UiO : **Det matematisk-naturvitenskapelige fakultet**
Universitetet i Oslo

Til: MN- fakultetsstyret

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Saksbehandler: Bjørg Mikalsen

Evaluering av Senter for materialvitenskap og nanoteknologi (SMN)

Bakgrunn:
Senter for materialvitenskap og nanoteknologi (SMN) ble opprettet i 2003 som fakultetets tverrdisiplinære satsing på materialer og nanovitenskap rettet mot funksjonelle materialer, energi og IKT. Senteret består av forskningsgrupper fra Kjemisk og Fysisk institutt, og har egen senterleder og egen administrasjon.

De viktigste problemstillingene:
Fakultetsstyret vedtok i 2017 et eget senterreglement for interne sentre oppnevnt av fakultetet (se vedtakssak 47/17). I følge reglementet skal sentre normalt opprettes med en virkeperiode på 5 år. Sentrene kan forlenges for en eller flere virkeperioder basert på evaluering av senterets progresjon og virksomhet.
SMN hadde i 2021 hatt en virkeperiode på 18 år uten å ha blitt evaluert. Fakultetsledelsen inviterte derfor en ekstern faglig komite til å evaluere senteret. Evalueringen tok utgangspunkt i evalueringskriteriene presentert for fakultetsstyret 21. juni 2021 (sak 22/21). Rapporten fra evalueringskomiteen forelå 20. mai 2022 (se vedlegg).

Kort oppsummert vurderer komiteen at den faglige aktiviteten generelt er høy, og at SMN er en ressurs for de to instituttene, og i særdeleshet for de unge forskerne. Komiteen anbefaler at SMN fortsetter som et senter, men med betydelige endringer:
- det oppnevnes en Scientific Advisory Committee (SAC)
- det utnevnes en faglig leder for senteret
- flere organisatoriske endringer og relokasjon
- density-functional theory (DFT) bør integreres bedre i hele SMNs aktivitet
- samarbeid med industri bør økes
- ha en tydelig plan for videre faglig utvikling
- ha en rekrutteringsstrategi for fremtidige avganger

Videre anbefales det at senteret evalueres hvert femte år.

På styremøtet vil det bli gitt en presentasjon av evalueringsrapporten og planer for videre oppfølging.

Vedlegg: Rapport fra evalueringskomiteen, datert 20. mai 2022.

EXTERNAL EVALUATION OF THE CENTRE FOR MATERIALS SCIENCE AND NANOTECHNOLOGY (SMN)
UNIVERITY OF OSLO

20th May 2022

Contents

INTRODUCTORY REMARKS

This report has been prepared by the Evaluation Panel appointed by the Faculty of Mathematics and Natural Sciences of the University of Oslo. It consists of the following members:

- Prof. Mats Larsson, Stockholm University (Chair)
- Prof. Eleanor Campbell, University of Edinburgh
- Prof. Hannu Häkkinen, University of Jyväskylä
- Prof. Kornelius Nielsch, IFW Dresden

The report is based on the comprehensive material provided in the self-evaluation document prepared by the Centre for Materials Science and Nanotechnology (SMN) with its appendices. The evaluation took place as an on-site visit on the 9th and 10th March 2022 and included meetings with the SMN Board consisting of the Vice-Dean of Research Prof. Bjørn Jamtveit and the Department Heads of Chemistry (Prof. Einar Uggerud) and Physics (Prof. Susanne Viefers), the centre leader Klaus Magnus Håland Johansen and representatives of the SMN research groups and early career researchers. All SMN research groups gave presentations to the panel and lab tours took place. A follow-up digital meeting was arranged on 23rd March 2022 for the panel to meet with the SMN Head of Administration and the four Research Advisors.

The evaluation was excellently supported by the SMN centre leader Klaus Magnus Håland Johansen.

The Evaluation Panel had all input needed to formulate this report, ample time to evaluate, assess and discuss its findings. The following description and recommendations have been unanimously agreed upon by the Evaluation Panel.

Mats Larsson (Chair)

Eleanor Campbell Hannu Häkkinen Kornelius Nielsch

1. EXECUTIVE SUMMARY

The Panel notes that the scientific quality of SMN is generally high, ranging from good to excellent. The SMN is an asset for the two host departments and in particular beneficial for young researchers. The panel recommends that SMN continues as a centre, but with substantial changes. A Science Advisory Committee (SAC) should be established and a scientific leader appointed. The centre should be evaluated every fifth year.

The activities of Catalysis, Electrochemistry and NAFUMA should be brought together to form the core of a reorganised SMN. This will be facilitated by the move of these three groups to the new Life Science building. The retirement of two leading persons at SMN requires a carefully thought-out recruitment plan that must be implemented as soon as possible.

The move of Structure Physics to the new Life Science building should be seriously considered.

A new strategy for LENS and the clean room is required.

The DFT efforts should be better integrated across SMN for stronger mentoring of young researchers working on modelling in the different SMN groups.

Collaboration with industry should be increased.

The future plans of SMN are only vaguely described. At least two workshops should be organised in order for SMN to identify whether they can/should establish successful and focused new research within the broader areas of quantum technology and life sciences.

2. ADMINISTRATION AND ORGANISATION

Observations

The research conducted by the Centre for Materials Science and Nanotechnology (SMN) is strong, with some research with international visibility and even, to some extent, some that is internationally leading.

The Panel initially noted some anomalies not common for research centres: SMN has been in operation for an unusually long time, it has never been evaluated, it lacks a scientific director, and it has never consulted an external scientific advisory board.

The present organisation is not suitable for taking long-term strategic decisions. SMN is very much decentralised and the research across the centre is heterogeneous. Decentralisation has some benefits, but if SMN is to retain its research strength, a reorganisation is recommended, or SMN may lose out to research environments at other universities that can tackle challenges more cohesively and flexibly.

Two individuals play an important role for the centre, Helmer Fjellvåg and Truls Nordby. They are both approaching retirement age, but the succession was unclear to the Panel. Unfortunately, and maybe it was just a coincidence, the presentations of NAFUMA (Helmer Fjellvåg) and Electrochemistry (Truls Norby) were performed by the Group Leaders only, and for NAFUMA nobody else of the senior group members was present. This gave the Panel the impression of "one-man-shows", which amplified the succession concerns.

The Panel appreciated having the possibility to meet and discuss with young group members of SMN, PhD students, postdocs and researchers. It was very clear that they found SMN to be of great benefit for their scientific careers, but also that there are things that can be improved. For example, the Panel noted that despite excellent conditions no graduate school has been established.

The SMN administration is slim and seems to be functioning well. The zoom meeting with the research advisors two weeks after the site visit was illuminating to the Panel. One weak point that the Panel could identify is the lack of a dedicated outreach programme.

The centre is geographically fragmented. This will be improved when the new Life Science building is ready. However, breaking up the geographic proximity of Electrochemistry and Structure Physics, two groups with a long and successful history of collaboration, seems ill-advised.

The future tentative scientific focus of SMN was not clearly spelled out. For example, "quantum technology" is a very broad and presently highly competitive area. Also the future "life science" focus was quite vague and generic.

Recommendations

The Panel recommends the following:

- The Board of SMN should appoint a Science Advisory Committee (SAC) with the main task to ensure that SMN continues to meet the highest scientific standards. The SAC should meet once a year. Detailed Terms of Reference must be worked out. The chair of SAC should be a permanent member of the Board of SMN.
- The SMN should be evaluated once every fifth year.
- A Scientific Director of SMN should be appointed. The directorship could, for example, be rotated among the Group Leaders.
- SMN is experiencing retirements of individuals with strong competence. It is of utmost importance that the highest scientific level of competence is recruited to replace retirements. The details of the recruitment strategy must be worked out.
- The establishment of a graduate school should be seriously considered.
- The MENA programme is very attractive and an asset for SMN. MENA should be vigorously promoted.
- One full time research advisor should be hired, with 50% of working time used for outreach and 50% for support of the four other research advisors.
- At least two workshops should be organised, one with the aim to identify suitable initiatives for SMN in quantum technology, and the other to identify suitable initiatives in the life sciences.

3. SMN GROUP EVALUATIONS

3.1 CATALYSIS
(Group Leader: Stian Svelle)

Observations

The Catalysis group is internationally well known for being the first (Lillerud and Olsbye, 2008) to synthesise and characterise one of the archetypical metal-organic frameworks UiO-66. This highly porous and stable material has many favourable properties such as ease of synthesis and high stability, and is now widely studied worldwide. The publication metrics of the group as a whole are very impressive and it is interesting to note that over half of the 31 highlighted "high impact" SMN papers since 2017 stem from the group. The Oslo group is able to compete internationally in what is a very competitive and crowded research field. This is partly due to the close collaboration among the senior academics within the group , bringing together the joint expertise in MOFs combined with homo- and heterogeneous catalysis, and the excellent success the group has had in attracting European funding in recent years. The leadership of a recently

awarded ERC Synergy grant (CuBE, PI Olsbye) is clear evidence of the international standing. The group has strong activities at international synchrotron research infrastructures for material characterisation and carries out *in operando* techniques to investigate reaction mechanisms. The experimental activities are complemented by DFT calculations and collaboration with the Hylleraas Centre for Quantum Molecular Sciences.

The Catalysis group consists of 3 Professors, plus one recently retired, and an Associate Professor. There appears to have been good succession planning within the group with leadership having been successfully passed on to the following generation. The Assoc. Prof brings interesting new approaches to autocatalytic amplification of chirality. A second Assoc. Professor is expected to start in August 2022, bringing additional complementarity. The diversity among the senior staff is very good. In comparison to other international materials chemistry groups there is a relatively low number of PhD students per professor and (similar to other SMN groups) a reliance on so-called "permanent" researchers.

The group has been working largely as a self-contained unit within SMN and there has been very little evidence of synergetic collaborative interactions with the other groups until the very recent (2021) preparation of two CoE applications with Electrochemistry (Olsbye) and NAFUMA (Svelle), respectively. The main advantage of being part of SMN appears to have been the better administrative support compared to departmental level and the access to flexible funding.

In conclusion the research activities of Catalysis can be judged as excellent. The scientific output in terms of publications and the attraction of European funding is excellent. The interaction with industry is good but could be increased.

Recommendations

There is considerable potential for forming an internationally leading materials centre by more closely integrating the activities of Catalysis, Electrochemistry and NAFUMA within a reorganised SMN. This would be greatly aided by bringing the three groups geographically closer together within the same building. The research activities of the Catalysis group are very much focused on important topical problems related to reducing reliance on fossil fuels and utilising CO_2 as a sustainable carbon resource for value-added chemicals and complement the energy-related materials research in the other groups. The recent activities to combine efforts in the preparation of CoE applications are very promising and will hopefully lead to closer interactions between the groups and new synergies in future.

The current limited industrial collaboration is surprising and efforts should be made to increase this. The current laboratory infrastructure is in urgent need of improvement and a move

to a new building can provide the kind of facilities that are urgently needed to remain internationally competitive.

3.2 ELECTROCHEMISTRY
(Group Leader: Truls Norby)

Observations

The Electrochemistry group was one of the founding groups in the first instalment of the research centre nowadays known as the SMN. The group has a long history and expertise in solid state electrochemistry, and it has demonstrated world-class research particularly in proton transfer processes (mechanisms and materials), publishing several papers in top journals (Science, Nature sub-journals) over the last several years (the latest Science article on 21.4.2022 is on single-step hydrogen production from biogas, ammonia and methane - a topic of great current relevance for the green transition of society). The group has had success in starting spin-off companies.

The group has a long-standing, strong collaboration with the Structure Physics group. The group has expertise also in relevant DFT modelling in solid state electrochemistry (Polfus).

Electrochemistry has three professors / associate professors, four staff researchers, and dedicated technical and administrative support. This places the group as the smallest among the current SMN groups. The senior leader of the group is approaching the retirement window. Future leadership of this group and future connections to other groups in SMN are some critical questions to solve for the future of SMN.

This group was the only one where the Group Leader presented a group strategy for the future. The strategy included an "innovation arrow" describing new materials and research methods relevant for a "green transition" in society, and the role of supporting technology companies, potential end users (big industry), and critical funding sources. The evaluation committee would have liked to see this kind of strategy discussion also from the other SMN groups.

In conclusion, the research activities of Electrochemistry are excellent. The group is heavily involved in collaborations with industry (also through its spin-off company).

Recommendations

The research expertise represented by this group has potential to play a crucial role for "re-defining the new SMN" if the focus of the renewed Centre would be in materials and

technologies relevant for a future sustainable society (such as green energy production by photo/electro/catalysis). It could serve as a linchpin for synergetic collaborations between parts of the current NAFUMA, LENS, Catalysis and Structure Physics groups.

The group needs to hire 1-2 subgroup leaders (at assoc/full prof level, from an open international call) to fill the gap after the current Group Leader retires. One has to clearly identify who will take the overall responsibility of leading Electrochemistry in the transition period of re-organising SMN geographically and operatively. This process should be started soon.

The in-group DFT expertise could be combined with the current Structure Physics group (Persson), for stronger mentoring of young researchers that are working on modelling in all other SMN groups.

3.3 NAFUMA
(Group Leader: Helmer Fjellvåg)

Observations

The NAnostructures and FUnctional MAterials group (NAnostructures and FUnctional Materials) is under the leadership of Prof. Helmer Fjellvåg who is one of the pioneering figures of SMN. This group is quite visible on the international level at the interfaces between inorganic chemistry, material science and nanotechnology. The group is very broad and covers areas from the investigation of chemical reactions at interfaces by scanning tunnelling microscopy, atomic layer deposition (ALD) for the deposition of functional materials on non-planar interfaces, state of the art modelling by using DFT methods, synthesis of inorganic materials and compounds with a strong focus on battery materials. The Group Leader of NAFUMA and faculty members are very complementary in their expertise and highly visible internationally. The recent hire of Prof. Martin Valdor has brought new scientific expertise to the NAFUMA group in solid state chemistry. The activities of Prof. Ola Nilsen on the synthesis of functional oxides by ALD and molecular layer deposition are highly visible internationally. NAFUMA can rely on a solid and extensive infrastructure, which includes a national facility for x-ray diffraction techniques, ALD labs, UHV STEM, battery testing labs, analytic scanning electron microscopy and regular beamtime measurements at different synchrotron facilities. State-of-the-art (interpretative/predictive) modelling of materials' properties has been and continues to be a crucial component for design of novel materials with tunable properties. However, critical knowledge in DFT modelling is disappearing from the NAFUMA group since a senior researcher is leaving for industry. Theory support is usually sought from younger researchers that are hired to temporary positions according to available grants.

Although the research area exhibits a very good to excellent research performance, this SMN group is facing a number of serious challenges:

1) The scientific infrastructure has aged and it is concerning that a number of high-end scientific setups are approaching the end of their life-cycle, e.g. the Physical Properties Measurement System (PPMS)

2) This group has particularly suffered in recent years from the loss of scientific and technical expertise due to attractive job offers from industry and research institutes.

3) The retirement in the near future of Prof. Fjellvåg as an inspirational leader for NAFUMA and SMN.

Recommendations

The planned move of the NAFUMA-Labs into the new Life Science lab building is timely, strongly supported and should not be delayed since the NAFUMA activities are currently hosted in laboratories that are no longer state-of-the-art. A strategy should be developed for appointing an internationally competitive replacement for Prof. Fjellvåg in combination with a general strategy for the restructuring of SMN. This should be aided if possible by a competitive start-up package with some possibility for equipment renewal. Furthermore, the high turnover of support personnel is concerning and an action plan for ensuring the sustainability of these essential roles would be desirable. The collaboration with SINTEF and Norwegian Industry is very strong and should be enhanced further. The group would benefit from a stronger interaction with other SMN groups (especially Electrochemistry, Catalysis and Structure Physics). The group would also benefit from the recommended common DFT group under a clear leadership (from Structure Physics) to widely benefit the renewed SMN activities.

3.4 STRUCTURE PHYSICS
(Group Leader: Anette Gunnaes)

Observations

The Structure Physics (SP) group, affiliated with the Department of Physics, is one of the two leading materials science electron microscopy groups in Norway, the other one being located at NTNU in Trondheim. The research of the group is of very good quality and the group has international visibility. Benchmarked with two of the leading electron microscopy groups in Sweden, at Lund University and Chalmers University of Technology, the SP group does not have the same international impact.

The collaboration with the SuperSTEM in Daresbury, UK, and the electron microscopy group at the Humboldt University in Berlin, Germany, is commendable.

Electron-microscopy based research is very instrument-dependent and in this respect the SP group is in a strong position. The major breakthrough in electron microscopy for materials science has been, after decades of work, the solution of the aberration problem. Aberration-corrected electron microscopes now allow sub-Ångström resolution, which means that one can now ”see” individual atoms. The aberration-corrected microscopes can be operated in different modes. For low-Z atoms, which have low contrast, conventional imaging with transmission electron microscopy (TEM) is the preferred mode, whereas for heavier elements scanning transmission electron microscopy (STEM) can be combined with electron energy loss spectroscopy (EELS) to allow atomically resolved chemical analysis and visualisation of bonding states at the same time.

Aberration-corrected TEM has made it possible to resolve lighter elements such as oxygen, which in turn opens up the possibility to structurally characterise oxide materials, a highly active research area that the SP group works in. STEM-EELS now allows plasmon modes to be studied, and the SP group has shown how correlations between optical band gaps and plasmon modes can be established in semiconductors.

The SP group has access to the aberration-corrected FEI Titan G2 60-300 instrument for STEM-EELS and JEOL JEM-2100F for TEM, which are part of the Norwegian Centre for Transmission Electron Microscopy (NORTEM) and located at the premises of the SP group in the Oslo node of NORTEM. A new instrument is being procured, which will further increase the group’s possibilities of pursuing strong research programmes. The present instruments are located in adjacent laboratories, which is an advantage from operational and maintenance points of view. However, the Panel had the impression that the laboratory for the new instrument is not clarified. Clearly none of the present instruments should be decommissioned to provide space for the new instrument, particularly considering the high degree of instrument usage (80%). Whereas several of the other SMN groups plan for moving to the new Life Science building, the Panel was informed that the SP group should remain in the old part of the Oslo Science Park building. It is the Panel’s understanding that this has been decided at the highest level at UiO, but no compelling argument was presented to the Panel. The decision seems sub-optimal for both the SP group and SMN.

The research in the group is focused on the relation between structure and properties for a range of materials such as sensor materials, batteries, semiconductors etc. Some of the work is carried out together with other groups in SMN, and in particular the collaboration with the Electrochemistry group is important. The SF group has capabilities for synthesis. The publication output is rather diverse, with publications in both chemistry and physics journals, and in more specialised journals, and citations remain average or slightly above average.

The theoretical efforts by means of DFT constitute an important part of the SP group. The DFT group not only provides support for understanding and interpreting experimental data, but it

also actively develops new computational methods and analysis tools. A general challenge in the field is to develop and apply new numerically efficient DFT-based methods to understand electron dynamics in excited states in (nano)materials. This is critical, e.g., for understanding next-generation solar cells and solar-fuel conversion.

SP group's age and leadership structures are healthy. There is no immediate need for recruitments. The balance between tenured faculty and younger researchers at the master, PhD and postdoc levels also seem adequate. The 2-year master's programme for Materials Science for Energy and Nanotechnology (MENA) is an asset for the SP group in recruiting young people to their research projects. The group is presently quite well funded, with nine externally funded projects, but this is of course something that can change and is listed as a threat in the SWOT analysis. This is a situation that many research groups face not only in Norway but in any Nordic country.

In conclusion the research activities of Structure Physics are very good. There is a clear potential for an increased international visibility and impact. The interaction with industry is limited and could be increased.

Recommendations

The most pressing need for the SP group is laboratory space for the new instrument. Since state-of-the-art aberration-corrected electron microscopes require very specialised laboratories, with suppression of electromagnetic fields and minimal vibrations, and the fact that it is advantageous for microscopy groups to operate their instruments in adjacent laboratories, this issue requires careful planning. The Panel was informed that the new Life Science building will be prepared to host cryo-electron microscopes for structure determination of biomolecules, but also that no funding for this type of microscope had yet been secured. Aberration-corrected electron microscopes have not yet had the same impact on life sciences as they have on materials science, but this may very well change over the next few years, when the first chromatic-corrected cryo microscopes are delivered. The Panel's recommendations take this development into account.

The Panel recommends the following:

- The board of SMN together with the management of the new Life Science building should carefully analyse the advantages of moving the SP group to the new Life Science building. It seems obvious that any new activities in cryo electron microscopy will benefit from the considerable microscopy expertise in the SP group. It would also allow the SP group to be located in the vicinity of the Electrochemistry group, which has for a long time been a winning concept for both groups and for SMN.
- The SP group should carefully analyse how they can exploit ptychography to further improve the performance of their aberration-corrected instruments. This is most probably

something which is already considered, as indicated by the hand-outs, but worth pointing out, in particular since ptychography offers more robust phase retrieval than holography.

- The possibilities of phonon and vibrational spectroscopy by means of STEM-EELS are exciting developments that the SP group is strongly encouraged to pursue.
- Even if recruitments are not urgently needed, the group should assume a strategic recruitment strategy for renewal, emphasising the need for external recruitments.
- A strategic plan for future large and medium size infrastructure investments should be developed.
- Theoretical and computational efforts should be integrated more widely with other current SMN groups, to create a common knowledge base for the "renewed SMN". The SP DFT group is in the position to be the driving force here.

3.5 LENS
(Group Leader: Andrej Kuznetsov)

Observations

The LENS group is very visible in the area of semiconductor physics and has exceptional expertise on the epitaxial growth of semiconducting thin films based on Si, SiC and high bandgap semiconductors, with a specific focus on defect engineering on the mostly epitaxial systems. Additionally, they have strong expertise in ion beam modification and analysis and electrical, chemical and optical analysis. With this combination they are very good in the area of defect engineering and the LENS group publishes high impact publications on this topic. Due to a lack of capabilities to measure electrical transport at low temperature, they have not entered current topical research activities on nanowires, quantum and 2D materials. This group has been successful in improving gender diversity. The establishment of new research activities in the area of life science could be very promising.

Historically, the LENS group was built-up and influenced predominantly by Prof. Bengt Gunnar Svensson, who passed away in 2018. The gap that was left has not been closed in recent years and the program focus seems to be unchanged, although the group remains scientifically very productive.

The LENS group operates a large clean room facility, which is, on one hand, the scientific core infrastructure for LENS and, on the other hand, a national scientific (open) facility for services in the areas of microstructured devices and nanotechnology. The role of this facility is unclear in terms of current academic users of the clean room, interactions with industry and specific services, which can be offered only in a clean room facility. Some large scientific instruments placed in the clean room do not require to be operated inside an expensive clean room, such as the pulsed laser deposition system or the ion beam implanter. On the other hand,

standard competences in the areas of nanostructuring and fabrication of microstructured devices are missing, like e-beam lithography and a reactive ion etching system.

In conclusion the research activities of LENS can be judged in the range from good to very good. The scientific output in terms of publications and supporting young talents is very good and can be enhanced further with limited efforts.

Recommendations

A change of focus for LENS and the clean room facility is required. We strongly encourage the leading scientists of LENS to develop a new research strategy for the coming 5 to 10 years and to establish new research directions and collaboration within SMN and outside. The clean room facility requires additional investment in terms of small and large equipment and scientific expertise in areas like 2D and 3D nanopatterning to enlarge and optimise the usage and competences of the clean room facility.