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Delivering excellence in nanoscale science and technology through world-class education, research and innovation

NTNU Nano: Overview and Strategy Document (2018 – 2023)

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1. Introduction

NTNU Nano is a strategic initiative that aims to promote the study and use of nanoscience, nanotechnology and functional materials across the university. The purpose of this document is to set out the structure and remit of NTNU Nano, specific examples of the support offered to researchers, and plans for expansion over the next five years.

2. Remit of NTNU Nano

Alongside biotechnology and digital technology, NTNU has identified functional materials and nanoscale science and technology (NanoST for short) as key "enabling technologies" that are capable of driving innovation across its full portfolio of research. NTNU Nano (formerly Nano@NTNU) has been set up to promote NanoST across the university through the provision of training, high quality research infrastructure, and tailored support initiatives. We are currently in the process of reviewing the remit, structure and activities of NTNU Nano, and we have set out below our initial views on how it should evolve and operate over the next five year period. For convenience, we divide NTNU Nano into two parts: the "Community" and the "Administration". The Community comprises all NTNU researchers and educators involved in (NanoST), while the Administration is responsible for coordinating NanoST activities across the university. The Administration is responsible for strategic planning, provision of centralised support to the Community and management of research infrastructure.

Key questions that we have tried to answer are: (i) How can we raise the international profile of NanoST research at NTNU? (ii) How can we ensure that NTNU maintains a balanced research portfolio with respect to NanoST, and that it invests in areas that are capable of delivering significant scientific and societal impact. (iii) What practical support can we offer to stimulate new research collaborations, increase research income, and increase the impact and visibility of NTNU's nano-related research and publications? (iv) How can we make best use of NTNU's existing nano infrastructure, and how should this be expanded in the coming years? (v) In what ways can NTNU Nano assist with industrial engagement and commercialization of NanoST? (vi) What educational and training programmes should we offer in NanoST? (vii) How can we best represent the interests and needs of NTNU's nano community externally, e.g. to policy makers and funding agencies?

3. Structure of NTNU Nano

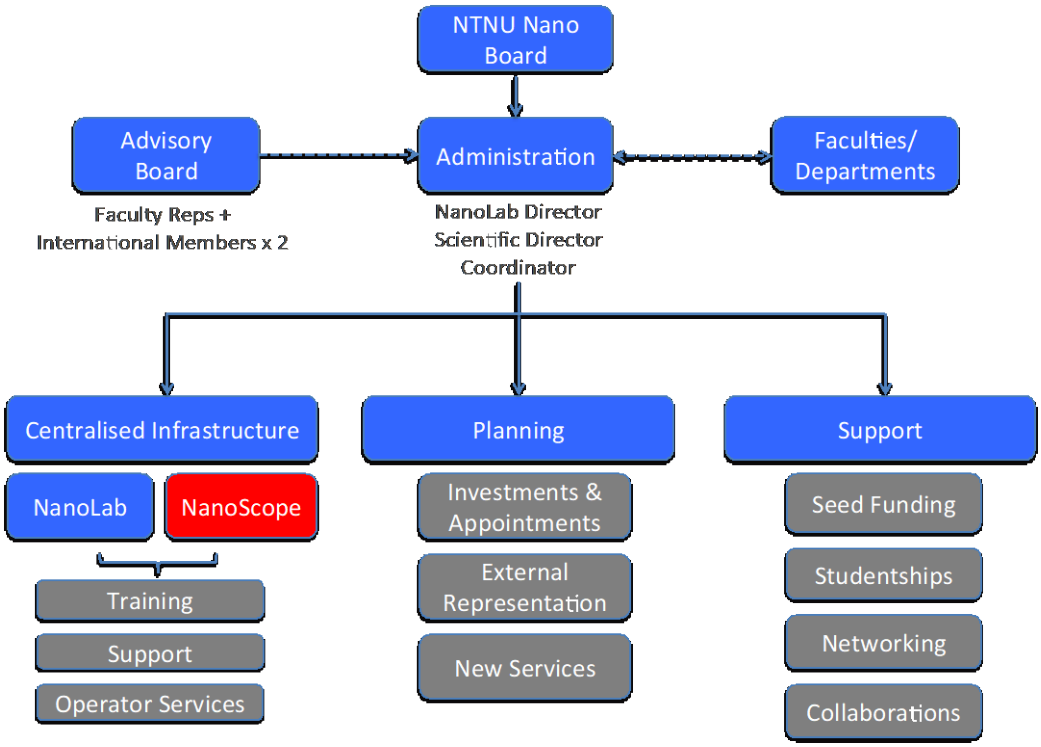

Fig. 1 – Organisational diagram for NTNU Nano

The new organizational structure for NTNU Nano is shown in Fig. 1. The administration of NTNU Nano will be the responsibility of a three-person management team, comprising NanoLab Director (Kay Gastinger), Scientific Director (John de Mello, arriving August 2018) and Coordinator (Hanna Gautun). The management team will report to the NTNU Nano Board, which comprises Dean-level representatives from each of the major NanoST-using faculties (Natural Sciences, Engineering, Medicine and Health Sciences, and Information Technology and Electrical Engineering) plus one external representative. The management team will maintain close contact with all nano-active faculties and departments, and will formulate policies in line with their needs and views. The management team will also be served by a Scientific Advisory Board, comprising NanoST specialists from each faculty. The Advisory Board will meet on a monthly basis, and will be complemented by two international representatives who will attend in person or via video conferencing at least twice per year. Separate from the Advisory Board, it may also be useful to establish a NanoLab User Board, comprising key users of NanoST infrastructure from each faculty. The management team will work together to ensure all aspects of NanoST policy-making and delivery are properly coordinated, with the NanoLab Director having lead responsibility for infrastructure and the Scientific Director taking the lead on issues relating to research and science policy.

4. Centralised Functions

This section covers key services and activities to be provided by NTNU Nano at a university-wide level.

Marketing of NTNU Nano - An important role of NTNU Nano is to increase the external profile and visibility of NTNU's activities in NanoST, with a view to enhancing impact, increasing teaching and research income, and making NTNU a "partner of first choice" for academic and industrial collaborations. The main marketing activities carried out by NTNU Nano will be:

- The development of general publicity materials describing NanoST activities at NTNU, including a short annual report and a series of slides for incorporation into presentations.

- The maintenance of a professional website, summarising NanoST activities at NTNU. The website will provide an overview of the university's teaching, research and innovation activities in NanoST (with links to associated research groups); details of the master's degree in nano-technology; descriptions of our NanoST infrastructure; links to relevant NanoST documentation; a contacts page; and a regularly updated news section, providing topical information, e.g. papers, student-ships, job vacancies and scientific meetings.
- Marketing via social media, including Facebook, Twitter and Instagram.
- Networking**,** including hosting of scientific meetings at NTNU and representing NTNU at external meetings and conferences. Examples of such activities include NTNU Nano's biennial hosting of the Kavli Prize events and this year's "International Nanoscience Student Festival". We believe such meetings can greatly enhance the international profile of NTNU, and aim to host at least two significant meetings each year.
- Serving as a "shop-window" and contact point for external enquiries related to NanoST.

Mapping of NanoST capabilities and outputs – For the purpose of maintaining an accurate picture of NanoST research across the University, NTNU Nano tracks a variety of key indicators (by faculty and department), including: the numbers of tenured academics, postdoctoral researchers and PhD students; main research areas; the level of NanoLab usage; publication statistics; research volume; and principal funding sources. In order to obtain a more complete picture of the university's activities in NanoST, we believe it would be useful to widen the current mapping exercise to include NanoST equipment, innovation activities, public communication, software development, graduate employment statistics and other relevant outputs. We also believe it would be useful to assess NTNU's standing compared with other NanoST-focused research institutes, with a view to understanding our competitive strengths and weakness. We consider information of this nature to be essential for understanding where NTNU can have the greatest scientific and societal impact, and for developing a sensible and effective strategy for future investments and appointments. (Note, it has been pointed out by the Physics department that, due to the significant amount of work involved, this activity might be better carried out centrally by the university. Alternatively, it might be possible to use bibliometric software to partially automate the procedure).

Education and Training – NTNU Nano has a role to play in ensuring the University offers a balanced range of teaching and training opportunities in NanoST. NTNU currently offers a 5-year MSc in Nanotechnology, which is administered by the NV Faculty and is taught principally by the NV and IE faculties, with research projects available in most NanoST-supporting faculties. The programme attracts strong students, many of whom continue on to PhD-level research. It would be sensible to review the current cap of thirty five students per year, which was set when the course was first established on the basis of the capacity then available within NTNU and the perceived job prospects for NanoST graduates. NanoST forms a component of several other Masters programmes, and it would be useful to assess whether synergies exist between the different courses, and if any opportunities exist for joint, cross-disciplinary teaching.

The university does not currently take a unified approach to PhD teaching in nanoscience. Instead, it is left to individual departments to develop and deliver their own courses. By taking a more coordinated approach to PhD level training, it would be possible to ensure a consistent level of teaching across the university, while also avoiding unnecessary duplication of effort. We will discuss with individual departments the possibility of developing a core curriculum for all NanoST PhD students, on top of which further specialised courses could be added according to the needs of individual departments. In addition to making better use of staff time, this would also ensure a broader education for our NanoST students and provide them with regular opportunities to interact with peers from other disciplines. As part of this discussion, it will be necessary to consider the future of The Norwegian PhD Network on Nanotechnology for Microsystems (NanoNetwork), which has funding until the end of 2019. NanoNetwork has been an effective means of supporting and bringing together

PhD students from across Norway, and NTNU has a key role to play in deciding if and how it can be continued.

Through NTNU NanoLab, researchers receive training on safe cleanroom practice and equipment-specific training on almost 100 advanced tools. The training mainly consists of workshops and courses, with online videos and e-learning solutions currently under development. Following initial training, all users receive hands-on training on the tools they require for their fabrication or characterisation process, as well as follow-up throughout their use of the tool. NanoLab also offers help in designing and establishing base processes for those with no prior experience of micro- or nanofabrication, and aims to be a competence holder by documenting processes developed by current users for future applications. NanoLab reviews its training provision on a regular basis, and welcomes suggestions for improvements and changes.

Innovation and commercialization – NTNU is currently expanding its support for innovation through a three-year investment of 50M NOK in its Strategic Programme for Knowledge-Based Innovation (SKI). SKI aims to stimulate innovation within NTNU by identifying promising ideas and technologies, encouraging a culture of innovation, and simplifying the process of innovation. Key support measures include early (pre-spin-out) stage funding for commercialization, grants for PhD students, general Technology Transfer Office (TTO) support services, and the appointment of 15 departmentally-based "Innovation Managers" (IMs). NTNU Nano will work closely with SKI and the TTO to ensure the services and support they provide meet the needs of NanoST researchers at NTNU. We believe it is especially important that we are able to assign an Innovation Manager to NanoST to track synergies across departments, encourage industrial engagement in all areas of NanoST and to learn and promote "best practice" from universities with a strong track record in nanotech innovation,. We would welcome suggestions for any other measures that would help improve the process of technology transfer. It has been suggested by the Physics Department that the long term goal for NTNU Nano should be to support the establishment of an innovation cluster in nanotechnology in the Trondheim area.

Industrial affiliates programme – To stimulate closer links between NTNU and industry, we will explore the feasibility of setting up an affiliates program for industrial collaborators. In return for an annual subscription fee, affiliated companies would receive a broad range of benefits such as a quarterly newsletter describing the latest NanoST research at NTNU, invitations to affiliate meetings, access to publications, presentations, and patents (including abstracts of recent filings), access to web-based learning materials, and recruitment support based on NTNU's pool of NanoST-trained PhD and Master's students. Other potential benefits to affiliates would be the opportunity to sponsor (and potentially co-supervise) PhD projects of strategic interest, or to request (paid) training in specific areas of NanoST. We recognize that the effort involved in setting up such a programme would be considerable. However, if implemented correctly, the scheme could greatly boost our level of industrial engagement, stimulate new research collaborations, and provide a regular income stream to support a range of NanoST activities. Ideally, the day to day running of the Affiliates Program would be handled by a full-time Innovation Manager appointed under the SKI scheme.

Large Scale Funding opportunities and EU-research – NTNU Nano will support large scale project initiatives in NanoST such as SFF and SFI bids, taking a coordinating role if appropriate. This is likely to be of most value in the early stages of proposal development when the scope of NTNU´s involvement is still being defined, and NTNU Nano can draw on insight from its mapping activities to bring together an appropriate team of project participants.

NTNU Nano has a specific role to play in EU research activities. Together with NTNU's Brussels office, NTNU Nano will identify – and seek membership of – lobby organizations and European Technology Platforms that are of particular relevance to NanoST, with a view to helping NTNU achieve preferred-partner status in research initiatives. NTNU Nano will help the Brussels office find partners for EU initiatives and will support it in taking an active role in the preparation of the FP9 program.

5. NanoST Infrastructure

Experimental Infrastructure: A key priority for NTNU Nano is to ensure NanoST researchers have access to the facilities they need to carry out innovative and internationally competitive research. The largest experimental facility within NTNU Nano is NanoLab – a 700 m^2 cleanroom that forms part of the "The Norwegian Micro- and Nano-fabrication Facility", NorFab. NanoLab is an open access, user-operated facility funded through a combination of user fees, basic funding from the Rector, direct contributions from participating faculties, and funding from the Research Council of Norway (RCN) via NorFab. The facility is managed by a staff of nine full time engineers, who are responsible for maintaining equipment, developing standardized procedures, and providing operator services. Designed as a multipurpose facility for interdisciplinary research, NanoLab comprises a series of vibrationally damped ISO-9 to ISO-5 work zones equipped for chemical processing, thin film deposition, high resolution lithography, soft lithography and nanobiotechnology. In addition, NanoLab offers a number of characterization methods, and a dedicated cleanroom area for education. The emphasis is on general purpose, user-operated equipment that is capable of meeting the diverse needs of NanoLab's broad user base. A complete list of current NanoLab facilities may be found at: https://tinyurl.com/yae5rf9j. (NTNU has a number of additional NanoST facilities outside of NanoLab run by individual institutes, and NTNU Nano has a coordinating role in relation to these facilities to ensure they pursue complementary equipment strategies).

Based on our recent consultation exercise, the principal of issues of concern for NanoLab users are the specific facilities available in the cleanroom, the cost and ease of accessing them, the reliability of their operation, and the provision of training and support. These issues are discussed below.

Access Fees: NanoLab is open to both internal and external researchers. Individual access fees are determined on the basis of the user category (academic or industrial), the required level of access (basic or advanced), and the desired fee structure (hourly or annual – annual only for academic users). Access fees are reviewed annually and set according to the Norwegian cost model for research infrastructures defined by the UHR (see e.g. https://tinyurl.com/ycovphxm). NTNU Masters students are fully funded by NTNU through the direct contribution from the faculties; internally funded PhD students and post-docs pay 10 % of the appropriate access fee, with the rest covered by the Rector and NorFab; while externally funded PhD students and post-docs are expected to cover the full access fee.[*] Academic users from outside NTNU are charged at the academic rate, but can apply to NorFab for a reduction in the cleanroom fees. The NanoLab price policy is described in detail at https://tinyurl.com/y8c2guq5.

Investment plan: New equipment purchases are made on the basis of an investment plan (Appendix 1), which aims to: (i) ensure essential equipment is replaced before it reaches the end of its operational lifetime or becomes obsolete; (ii) solve faults or bottlenecks in the fabrication lines; (iii) minimise downtime due to equipment failure; and (iv) address capability gaps and allow for the introduction of new state-of-the-art technologies. The investment plan is a 'living' document that may be updated on the recommendation of the NanoLab management team or the Advisory Board, although changes are made only if they are shown to be of significant benefit to NanoLab's broad user base, technically feasible, and financially viable. Expenditure below 1.1 M NOK can be approved by the NanoLab Director, while larger expenditure requires approval by the NTNU Nano Board.

Housing of externally funded equipment: The departmental responses to our recent survey revealed a significant demand for new characterization equipment and instrumentation that cannot be met through NanoLab's existing income streams. Much of the requested equipment already exists within NTNU, but is scattered across departments and individual research groups. By transferring – on a voluntary basis – some of this equipment to a well staffed, centralized facility, it would be possible to meet many of the equipment needs identified in the survey with only a modest financial outlay. As a

[*] If suitable funding is not available, externally funded PhDs and post-docs may apply to NorFab for 90 % of the access fee, with the remainder being charged directly to the user.

first step, NanoLab has recently assumed responsibility for an X-ray Photo-electron Spectroscope (XPS) and an Auger Electron Spectroscope (AES), which were previously housed in the Department of Electronic Systems and SINTEF. Our ultimate goal is to provide in a single location a comprehensive suite of characterization methods for nanomaterials, similar to facilities found at other European universities, e.g. the ScopeM facility at ETH Zurich and the CMAL facility at Chalmers. We have given this facility the working title of NTNU NanoScope, and are confident it would operate more efficiently than the current system, in which departments and research groups are required to find the space, manpower and resources to house, operate and maintain each piece of equipment. Benefits to researchers include easy access to a broad range of properly maintained and well supported equipment, while benefits to equipment donors include transferal of maintenance and running costs to NanoScope, together with guaranteed levels of access to the donated equipment, and discounted access to other characterization equipment within the facility. Clear criteria would need to be established for deciding which equipment should be housed centrally within NanoScope and which should be retained within departments/faculties.

As with NanoLab, a staff of full-time engineers would be responsible for maintaining equipment within NanoScope, providing training, offering operator services and developing optimized analysis procedures. Up to 420 m^2 of space within Chemistry Building 1 could be assigned to NanoScope using areas that currently serve as supporting labs, offices and storage rooms for NanoLab. Importantly many of these areas have good vibration isolation and could easily be connected to NanoLab's existing gas lines and process water. NanoScope would run as a sister organization to NanoLab, with the same leadership and a unified staff of engineers. The running costs of the instruments and engineer salaries would be financed through user fees, using a similar fee structure to NanoLab (i.e. different costs depending on user category and desired level of access). Investments in new equipment would be covered by income from user fees and contributions from NTNU and RCN.

The existence of two tightly integrated, properly staffed, and well equipped multi-user facilities, covering both nanofabrication and nanocharacterisation, would be of great value to researchers across the University and would favourably differentiate NTNU from many European competitors, making it a "partner of choice" for multi-institute projects and funding bids, e.g. Horizon 2020.

Computational Infrastructure: The consultation exercise has revealed an urgent need to improve access to small amounts of computing power for nanocomputation. The availability of "low-level" computing power has declined recently since time on NTNU's cluster is now assigned exclusively through the national infrastructure, Sigma2. (Sigma2 distributes computing time on a twice-yearly basis and is not meant for small projects and test runs). The inability to access small amounts of computing power on short time-scales is preventing researchers from undertaking responsive small-scale computational projects or completing the groundwork needed for larger applications to Sigma2. This issue is broader than NTNU Nano and, in coordination with the other strategic initiatives (NTNU Digital and NTNU Biotechnology), we will raise it with the university and look for a workable remedy.

6. Individual Support Mechanisms

This section covers proposed support to be offered to individual researchers.

Internal Funding – Small obstacles can often prevent a research project from getting off the ground or having its intended impact. For example, short-term salary funding may be required to acquire the proof-of-principle data needed to underpin a grant application; a small piece of equipment may be required to carry out a critical experiment; travel funds may be required to establish a new collaboration or attend a scientific meeting; or support may be needed to develop the business case for commercializing a scientific concept. In such circumstances modest amounts of funding can have a significant effect, but obtaining such funds from funding agencies can be difficult, and may not be feasible on the required timescale. To address this issue, the management team believe it is important to introduce an internally-administered funding scheme for competitively allocating low level

(<500000 NOK) funds. The scheme would require a short two-page proposal from (tenured academic) applicants and would operate on a monthly or quarterly cycle to allow fast fund allocation, mirroring flexible funding programmes operated by several other European universities and national funding agencies (c.f. the Impact Acceleration Accounts offered by the Engineering and Physical Sciences Research Council in the United Kingdom). Given the flexible nature of the proposed scheme, we believe it would be most appropriate to seek the requisite funding from the University, and we will develop a case for consideration by the Rector's office. It will be important to distinguish support offered via this route from support that is already available through departments.

Studentship Funding – Since 2008 the Rector has offered two PhD studentships each year for research in "nanotechnology, nanosciences and functional materials", with an emphasis on trans-formative, early-stage projects that have the potential to attract significant follow-on investment from external funding agencies. While such funding has been of signficant benefit to individual research groups, it has had only a limited impact on NanoST research at a university-wide level. The recent call for project proposals in digital transformation, organised by NTNU Digital, offers an attractive model to expand on the existing NanoST studentship provision, and to initiate new and innovative research collaborations across the university. Under the digital transformation call, NTNU earmarked ~40 PhD positions to pursue transformative research in all areas of digital technology. By specifically inviting proposals from cross-disciplinary research teams – involving 3-6 new PhD students supervised by 2-5 tenured researchers from two or more disciplines – the call aimed to create university-wide research programmes capable of delivering major scientific breakthroughs on a five- to ten-year timescale. We believe a similar initiative focused on NanoST would be hugely beneficial, allowing NanoST researchers from across the university to come together to target highly ambitious projects beyond their individual reach. The NTNU Digital call was made possible through exceptional "windfall" funding to the university, and we recognize that it may not be possible to replicate the scheme in exactly the same format. However, we believe that the general principal of funding larger collaborative research programmes capable of addressing strategic priorities is a sound one, and we will accordingly explore options for financing this within the area of NanoST.

7. Next Steps

We recognize the need for a responsive approach to NanoST that evolves over time in light of experience and events, and we will continue to review and update our strategy on an ongoing basis after this date. The plan will be formally reviewed and updated in the second half of 2020.