Materials Science Master Programmes at Technical University of Darmstadt

Innovative. Practical. Pioneering.







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1 Materials Science – what is it and how is it relevant?

Ever wondered what the technology of the world will be based on in the next 50 years? What kind of materials will be important for specific tasks? Which materials can be used, for instance, to build solar and fuel cells to secure our energy supply sustainably? These and similar questions are what materials scientists are concerned with.

Materials Science is a key discipline that provides a multitude of solutions for technical and socially relevant challenges, especially for future technologies in the fields of energy, climate, and environmental protection, mobility and health. The knowledge of Materials Science enables the production of technical materials with new or improved properties. This involves the whole life cycle - from the raw material to the application to recycling.

- Materials science focuses on the relationship between the atomic and molecular structure of a
 material, its properties (such as strength, electrical conductivity, or optical properties), and the
 ways in which the material is manufactured or processed into a shape or product.
- Another essential part of materials science is how products can be improved using the knowledge of structure and processing techniques and how structure and processing influence material properties.
- Materials science, engineering and technology include elements of applied physics and chemistry, along with aspects of electronics, manufacturing and production, combined with environmental, cost and quality considerations.
- The field is also an essential part of forensic engineering and failure analysis with applications from aerospace to health. With significant media attention in recent years on new areas such as nanotechnology, biomaterials, and electronic and optical systems, materials science has been propelled to the forefront of the public's consciousness. This leads materials technology, engineering and science to a new threshold of importance in the future of science and technology¹.

Materials Science students at the Technical University of Darmstadt (TU Darmstadt) are prepared for the challenging tasks involved in developing and investigating next-generation materials. The education covers a combination of engineering and natural science topics that opens up a broad spectrum of innovative fields of study and research.

Hear from our students:



Materials Science is a very diversified study, so it never gets boring. Above all, the core subjects always have a connection to current everyday life.



Rishabh Kundu, (2nd Master's semester)

Materials Science is where natural sciences and engineering come together to create breakthroughs that are urgently needed for sustainability-driven innovations. I can't think of anything more fascinating!



https://materialseducation.org/

2 The TU Darmstadt Institute of Materials Science



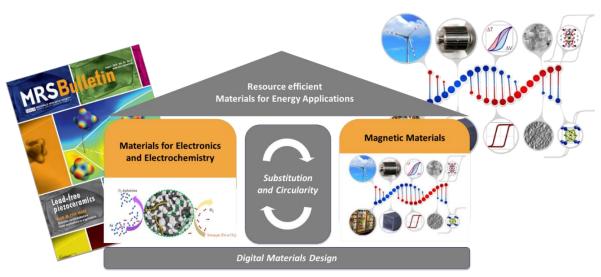
Our Mission

On a planet with limited resources and a growing world population,

- we look for solutions for technical and socially relevant challenges in the areas of resources, energy, mobility, information technology, and environmental protection.
- we understand sustainability not as a choice to make but as a necessity for maintaining our way of living and making it accessible to a growing number of people.
- we research pathways for the sustainable use of geo-resources and work on resource-efficient materials for a future with renewable energies.

We train experts who will help shape our future in these subject areas in coordinated bachelor's and international master's programmes, as well as in PhD projects.

Overview of Core Research Areas



We are focused on creating a sustainable tomorrow by eliminating the usage of critical elements in permanent magnets, piezoceramics, etcetera; reducing heating/cooling energy requirements by developing magnetocaloric cooling methods; conversion and storage of energy from renewable sources like the sun; utilising waste energy. Essentially, we have two pillars of research areas: *Materials for Electronics and Electrochemistry* and *Magnetic Materials* bound together by the principles of <u>substitution</u> and <u>circularity</u>. Strong expertise in Materials Modelling and Simulation forms the basis of our work. The focus of these research areas adversely influences our curriculum.

Our Divisions and Faculty Members

The fields of research of our faculty members can be categorised into five major sections:

- 1. Electronic Properties and Thin Films
- 2. Synthesis and Properties of Ceramics
- 3. Metals & Processing
- 4. Modelling
- 5. Characterisation

TU Darmstadt materials researchers work in fifteen in-house divisions and eight associated groups and pass on their first-hand expertise through their teaching activities:



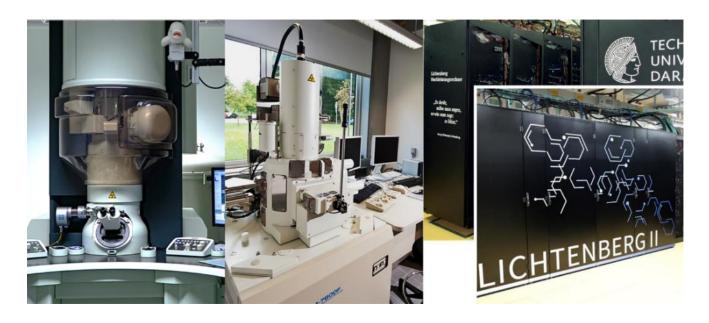
Detailed information on individual divisions can be found here:

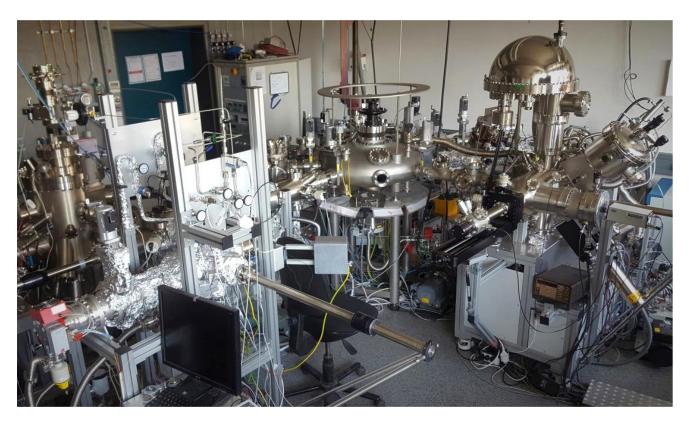


www.mawi.tu-darmstadt.de/divisions

In-house Equipments

Students who decide to join us in one of the Master's programmes will be exposed to our state-of-the-art equipment for synthesis, analysis, and simulation. This comprises our highly integrated ultra-high-vacuum synthesis & in-situ analysis systems (DArmstadt Integrated SYstems for SOLar Cell Research: <u>DAISY-SOL</u>, for MATerials Research: <u>DAISY-MAT</u>, for FUNdamental Research: <u>DAISY-FUN</u>), or the TU Darmstadt computing centre *Lichtenberg II* for modelling and simulation.





3 The M.Sc. Materials Science at TU Darmstadt

All courses within our Master's curriculum are taught in English. No German skills are required for admission. The M.Sc. Materials Science is a two-year full-time programme. Part-time studying is possible, too. Studying at TU Darmstadt is <u>tuition-free</u>.

Curriculum Key Data

- 1. **120 ECTS** required for graduation.
- 2. Two **Research Labs** in the first two semesters for hands-on experience.
- 3. Four compulsory subjects: **Functional Materials**, **Surfaces & Interfaces**, **Advanced Characterization Methods**, and **Theoretical Methods in Materials Science**, are to be taken in the first two semesters. They provide overall exposure to the field of Materials Science.
- 4. **Quantum Mechanics** OR **Micromechanics** has to be taken as an elective in the initial semesters.
- **5.** Electives worth 29 ECTS ought to be completed from within the departmental choices: this will determine your specialisation, and there are no obligations on their selection or order. You can **choose a professor at the beginning of your studies as your mentor** and plan out according to your interest (more details on possible electives are mentioned in the next section).
- 6. Electives worth 9 ECTS have to be completed from outside of Materials Science. You can choose from any department apart from Materials Science (e.g.: Project Management, Introductory German Course, etcetera).
- 7. Advanced Research Lab (15 ECTS) as a training for your M.Sc. thesis.
- 8. **Master Thesis** (30 ECTS) 6 months.

1st semester	2nd semester	3rd semester	4th semester
Research Lab I (4 CP)	Research Lab II (4 CP)	Advanced Research Lab with Seminar	
Functional Materials (6 CP)	Theoretical Methods in Materials Science (6 CP)	(15 CP)	
Surfaces and Interfaces (S CP)	Advanced Characterisation Methods of Materials Science (6 CP)		Master's Thesis
Elective Courses Quantum Mechanics/ Micromechanics (6 CP)			(30 CP)
(i.e. Fundamentals and Tech			
(i.e			

The semester of completion of certain lectures/labs is recommended and may not be strictly followed.

Specialisation: The Broad Set of Electives

Students have no bound to follow any specific specialisation – they have complete freedom in choosing their Materials Science specific elective courses worth at least 29 ECTS. The table below shows three exemplary specialisation options. Given the approximately 50 elective courses offered at our institute plus countless more in other TU Darmstadt institutes, many more specialisations are possible. We also offer a faculty mentor, and students can choose their mentor and discuss their specialisation.

Examples for Specialization	Examples of relevant Elective Modules
Materials for Energy Applications	Electrochemistry in Energy Applications (I & II) Fundamentals and Technology of Solar Cells Materials Chemistry in Electrocatalysis for Energy Applications Porous Ceramics for Energy Applications
Ceramics	Ceramic Materials: Synthesis and Properties (I & II) Mechanical Properties of Ceramics Porous Ceramics for Energy Applications Dislocations in Ceramics
Materials Characterisation	Advanced Microscopy Analysis of Powder Diffraction Data Characterisation Methods in Materials Science: Neutrons & Synchrotrons Focused Ion Beam Microscopy Transmission Electron Microscopy Scanning Probe Microscopy in Materials Science

Eligibility

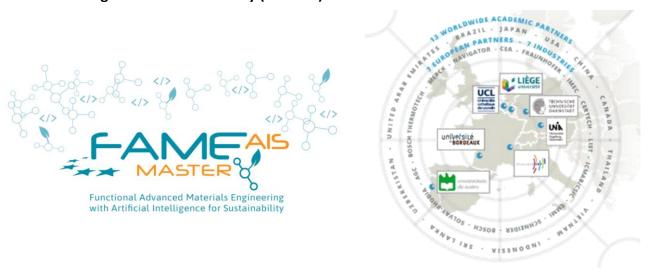
For admission to the M.Sc. Materials Science, a background in Material Science equivalent to the B.Sc. programme at TU Darmstadt is expected. The required skills (and extent; 1 CP equals 1 credit point in the European Credit Transfer System (ECTS)) are as follows:

- Mathematics (24 CP)
 - o Linear Algebra, Fundamental Analysis, and Engineering Mathematics (ODE, PDE).
- Natural Sciences (30 40 CP)
 - o General Chemistry, Experimental Physics, and Physical Chemistry (Thermodynamics, Quantum Chemistry of atoms and simple molecules, spectroscopy).
- **Engineering** (optional 10 15 CP)
 - o Continuum Mechanics and elementary Electrical Engineering.
- Fundamental Materials Science (25 35 CP)
 - o Fundamental knowledge of all classes of materials.
 - o Solid structure, thermodynamics, properties, and defects
 - Solid-state analytics (e.g.: scattering, spectroscopy, EM, electronic testing)
- Advanced Materials Science (45 60 CP)
 - o Defects
 - o Physical Metallurgy
 - o Solid-state Physics
 - o Introductory Numerical Methods in Materials Modelling
 - Advanced Solid-state Analytics
- **Bachelor Thesis** on a Materials Science related topic (15 CP)

4 Our International Double Degree Master Programmes

We offer possibilities to study our M.Sc. programme as part of International Double Degree programmes. Graduates not only receive a Master's Diploma from TU Darmstadt but also from a partner institution at which they spend the other half of their studies.

Functionalized Advanced Materials and Engineering with Artificial Intelligence for Sustainability (FAME^{AIS})



FAME^{AIS} is an Erasmus Mundus Joint Master Degree Programme in Functional Advanced Materials and Engineering with Artificial Intelligence for Sustainability, organised by high-level European Universities in the frame of Erasmus+. The fast evolution of Nanomaterials and Functional Materials Sciences requires a strong consortium with recognised educational experience, close links between education and research and awareness of industrial transitions while sharing the latest developments in Materials Science. Participating students will benefit from the best practices used at the partner institutions and from their involvement in the management of scientific research-oriented projects.

- A two-year education programme (120 ECTS) taught in English in Advanced Materials Science
 within 7 European universities (Belgium, France, Germany, and Portugal), providing high-level
 academic and research-oriented education about the synthesis, characterisation and processing
 of all classes of materials, with particular emphasis on Nanomaterials, Hybrids and Ceramics
- The seven partner institutions host world-renowned **leading research laboratories** in the field of Advanced Materials Science
- **Associated partners** from research and industry play an active role in the definition of the students' Master's Thesis and through seminars or career advice
- Offering **mobility** during the two-year master's programme in order to take advantage of the complementary skills of the universities in the network
- **EMMI** (European Multifunctional Materials Institute) is a unique structure in Europe, integrating education, collaborative research, and sound contacts with industry, offering services such as jobs, training schools or e-learning websites and databases

Tuition fees for the FAME^{AIS} programme are as follows:

Non-EU/EEA Citizens	EU/EEA Citizens	EU/EEA Citizens from consortium universities
9000 €/academic year	4000 €/academic year	Local rules apply [1000 €/academic year for Darmstadt students]

High-achieving students may qualify for the Erasmus Mundus scholarship, which amounts to up to $49000 \in$ for two years for non-EU students or up to $34000 \in$ for EU students. EU students may also apply for an Erasmus grant that amounts to $150 - 300 \in$ /month (depending on the country of origin) plus partial payment of the programme fees.

FAME+ Master students spend their first year at Grenoble INP or TU Darmstadt and may choose a partner university from another country for their second year. The study plan for a first or second year at TU Darmstadt (Specialization - Functional Ceramics: Processing, Characterization and Properties) is as follows:

Option 1: First Year at TU Darmstadt

1 st Semester (at TU Darmstadt)	2nd Semester (at TU Darmstadt)	3rd Semester (abroad)	4th Semester (abroad)			
FAME/e-project I (5 ECTS)	FAME/e-project II (5 ECTS)	(5 ECTS) 60 ECTS from one of the partner universit			60 ECTS from one of the partner universities, including the Master's Thesis (4 th semester).	•
Functional Materials (6 ECTS)	Advanced Characterization		cialisations:			
Surfaces and Interfaces (5 ECTS)	Theoretical Methods in Materials Science (6 ECTS)	Surfaces, Composites atUniversidade de AveirHybrids	nd Coatings			
Micromechanics or Quantum Mechanics for Materials Science (6 ECTS)	Machine Learning in Materials Science (6 ECTS)	 Université de Liège: Nanostructured Interfaces and Quantum Materials Université catholique de Louvain: Engineering of Materials and Nano-Structu 				
Research Lab I (4 ECTS)	Advanced Research Lab -	Université de Bordeau Materials and Ceramics	x : Advanced Hybrid			
Computational Materials Science or an equivalent elective (4 ECTS)	ience or an equivalent		s for Micro and Nano			

Option 2: Second Year at TU Darmstadt

1 st Semester (at Grenoble INP or Aalto)	2 nd Semester (at Grenoble INP or Aalto)	3rd Semester (at TU Darmstadt)	4th Semester (at TU Darmstadt)
General Curriculum in Materials Science: 60 ECTS from one of the partner universities (see above).		Research Lab I (4 ECTS)	
		Micromechanics or Quantum Mechanics for Materials Science (6 ECTS)	Master's Thesis (30 ECTS)
		Electives (20 ECTS)	

For either of the afore cases, the module "Discussion with Mentor" is also compulsory at TU Darmstadt.

More information on the FAME Master's programme can be found here:



www.mawi.tu-darmstadt.de/fameDD



Advanced Materials for Innovation and Sustainability (AMIS)



Advanced Materials for Innovation and Sustainability (AMIS) is a launch pad for understanding the entire raw materials value chain and developing a mindset for innovation and entrepreneurship. AMIS students get prepared to influence positive change for the environment and help secure a sustainable future. The following themes are tackled:

- Substitution of critical or toxic materials in products and for optimised performance
- Material chain optimisation for end-of-life products
- Product and services design for a circular economy

By studying for an EIT-labelled Master's, you are joining an **international community** established to unite forward thinkers and entrepreneurs to share ideas and innovate.

The AMIS programme has received the **EIT Label**, a quality seal awarded to top Master and PhD programmes that excel in shaping a new generation of students into game changers and innovators. **EIT Raw Materials**, initiated and funded by the EIT (European Institute of Innovation and Technology), a body of the European Union, is the largest consortium in the raw materials sector worldwide. Its vision is to develop raw materials into a major strength for Europe. Its mission is to enable sustainable competitiveness in the European minerals, metals, and materials sector along the value chain by driving innovation, education and entrepreneurship.

Programme fees to join AMIS are the following:

Non-EU/EEA Citizens	EU/EEA Citizens	EU/EEA Citizens from consortium universities
8000 €/academic year	1000 €/academic year	Local rules apply [no extra fees for TU Darmstadt students]

So-called "Added value student activities grants" can be awarded to AMIS students. These amount to 13500 € covering travel, subsistence and living.

AMIS students are free to choose their first- and second-year affiliation. The study plan for a first or second year at TU Darmstadt is as follows:

1 st Semester (at TU Darmstadt)	2 nd Semester (at TU Darmstadt)	3 rd Semester (abroad)	4 th Semester (abroad)	
Research Lab I (4 ECTS)	Advanced Research Lab (7 ECTS)	60 ECTS from one of the partner universiti including the Master's Thesis (4th semester Partner universities and specialisations:		
Functional Materials (6 ECTS) Advanced Characterization Methods (6 ECTS)		Aalto University: Nanomaterials and Interfaces: Advanced Characterization and Modelling		
Surfaces and Interfaces (5 ECTS)	Theoretical Methods in Materials Science (6 ECTS)	Modelling • Université de Liège Modelling	: Nanomaterials and	

Micromechanics or Quantum Mechanics for Materials Science (6 ECTS) Inno Project Ia (3 ECTS)	Electives (5 ECTS) Inno Project Ib (3 ECTS)	•	Université de Bordeaux: Advanced Hybrid Materials: Composites and Ceramics by Design Grenoble INP: Materials Interfaces: Surfaces, Films & Coatings
	_		Surfaces, Timis & County
Venture Valuation (6 ECTS)	Career Coaching, Summer Camp (3 ECTS)		

Option 1: First Year at TU Darmstadt

Option 2: Second Year at TU Darmstadt

1 st Semester (abroad)	2 nd Semester (abroad)	3rd Semester (at TU Darmstadt)	4th Semester (at TU Darmstadt)
		Research Lab I (4 ECTS)	
		Alto Winter School (0 ECTS)	
60 ECTS from a partner university's curricula (see above).		Micromechanics or Quantum Mechanics for Materials Science (6 ECTS)	Master's Thesis (30 ECTS)
		Electives (14 ECTS)	
		Venture Valuation (6 ECTS)	

For either of the afore cases, the module "Discussion with Mentor" is also compulsory at TU Darmstadt.

More information on the AMIS Master's programme can be found here:



www.mawi.tu-darmstadt.de/amisDD



Advanced Materials: Innovative Recycling (AMIR) – EMJM or EIT Label Scholarships















The Master in Advanced Materials: Innovative Recycling (AMIR) is a world-leading programme that explores the raw material value chain, particularly focusing on recycling. The programme aims to educate students to become highly-skilled professionals with expertise in various raw materials fields and to instil a deep entrepreneurial mindset from a wealth of businesses, incubators, innovation services and industry contributors that make up the programme.

- The AMIR Master programme offers students the possibility of obtaining a double diploma, a nationally accredited diploma from each of the **two partner universities** where they study.
- Educating students to become highly-skilled European professionals with expertise in various
 materials. This expertise will enable them to develop, at a large and ambitious scale, new
 methods for material recycling. In addition, the AMIR programme includes classes on
 transferable skills such as innovation, ethics, intellectual property, life cycle assessment,
 sustainability and advanced research strategies.
- Developing a deep **entrepreneurship mindset** with the help and expertise of associated businesses, incubators and innovation services as well as a large panel of industries.

Tuition fees for the AMIR programme (EIT label) are as follows:

Non-EU/EEA Citizens	EU/EEA Citizens
4000 €/academic year	2000 €/academic year

All AMIR (non-Erasmus Mundus/EM) students receive the EIT label grant, which amounts to 13500 €, paid during the second and third semesters.

Tuition fees for the **AMIR-EM** programme are as follows:

Non-EU/EEA Citizens	EU/EEA Citizens
9000 €/academic year	4500 €/academic year

The AMIR-EM Master has obtained the EMJM label and funding, meaning scholarships can be offered for four intakes of students, beginning with the 2022-2024 intake. These scholarships are provided to a limited number of candidates with the highest scores following the written and oral evaluation in the selection process. They can be considered full scholarships, with the amount being 1400 € per month for the 2-year duration of the programme. This amount is intended to cover all costs incurred by students' participation in the Master programme (accommodation, travel costs, subsistence costs, materials, etcetera). *In addition, EMJM scholarship holders do not pay the AMIR-EM fees* (detailed above) and are provided with comprehensive insurance for the 2-year duration of the programme.

Depending on the individual specialisation, AMIR Master students spend their first year at University of Bordeaux, NOVA University Lisbon, or the University of Miskolc and their second year at TU Darmstadt, University of Liège, or Technical University of Madrid. Typically, students coming to Darmstadt spend their first year in Bordeaux. The study plan for this scenario is as follows:

1st Semester (at U Bordeaux)	2nd Semester (at U Bordeaux)	3rd Semester (at TU Darmstadt)	4th Semester (TU Darmstadt)
Elaboration of Materials (6 ECTS)	Creativity, Innovation, Leadership and Entrepreneurship (12 ECTS)	Advanced Research Lab (12 ECTS)	
Bonds in Materials (6 ECTS)	Solid State Physics (6 ECTS)	Surfaces and Interfaces (5 ECTS)	
Chemical/Structural Analyses of solids (6 ECTS)	Internship: Research Skills (8 ECTS)	Functional Materials (6 ECTS)	Master's Thesis –together with a company or a Research and Technology Organisation (30 ECTS)
Sustainability, criticality & LCA of materials (6 ECTS)	French (3 ECTS)	Life Cycle Assessment of Products and Systems (3 ECTS)	
Materials Dismantling & Recycling (6 ECTS)	Project: From devices to fundamental aspects (3 ECTS)	Electives (4 ECTS)	
	Industrial Seminars (3ECTS)		

The module "Discussion with Mentor" is also compulsory at TU Darmstadt.

More information on the AMIR Master's programme can be found here:



www.mawi.tu-darmstadt.de/amirDD



Double Master Tongji – TU Darmstadt





The Tongji – TU Darmstadt Double Master in Materials Science and Engineering is research-based and builds on the competencies and skills acquired throughout a Bachelor's degree course in Materials Science and Engineering (Tongji University) or Materials Science (TU Darmstadt). Qualified BSc. graduates possess demonstrable study skills, a basic grasp of both mathematics and sciences as well as a sound knowledge of the fundamentals of materials science, as taught during the BSc. degree courses at both institutions.

This M.Sc. programme aims to enrich skills in Materials Science and qualify students to pursue a scientific career in all relevant fields. The study objectives are:

• Develop the ability to study the subject in a broader context and establish an association between newly acquired and prior knowledge.

- Encourage students to adopt a creative approach to developing materials, products, processes, or methods in an entirely new design or context.
- Train students to independently solve practical problems by applying research-based or scientific methods.
- Foster the ability and sovereignty to scrutinise assertions related to Materials Science and to confidently argue one's standpoint in front of professional peers and non-professionals.
- Foster the aptitude to present a written or oral account of scientific results accurately and coherently.
- Develop the skill to solve complex problems considering criteria relevant to Materials Science, Materials Engineering and Ecology. This also includes economic issues specific to materials, e.g.: manufacturing costs subject to the availability of raw materials and technology.
- Foster the ability to work with other disciplines, i.e., to tackle problems posed by other fields while recognising which scientific approach to adopt to solve the problem. This particularly applies to the inextricably interwoven nature of Materials Science and Materials Engineering.
- Pinpoint the social challenges and consequences of a materials scientist's work while encouraging students to adopt a responsible attitude.
- Develop the capacity to set realistic yet demanding goals attainable within a reasonable time frame and involve reflection upon both the results and the respective approach.
- Develop intercultural competencies alongside the improved proficiency in the foreign language acquired abroad.

The study programme generally follows the structures of the Materials Science and Engineering and the Materials Science programmes of both universities. The course of studies is shown in the following table:

1 st Semester (at TU Darmstadt)	2 nd Semester (at Tongji U)	3 rd Semester (at Tongji U)	4 th Semester (Darmstadt or Tongji)
Research Lab I (4 ECTS)	Interdisciplinary Course (4 ECTS)	Advanced Research Lab (15 ECTS)	Master Thesis [supervised by one Darmstadt and one Tongji Prof.] (33 ECTS)
Functional Materials (6 ECTS)	Materials Seminar (5 ECTS)		
Surfaces and Interfaces (5 ECTS)	Overview of China (4 ECTS)	Full-time specialised field practice	
	Code of Academic Integrity (1 ECTS)		
Micromechanics (6 ECTS)	General Chinese (5 ECTS)		
Elective Course Materials Science (13 ECTS)	Elective Courses (12 ECTS) [Materials Chemistry / Introduction to Optical Materials / Metallic Glass & Nanocrystalline materials / Functional Polymeric Materials / Energy Materials / Sensors and Transducers / Cement Chemistry / Concrete Science]	Thesis proposal (4 ECTS)	
Elective Courses outside of Materials Science (4 ECTS)		Mid-Term Exam	

More information on the Tongji – TU Darmstadt Double Master's programme can be found here:



www.mawi.tu-darmstadt.de/TongjiDD

5 More about us

Contact us at the Institute

Prospective students are welcome to send questions or queries to:

master@mawi.tu-darmstadt.de

FAQ

Answers to the most frequently asked questions are collected here:



www.mawi.tu-darmstadt.de/FAQ-MSc

Online Self-Assessment

We completely understand if you are unsure if our Master's programme is right for you. Spare a few minutes and gauge yourself with our Online Self-Assessment (free and anonymously):



www.mawi.tu-darmstadt.de/OSA-MSc

Info Video

A video from students for (future) students, picturing everything you want to know about our MSc. programmes:



Information from the Central Student Advisory Service of TU Darmstadt

Some hard facts about our M.Sc. programme from the TU Darmstadt Central Student Advisory Service:



www.mawi.tu-darmstadt.de/CSAS-MatSci

We look forward to welcoming you as one of our sTUdents!

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