesis is presented as a monograph or as a compilation thesis of scientific articles, it should be of such quality that it is assessed to correspond to at least two articles published in internationally recognised scientific magazines with peer review.

After approval of the principal supervisor, the thesis is presented at a public seminar.

**Doctoral thesis**

A thesis for Degree of Doctor should contain new theoretical or experimental research results within the chosen subject area that the doctoral student has developed via theoretical or experimental research. It should also contain an overview of previous research within the chosen subject area and position the doctoral student's contribution in relation to previous research. Whether the doctoral thesis is presented as a monograph or as a compilation thesis, it should be of such quality that it is assessed to correspond to at least four articles published in internationally recognised scientific magazines with peer review.

A compilation thesis should, apart from a summarising chapter, include at least four publishable scientific articles.

The doctoral thesis should be submitted and defended at a public defence of doctoral thesis, according to KTH's general regulations. The thesis is assessed by an examining committee consisting of three or five members, appointed by the ITM school.

**Entry requirements and selection**

**General and special admission requirements and prior knowledge**

Qualified to the third-cycle courses and study programmes in Materials science are those that satisfy the following requirements:
General entry requirements for education for third-cycle studies consist of

- degree awarded for second-cycle studies, or completed course requirements of at least 240 credits, of which at least 60 credits should be for second-cycle studies, or in another way within or outside the country acquired equivalent knowledge.

Specific entry requirements apply according to Higher Education Ordinance, chapter 7, section 40. These requirements are set because the doctoral student should be able to absorb the education. The requirements may include:

- knowledge from higher education or the equivalent

- special professional or vocational experience, and

- necessary language skills or other conditions that are determined by the education.

For specific entry requirements at KTH, see Admission regulations for third-cycle studies at KTH. Doctoral students are expected to be able to read and write scientific English and be able to speak English fluently.

Selection rules and procedures

Admission to the third-cycle courses and study programmes in Materials science is decided by the Dean of the ITM school after check of eligibility and suitability by the Director of Third-Cycle Education of the ITM school and acceptance from the Director of doctoral studies at the department.

Suitability for third-cycle courses and study programmes is decided from a combination of grades, previous activities, interest and ability to independent assessment and critical analysis. A connection to the admission a funding plan should be presented for the doctoral student's entire study period (licentiate or doctor), approved by the head of department.

The programme’s degrees and examinations

Degree of Licentiate and Degree of Doctor (PhD)

For Degree of Licentiate, 120 credits are required, of which the course module should comprise at least 30 credits. The licentiate thesis should be submitted in accordance with KTH's general regulations. After approval by the principal supervisor, the thesis is presented at a public seminar. Since the principal supervisor is the examiner, he must/she be docent and employed on KTH.

For Degree of Doctor, 240 credits are required, of which the course module should comprise at least 60 credits. Courses and thesis that are included in Degree of Licentiate may also be included in Degree of Doctor. The doctoral thesis should be submitted and defended at a public defence of the doctoral thesis, according to KTH's general regulations. The thesis is assessed by an examining committee consisting of three or five members appointed by the ITM school.

The programme’s examinations

For courses for third-cycle studies a written examination, an oral examination or a project assignment should be included. The design of the examination should in each individual case be such that examiner ensures that the student has acquired all course content. The examiner in courses for third-cycle studies should be employed as teacher at KTH.