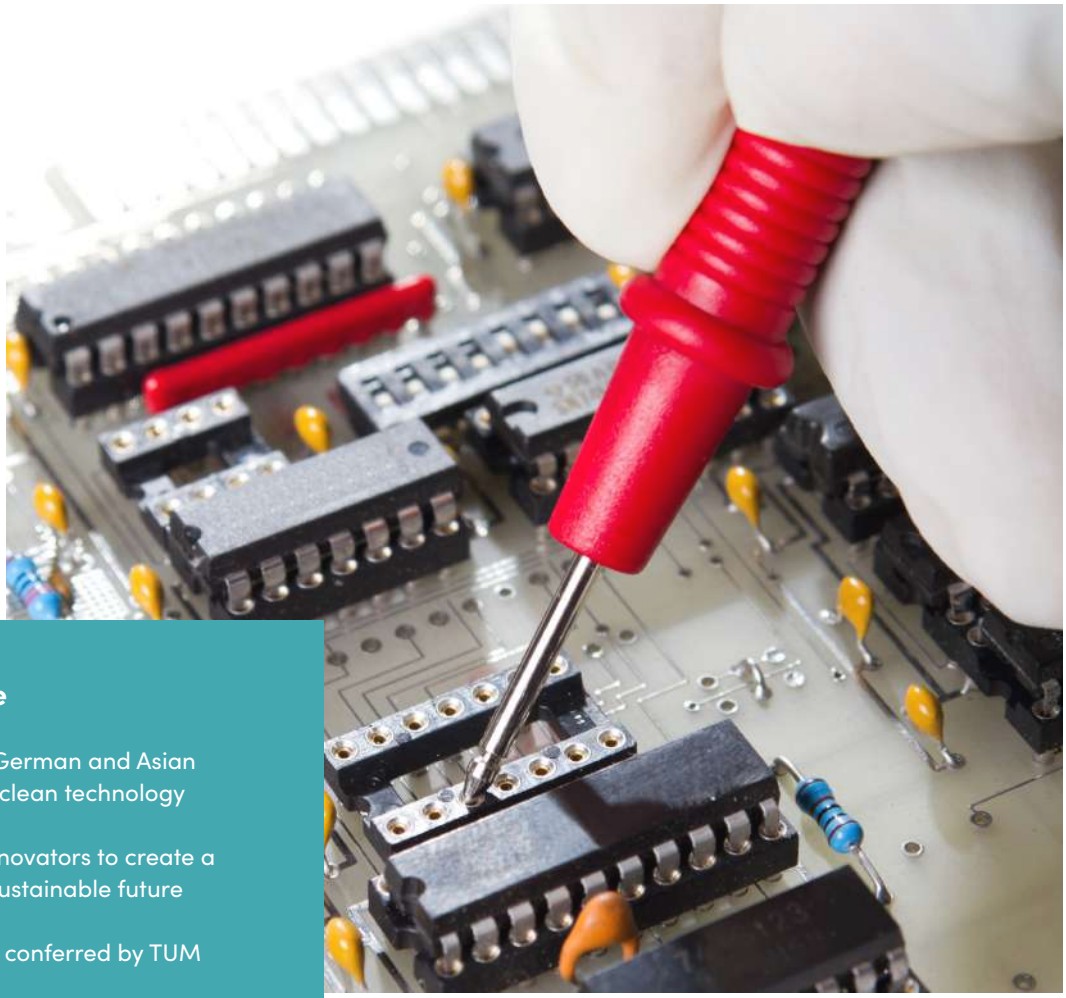
Technical University of Munich (TUM) Asia

TUM Asia

MASTER OF SCIENCE

Green Electronics



At a Glance

- The best of German and Asian expertise in clean technology
- Nurturing innovators to create a green and sustainable future
- Joint degree conferred by TUM and NTU
- Vast career prospects regionally and worldwide
- Apply online at **www.tum-asia.edu.sg**

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

Technical University of Munich

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About
TUM & NTU

Technical University of Munich (TUM)

The Technical University of Munich (TUM) was founded in 1868 and is one of Europe's leading technical universities. Serving as an entrepreneurial university that promotes talents and creates value for society, TUM has produced 18 Nobel Prize winners since 1927, most notably Ernst Otto Fischer (Chemistry) and Rudolf Mößbauer (Physics). Its focus areas are engineering sciences, natural sciences, life sciences, medicine, management and political and social sciences.

TUM promotes talents with its network of strong partners in research and industry. It is represented worldwide with the TUM Asia campus in Singapore, as well as offices in Beijing, Brussels, Cairo, Mumbai, San Francisco and São Paulo.

In international rankings, TUM regularly places among the best universities in Germany and worldwide. It is the only university to have won recognition as a German 'Excellence University' in every round since 2006.

Technical University of Munich (TUM) Asia

The Technical University of Munich (TUM) Asia was set up in 2002 as the first academic venture abroad by a German university, blending German academic excellence with industry relevance in Asia. Its partnerships with top Asian universities and industry leaders combine German engineering with Asian relevance to equip talents for industry and research sectors in the world.

With the changing needs of the economy, the specialised master's programmes that are offered keep pace with industry needs through an Asian-European perspective. Lecturers and professors hail from as far as Germany to equip students with their rich knowledge and experience.

More than two thousand students have come through the doors of TUM Asia and now ply their trades in top research institutes and companies across the globe.

Nanyang Technological University (NTU)

Inaugurated in 1991, Nanyang Technological University (NTU) has grown to become a full-fledged research university and has been ranked the world's best young university (under 50 years old) by Quacquarelli Symonds for the sixth consecutive year in 2019.

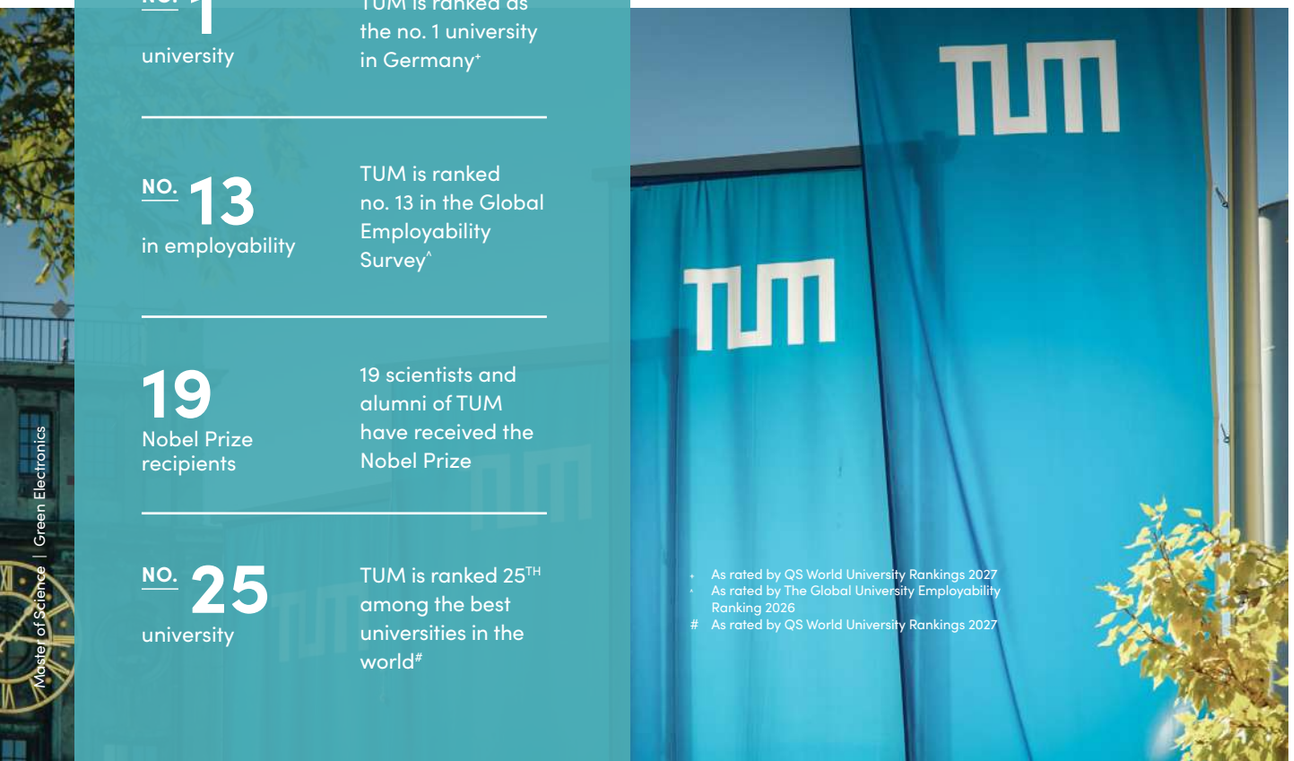
NTU's academic and research programmes, which bear strong real-world relevance, have garnered strong support from major corporations and industry leaders. As the main Science and Technology university in Singapore, NTU has made substantial contributions to Singapore's drive for research and innovation.

NO. 1 university
TUM is ranked as the no. 1 university in Germany*

NO. 13 in employability
TUM is ranked no. 13 in the Global Employability Survey^

19 Nobel Prize recipients
19 scientists and alumni of TUM have received the Nobel Prize

NO. 25 university
TUM is ranked 25TH among the best universities in the world#



* As rated by QS World University Rankings 2027
^ As rated by The Global University Employability Ranking 2026
\# As rated by QS World University Rankings 2027

Programme
Overview

Jointly awarded by TUM and NTU, the **Master of Science in Green Electronics (MSc in GE)** equips students with comprehensive and in-depth knowledge of micro-/nano-fabrication technology, renewable energy, power semiconductors, as well as organic semiconductor devices and systems.

Programme Structure and Timeline

14 modules
- 6 Core Technical Electives
- 2 Laboratory Modules
- 4 Specialisation Technical Electives
- 2 Non-Technical Elective Modules

45 contact hours
for selected Core and Specialisation Elective Modules

2 Years
- Full-time programme
- Coursework in Singapore
- Internationally-recognised degree

July	Year 1	Year 2	Graduation
Arrival in Singapore	• Laboratory Modules • Core Technical Elective Modules • Specialisation Technical Elective Modules • Non-Technical Elective Modules	• Non-Technical Elective Modules • Internship • Master Thesis at a company, university or research institute (Supervised by an NTU or TUM professor)	End of programme

Note: This outline is a general reference to the duration of study. A student's actual duration of study may or may not follow this general reference. This outline is subject to change during the course timetable.

Programme Modules

Laboratory Core Modules

Laboratory 1: Semiconductor Process and Device Simulation

Process models: diffusion, oxidation, implantation. Process variables/targets: doping profiles, junction depths, oxide thicknesses. Process simulation: Simulate a given sub-micron CMOS process recipe and study profiles and layer structures. Physical models. Numerical algorithms and solutions. Device performance parameters. Short-channel effects. DC simulations. Device simulation: Simulate the DC characteristics of the "fabricated" device and analyse device operation with respect to potential, field, and carrier distributions as well as terminal I–V characteristics. Wafer-split experiment. Device-target vs. process-variable relations. Transistor performance optimisation/trade-offs through process variation. Technology development and optimisation. Design of Experiment (DOE): Implement a computer experiment to study the scaling characteristics (varying gate length) of the given sub-micron technology. Study the influence of process variations on device performance parameters.

Laboratory 2: Design and Modeling of Nanodevices

Part I includes MOSFET analytical equations, short-channel effects, compact models for circuit simulation, parameter extraction, and transistor optimisation. Part II includes semiconductor fundamentals, simulation of Si, Ge, and Sn band structures, Quantum well (QW), Energy subbands and wave functions, k.p method. It also covers QW band structure calculation by using single band and 6-band kp method, density of state, doping concentration, and Fermi energy level calculations by using single band and 6-band kp method. Intersubband (intraband) transition, squared transition element calculation, absorption spectrum, and cut-off wavelength of QW infrared photodetectors are also discussed. The influence of Ge composition and well width on peak wavelength of photodetectors and optical gain simulation of Ge QW on Si are also covered.

Core Technical Elective Modules (Choose 6)

Bioelectronics

Introduction to bionanotechnology; Materials: electrolytes, organic molecules, lipid bilayers, DNA, proteins; Nanofabrication techniques and self-assembly; Biofunctionalisation of solid surfaces; Surface analytics and characterisation; Electrical biosensors: solid-liquid interface, surface plasmon resonance, quartz microbalance, electrochemical impedance, nanopores, nanowires; Charge transfer in biomolecules: fundamentals and applications.

Introduction to Power Systems

Structure of the power system: generation, transportation and distribution and electricity consumption; Introduction to typical power plant types including new renewable technologies. Description of the transport, distribution and control philosophy; Introduction to the electricity demand, especially due to new electronic services; Fundamental terms of energy economy and electricity markets and Introduction into smart grids.

Materials for Electronic Devices

Bonding between atoms. Electronic and atomic structures. Basic crystal structures. Energy band. Semiconductors, insulators and organic materials. Defects and doping. Surface and interface. Functional properties of materials. Compound semiconductors. Nanostructures. Electronic ceramics.

Microfabrication Technology

Photolithography technology. Photoresist technology. Advanced lithography. Metrology defect inspection and analytical technique. Cleaning technology. Wet etching process and technology. Dry etching process and technology. Chemical mechanical polishing. Epitaxy. Plasma enhanced chemical vapour deposition. Atomic layer deposition. Physical vapour deposition.

Microstructured Devices and Systems for Green Electronics

The course will focus on the operational principles and underlying physical effects of microstructured electronic and mechatronic devices and microsystems and their application fields. Other topics include: Basic physical effects in solid-state microstructured electronic and micromechatronical devices and their application fields; Characteristic material properties of semiconductors: Intrinsic and extrinsic electrical conductivity, mobility, charge carrier transport by drift and diffusion, carrier generation-recombination, thermal conductivity, energy domain coupling effects; Basic operational principles of microdevices: pn-junction, MOS field effect, unipolar and bipolar electronic devices, power devices, various transducer effects; Phenomenological transport theory: Onsager´s transport model, continuous field models of energy-coupled multi-domain systems, physics-based macro-modeling of microsystems and selected sensor and actuator application examples.

Nanotechnology for Energy Systems

Approaches to nanotechnology: bottom-up vs. top-down; Characterisation and fabrication issues in the nanoscale; Applications of nanotechnology in electronics, optoelectronics, telecommunications, medicine, biology, mechanics and robotics; Overview of nanotechnology programs in USA, Japan and Europe; Nanomaterials and nano-systems for energy applications; Examples of nanotechnology energy production, energy storage, energy harvesting, and high voltage technologies; A look into the future: electro and photocatalysis, hydrogen production and storage. Economic implications of nanotechnology in the energy field.

Optomechatronic Measurement Systems

This course will focus on optical principles and their application in green electronics production processes, photovoltaic devices, thin film measurement, display technology, distributed sensor networks and energy harvesting. Other topics include: fundamentals of optomechatronic measurement systems, light sources and detectors, refraction, interference and diffraction, electronic speckle pattern interferometry; thin film reflectometry as an in-situ deposition sensing technique; ellipsometry for thin layer analysis; optical waveguide sensors and their application in renewable energy devices such as wind turbines; Fourier transform infrared spectroscopy for detection of greenhouse gases.

Specialisation Technical Elective Modules* (Choose 4)

Advanced MOSFET & Novel Devices

Historical development of mainstream MOSFETs until today; economical, technological and physical fundamentals; properties of long channel and short channel MOSFETs, hot carrier effects; short channel effects, scaling rules; basics of charge carrier transport (quantum mechanical, hydrodynamics, ballistics); proposed new MOSFET structures (strain engineering, metal-gate, high-k, vertical MOSFETs, double gate MOSFETs); hot electron transistors; tunneling transistors; low dimensional devices; single electron transistors, single electron memories, quantum electronics.

Green Nanotechnology

Energy flow in environment; Optical properties of nanomaterials; Spectral selective windows; Solar thermal collectors; Solar cells; Cooling and energy harvesting; Electrochemical energy storage.

Modern Semiconductor Devices

Bipolar transistor operation principles. Bipolar device modeling. State-of-the-art bipolar structures. CMOS device scaling effects. Semiconductor memories. Future trends and challenges.

Nanophotovoltaics

Third generation photovoltaics;
Quantum dot tandem cells; Hot carrier cells; Multiple electron hole pair generation; Impurity and intermediate band devices.

Polymer Electronics

Fundamentals of electronic and optoelectronic devices and technologies based on polymer semiconductors; An overview of Polymer Electronics; Electronic structure and band theory; Beyond polyacetylene; Optoelectronic properties; Charge tranport; Synthesis and macromolecular design; The physics of polymers; Surfaces and interfaces; Polymer transistors; Optoelectronic devices; Photovoltaic devices (organic and dye sensitised solar cells) and Polymeric memories.

Semiconductor Power Devices

Fundamentals of semiconductor device physics: electronic band structure, intrinsic and extrinsic conductivity, mobility, carrier transport by drift and diffusion, carrier generation and recombination, impact ionisation, pn-junction, MOS field effect; Power device structures: PIN diode, Schottky diode, bipolar junction transistor, thyristor, power MOSFET, insulated gate bipolar transistor (IGBT); Robustness and destruction mechanisms of power devices: thermal breakdown, electrical breakdown, dynamic avalanche, latch-up in IGBTs and cosmic ray induced failure.

Non-Technical Elective Modules (Choose 2)

Business Administration

The primary purpose of the module is to introduce students to the different areas of business administration with the final objective to give them a basic understanding of how to face decision problems in a company. Most importantly, we will analyse long-term investment decisions, how to set up strategic planning in a company, how to gather timely information about the current situation of a company, and how to set up its long-term financial structure.

Industrial Marketing

Marketing strategies are developed for a typical commodity and speciality business. Students will work in teams to develop business cases, make their own business decisions and develop marketing concepts based on provided information of a real case study.

Innovation and Technology Management

This module presents the dynamics of technological development through innovation and the related management issues, the difference between creating a new product (invention) and improving an existing product/idea (innovation), Start-ups and financing of innovation, innovation-driven economic cycles and innovation impact on growth and jobs.

Intellectual Property and Technopreneurship

This module covers different types of Intellectual Property (IP) and methods of protection. Students will acquire up-to-date knowledge about patents as a connecting link between science, research, and technical developments on the one hand, and Technopreneurship opportunities on the other hand. At first, fundamentals of international patent systems and patent data bases will be presented. Then, the elements of a patent application and the patent grant procedure are detailed. Finally, use cases such as IP-based company startups and the interaction between intellectual property and market needs are discussed.

Modern Developments in Industry

The module will provide insights in the core elements of Industry 4.0 such as: introduction to Cyber-Physical System, Radio Frequency Identification (RFID) technologies, information collection with intelligent sensors, industrial networking to connect the machines and processes together, Manufacturing Execution System (MES) for order management, production control and value adding to the complete supply chain management.

Production Planning In Industry

Manufacturers are confronted with special requirements of their production processes. Cycles, by-products, batches and campaigns are difficult to handle by Enterprise Resource Planning (ERP) software packages nowadays. Concepts of material requirements planning, supply chain management (SCM) combined with basics in cost accounting will be explained.

Paradigm Shift to Industry 4.0

Introduction to Industry 4.0; Core elements of Industry 4.0; Fundamental workshop on AR/VR and digital twin; Fundamental workshop on additive manufacturing; Fundamental workshop on collaborative robot; Site visit and workshop on indoor vertical farming with disruptive technologies; Case study on Aquaculture 4.0; Site visit to Competence Centre for Digitalisation, Technology and Innovation (CDTI) and Advance Manufacturing Transformation Centre (AMTC).

Cyber Physical Systems

Introduction to Cyber Physical System; Elements of Cyber Physical System and its importance for a smart production system; Communication networks and the physical systems within a single entity; Overview of technologies enabling connectivity, open communication protocols, and cooperation between systems in a highly digitalised manufacturing environment; Essentials of a digital representation of a networked Cyber Physical System; Cyber Physical System for advanced digital manufacturing; and Case studies and discussions.

Industrial Additive Manufacturing Quality Certification

Introduction to additive manufacturing and fundamentals of AM processes; Status quo of industry and first steps to AM production; Health and safety in AM; Quality and production management in AM; Risk assessment and management in AM; Industry standards in AM.

Augmented Reality, Virtual Reality and Digital Twin

Fundamentals of AR/VR technology; Benefit of AR/VR application in production environment to increase work efficiency; Hands-on exercises to access information about production operation; Considerations for AR/VR development; Virtual design and commissioning of a factory layout; Design and verification of a manufacturing process in a 3D environment; Human modelling and ergonomics.

*Disclaimer: Elective modules available for selection are subject to availability. Unforeseen circumstances that affect the availability of the module include an insufficient number of students taking up the module and/or the unavailability of the professor. NTU and TUM Asia reserve the right to cancel or postpone the module under such circumstances. TUM Asia will update the list of non-technical electives from time to time. Kindly refer to our webpage for the updated list of non-technical electives.

The TUM Experience



With the increase in our population and the growth of our economy, we must be more careful about how our industrial activities and resource consumption impact the environment. Electronics is one of our most developed and pervasive technologies. In this perspective, green electronics show new ways to make electronic devices that are more attentive to the consequences of the environment.

Prof. Dr. Alessio Gagliardi
Professor, Technical University of Munich
Simulation of Nanosystems for Energy Conversion

Entrepreneurial Thinking and Engagement

You will formulate and discuss ideas based on the diverse economic realities and learn to see from multiple vantage points. The unique joint degree programme equips you not only with the technical knowledge, but also with the business and cultural aspects of the subject.

Industry Relevance

Our professors - the world's best – are industry experts and active researchers. This allows you to learn from a curriculum that is built around the latest technological trends and knowledge.

Highest International Standards

You will receive a holistic learning experience with the local lecturers from academia and industry. The majority of our modules are covered by professors who fly in from Germany on an exclusive teaching basis to ensure that you receive their undivided attention.

Global Prospects

You can choose to complete your internship and thesis in Singapore or anywhere in the world with a company, university or research institute. Your internationally recognised degree and experience is a great boost to your profile for future global job opportunities.

TUMCREATE

TUMCREATE was founded in 2010 as a research arm to foster research collaborations between TUM, Singapore and other top universities in the world in the advancement of electromobility, smart cities, medical technology and now food science. To date, TUMCREATE contributed more than close to 650 publications, developed 10 patents and innovations with more than 69 PhD candidates successfully trained in various specialisations. Graduates have the opportunity to apply for positions at TUMCREATE. especially if your interest lies in the areas of energy, medical technology and food science.

Industry Outlook

Did you know that a part of your gadget - computer, mobile phone, tablet or video console - **was designed or manufactured in Singapore?**

Clean Technology - Singapore's Environmental Commitment

Singapore is the leading clean energy hub in the region and the prime location for major cleantech companies. Singapore's strengths in manufacturing sectors such as electronics, precision engineering and chemicals, connectivity with regional markets, access to skilled international talent, and extensive supplier base are beneficial to cleantech companies. Singapore aims to further develop its cleantech industry, particularly its solar energy capabilities due to rising energy demands, climate change concerns and rapid technological advances. Other important growth areas are smart grids, green buildings, and energy efficiency.



Source: Singapore Economic Development Board

Our Graduates

Our graduates in Green Electronics are employed all over the world, with a majority in Singapore and Europe.

The most commonly accepted positions are Research Engineer, Product Development Engineer, Device Engineer, and Development Engineer.

Others may also choose to continue their academic journey with a doctoral candidate position (PhD).

CleanTech Park is Singapore's

1ST

eco-business park. It was developed for forward-looking corporations that have embraced environmental sustainability.

There is a

2% – 5%

annual growth in productivity over the past decade registered by the electronics sector.

In 2016, Asia-Pacific had become the largest solar-powered region in the world and contributes to a

55%

global market share, compared to just over 10% in 2010.

Today, the semiconductor industry's fixed assets investment in Singapore stands at over

S$50 billion



Programme Fees

	Before GST	After GST
Registration Fee+ Per application	SGD 5,000	SGD 5,450
Tuition Fee+ Green Electronics	SGD 51,520	SGD 56,156.80

Scholarships & Grants

For more information, please visit:
https://tum-asia.edu.sg/admissions/graduate-studies/scholarships/

Admission Criteria

- **Bachelor's degree** in **Electrical or Electronics Engineering** or a closely related discipline
- **Bachelor's degree certificate** or **enrolment letter*** (if you have not completed your bachelor's degree)
- **Academic transcripts** or **mark sheets**, including the credits/grading system of your university*
- **2 Recommendation letters** from your professors or employers
- **Statement of purpose** indicating the reason(s) you are interested in this programme
- **Curriculum Vitae / Résumé**
- **TOEFL** test score (≥88 for Internet-based test, DI code: 7368) or **IELTS** test score (≥6.5 overall) taken no more than two years ago from date of submission
- **Akademische Prüfstelle (APS) certificate** for applicants who hold a degree from China, India and Vietnam

+ Tuition fees are to be paid in 3 instalments.

+ The tuition fee includes teaching fees, laboratory expenses and cost of mandatory events. The tuition fee does not include airfare, accommodation, living expenses, and miscellaneous fees (registration, IT facilities, matriculation, examination, amenities, copy right, sports, insurance and medical).

+ All fees quoted are in Singapore dollars and are subject to the prevailing Goods and Services Tax (GST) rate imposed under the Singapore GST Act. Final tuition fees are subject to revision due to changes in GST rate and/or at the discretion of TUM Asia, and students will be informed accordingly. Please refer to our website for the final tuition fee and other fee updates.

* Documents that are not in English must be translated by a certified translator. Credits/ grading system of your university is required:
  - min. passing score (e.g. 50 out of 100);
  - max. possible score (e.g. 100 out of 100); and
  - the equivalent score/range of scores for each grade (e.g. 'A' grade is equivalent to a score of 90 to 100).

The full application process and documents required for submission is available at
www.tum-asia.edu.sg/admissions/graduate-studies/application/

Applications open on 1 October every year.

Technical University of Munich (TUM) Asia
Email: admission@tum-asia.edu.sg

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