Nanoscience

Content and application

Greater Copenhagen hosts one of the world's leading nanoscience research clusters. This wide-ranging research field is generally focused on manipulating materials on the nano-scale, i.e. on the order of a hundred millionth of a millimeter. The entire inception of nanoscience is primarily driven by the electron microscope, which has revolutionised materials science and made it possible to develop materials with new properties, e.g. with respect to strength, surfaces and electrical conductivity.

Copenhagen is generally regarded as being among the 5-10 strongest research environments in the world in the nano-field, a position, which will be strengthened with the establishment of the ESS (European Spallation Source) in Lund and Copenhagen. ESS is expected to be applied in areas such as medicine, diagnostics, treatment of diseases, food processing and electronics.

Key environments and star researchers

Greater Copenhagen has a sizeable, wide-ranging research environment, covering many different disciplines and applications of nanotechnology. It hosts two centres that each collaborates widely with researchers in many departments. The Nano-Science Centre at the University of Copenhagen is headed by Bo Wegge Laursen with 150 researchers and PhDs. Well-known names include Jesper Nygård, Dimitrios Stamou and Morten Meldal. The other is DTU Nanotech at the Technical University of Denmark (DTU), with 200 researchers and PhDs. Renowned researchers include Marcel Somers, Anne Ladegaard Skov, Anja Boisen and Kristoffer Almdal.

Potential for attracting investments

The research area's prospects for attracting investment is strong. Nanotechnologies carry many potential applications that are already profitable today, and they have a promising long-term potential. A company wishing to be at the cutting edge of nano-technology can benefit strongly from being in close proximity to the strongest research environments. Nanoscience in Greater Copenhagen is evidently among the strongest environments, especially after researchers have successfully established a long-term collaboration with China in form of the Sino-Danish Center for Nano Electronics at the University of Copenhagen and a Sino-Danish Masters course in nanoscience at the Sino-Danish Center for Education and Research.

Characteristics of the research area

Nanoscience in Greater Copenhagen is characterised by being broadly anchored at a number of departments and by employing researchers, who are exploring applications for the many new technologies in the area. Research in Greater Copenhagen is based at two major centres, the Nano-Science Center at the University of Copenhagen and DTU Nanotech. Researchers from many different departments and units collaborate with both centres.

The Nano-Science Centre was established in 2001 as a joint venture between the Niels Bohr Institute and Department of Chemistry at the University of Copenhagen. Subsequently the Department of Biology has also joined the centre. Moreover, the centre collaborates with several departments of the Faculty of Health and Medical Sciences at the University of Copenhagen. Research is spread across 15 teams, broadly covering a wide array of areas in medicine, biology, nano/quantum electronics and surface physics/chemistry.

DTU Nanotech hosts 100 researchers and 100 PhDs, accompanied by close collaboration partners from several DTU departments (DTU Mechanical Engineering and DTU Chemical Engineering). The department covers four fields: Biomedical Engineering and Life Science, Sustainable Nanotechnology, Lab-on-a-chip and Materials and Fabrication.

International top quality niches

The two nanoscience environments at the University of Copenhagen and DTU work closely together. Research at the DTU focuses on bioengineering, metals and polymer, while the University of Copenhagen concentrates on medicine, electronics and chemistry. Both conduct research into many different global applications for nanotechnologies (see the section on relevance for companies and society).

Bibliometric key figures

Employing bibliometrics to measure production and quality of research within nanoscience carry limited validity because it is a relatively new research field that cuts across many different fields of research.

According to the researchers we have interviewed, Copenhagen is among the 5-10 strongest research environments in the world within nanoscience. This assessment should, however, be interpreted with some caution, as specific strengths can differ widely between the many different sub-fields involved in nanotechnology.

Key arguments for the research area's prospects for attracting investment

For both society and industry, nanoscience carry great potential and in several areas nanoscience has already had a considerable impact. Possible applications for research cover different areas such as materials research, communication and food.

Healthcare applications is expected to hold the greatest potential. Nanotechnologies make it possible to develop more precise and more personalised diagnostics of diseases such as cancer, as well as personalised treatments. Ultimately, the area carries prospects of each individual patient having their own medication-profile. A stronghold in nanoscience in this area lies in the use of fluorescing substances and optical methods.

Another application concerns the development of healthy foods. A third area is healthy/environmentally-friendly materials for packaging, clothing and dyeing. A fourth area is the development of enzymes and materials to reduce energy consumption in processing. A fifth area is new materials with strong structures and surface properties that can be used for example to make wind turbine blades capable of tolerating very strong winds.

Star researchers and major scientific breakthroughs

Considering the size of the nanoscience research environment of Copenhagen, it displays a considerable number of star researchers who enjoy international acclaim. At the University of Copenhagen, Prof. Bo Wegge Laursen is head of the Nano-Science Center as well as the Sino-Danish Center for Molecular Nanoelectronics.

Other leading names include Prof. Morten Meldal at the Department of Chemistry who explores so-called "click chemistry" (new methods for assembling large molecules) and Prof. Jesper Nygård from the Niels Bohr Institute at the University of Copenhagen, who researches solid state physics. The Department of Chemistry at the University of Copenhagen has also been apt in attracting top international scientists such as Dimitrios Stamou (who researches bio-nano technologies) and Karen Martinez (who investigates nano technology in neuroscience), both from EPFL in Switzerland.

Leading names at DTU feature Prof. Marcel Somers, among the leading metallurgists in the world, Prof. Anja Boisen, who does nanosensor research and Prof. Kristoffer Almdal, who works with polymer research. Moreover, Anne Ladegaard Skov is the head of the Danish Polymer Center, which is one of the leading centres in the world for developing new silicone polymers.

Nanoscience has experienced a number of breakthroughs in recent years. By and large these breakthroughs have revolved around what scientists refer to as 'enabling' technologies that when used with other technologies, provide new solutions to important challenges.

Some of the scientific breakthroughs relate to methods for diagnosing such diseases as cancer. Another type of breakthrough relates to catalysts, including enzymes that can dramatically improve the properties of other substances. A third type of breakthrough relates to materials with new surfaces that can for example reduce the risk of attack by fungus and mould. A fourth breakthrough is in new kinds of polymers (plastics) that can be made without using oil products and have novel properties.

Large talent pool

The University of Copenhagen and DTU both educate/train a considerable number of talented individuals. DTU educates/trains around 40 PhDs annually, while several hundred undergraduate and graduate students are taught at the department. The University of Copenhagen trains 20-25 PhDs annually in nanoscience, and a total of about 50 students attend MSc and BSc programmes with an emphasis on the nano field.

Unique research facilities

Nanoscience has attracted considerable funding from the Danish National Research Foundation, the EU and private foundations. The Danish National Research Foundation has for example provided funding for the Sino-Danish Center for Molecular Nanoelectronics at the University of Copenhagen and the Center for Synthetic Biology at the University of Copenhagen, which was initiated in 2009 with a DKK 120m grant from the Ministry of Higher Education and Science. DTU has received grants from the Danish National Advanced Technology Foundation which has boosted collaborations with industry considerably.

Over the past 10 years, a total of DKK 400m has been invested in research infrastructure at the University of Copenhagen and DTU. Much of the investment has funded state-of-the-art infrastructure, including equipment for X-ray spectroscopy, quartz crystals, ellipsometry, fluorescence, scanning probe microscopy and spectroscopy/microscopy.

In terms of research infrastructure, MAX IV, which opened in June 2016, and the coming European Spallation Source, ESS, scheduled for 2019, will have a major impact on nanoscience. MAX IV is the largest X-ray system in the world for investigating materials at a previously untested molecular level. ESS will be one of the strongest neutron accelerators in the world. Denmark is the second largest investor in ESS, following Sweden, and ESS´ Data

Management Center is in the process of being established at the University of Copenhagen's Nørre Campus.

Strong collaboration with leading international research environments
With considerable exchanges of visiting researchers and other visits and robust scientific production, there are close relations with other research environments worldwide, especially in China, Japan, Korea, USA, Germany and the UK. The Nano-Science Center at the University of Copenhagen and DTU Nano routinely have visiting scientists from these countries and both departments have active knowledge exchange programmes with these countries. Collaborations include researchers at Lund University, which hosts MAX IV and the coming ESS.

Extensive corporate collaborations
The nanoscience-environments in Greater Copenhagen have strong commercial links with a range of Danish and international corporations. Important partners for the University of Copenhagen and DTU include Novozymes, Dyrup, Maersk and Airbus. Another example of the significant potential is the successful spin-out from DTU, Scandinavian Micro Biodevices, which sells nano-diagnostic solutions for veterinary purposes. The company was sold in the spring of 2016 for DKK 500m. According to the company's management, this was due to the high level of knowledge at DTU (see citation).

This investment might be an indication that the field, which has so far been characterised by major research funding from the EU, the Danish State and private foundations, may now be moving into a new phase with private investment playing a greater role.

Nanoscience is not only promising for spin-outs. DTU informs that nanoscience is the field that has displayed the highest level of innovations announced in the past five years.

Nanoscience is characterised by a high complexity, which is why a local presence is essential for enabling companies to keep up with developments in the field. The two Danish centres are known for having a wide range of international and Danish corporate collaborative partners. One example of these is SBM Offshore, which investigates methods for developing new plastic materials that the company can use in offshore wave energy systems. The company is French, but has opted to collaborate with Greater Copenhagen rather than the University of Darmstadt because they felt Greater Copenhagen was a key knowledge platform due to its openness and strong research.

"I enjoy working with the Copenhagen researchers from DTU. The possibilities of polymers are unknown to many people but really fantastic. SBM is basically an oil company today – but we want to be part of the renewables revolution too. With DTU we are investigating the possibilities of using polymers in new equipment to make sea wave energy"
- Ambroise Wattez, SBM Offshore

"As a new, rapidly growing company providing new surface technologies and highly advanced data processing, we need to keep up to date. We have just been sold for DKK 500m and only have a headcount of 40. But a quarter of them were educated at DTU Nano. That probably says it all."
- Niels Kristian Bau Madsen, COO, Scandinavian Micro Biodevices