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NFFA

Nanoscience Foundry and Fine Analysis

D3.6

Design Study of Nano-Bio labs

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Deliverable D3.6: Design Study of NFFA Nano-Bio labs

1. INTRODUCTION

1.1. Purpose of the document

The purpose of this document is to describe the concept for a NFFA Nano-Bio lab for synthesis and research on combined organic/inorganic nanoscale systems and its integration in the NFFA-RI.

1.2. Application Area

The targets of this document are the members of the NFFA Project, the EC Project Officers, and the general public.

1.3. References

Description of Work (DoW). See at web site:
http://www.nffa.eu/ResearchActivityData.aspx?IdRACT=14&idTypeRACT=1

The design study is based on information shared by NFFA partner facilities and during discussions with representatives from several other institutions in the frame of workshops:
1st NFFA Workshop Jun.09, Co-Nanomet Workshop Sept.09, SP&AC Workshop Dec.09. Valuable contributions were also collected during visits at the Molecular Foundry, Berkley and the MPI for Colloids and Interfaces, Potsdam.

1.3.1. Objective of Work Package 3

The Objective of WP3 is the design study of NFFA-RI centres, the technical layout of instrumentation and tools.

1.3.2. Description of work broken down into tasks

The following tasks are defined in WP3:

- T3.1) Design study of the overall infrastructure
- T3.2) Design study of a nanolithography station within the facility
- T3.3) Design study of user-oriented material growth facilities
- T3.4) Design study of user-oriented metrology facilities
- T3.5) Design study of a molecule and nano-particle manipulation lab
- T3.6) Design study of nano-bio labs
- T3.7) Assessment of the possible contribution of existing facilities that could be integrated in NFFA-RI

2. SUMMARY

Task 3.6 describes the concept of Nano-Bio labs for synthesis and research on combined organic/inorganic nanoscale systems and their integration into NFFA-centres. The main function of the Nano-Bio lab will be to provide both, technical and scientific access to state-of-the-art equipment and methods that are complementary to the characteristics of the associated large scale facility. The facility will need to have an ambitious scientific research program in order to maintain the state-of-the-art of the infrastructure and to enhance the methodological development. Characterisation equipment and support labs (chemical synthesis facility, cellculture/biolab) that are necessary for basic, frequently asked for biological research purposes will be available at all NFFA-centres. Additionally, each Nano-Bio facility should provide specialised equipment and expertise for biological applications in the framework of the research focus of the respective NFFA site (automated-, high throughput equipment, microfluidics lab, equipment for combined (organic/inorganic) material synthesis). Suggested focus research areas of NFFA-centres with a particular emphasis on Nano-Biological research, that will have an increasing social and scientific significance, are: Biointerfaces/Biomimetics, Biosensor devices, Nanomedicine, Toxicology, Proteomics/Protein crystallography.

3. MOTIVATION

A significant part of the present achievements in research and technological development is based on the increasing interest in biological research. The integration of biological concepts into technological development has been beneficial in fundamental and applied research, including classical areas as material science as well as emerging research fields as renewable energies and environmental technology. Biology and biotechnology, besides fundamental research more prominently in applied fields as medicine and toxicology, are finding new perspectives and research areas of high significance by accessing questions at the micro- and nanometer scale.

A NanoBio laboratory embedded in a Nanofoundry can provide infrastructure and access to state of the art equipment beyond a basic bio-lab user facility. The main motivation will be to provide access to methods (both, technically and scientifically) that are complementary to the possibilities of the associated large scale facility (LSF) and to establish and maintain synergies with other associated labs with different research focus.

3.1 Potential for a NanoBio laboratory in context with fine analysis at LSFs

Both, research and methodological development at LSFs and nanoscale biological research benefit from better integration of biological research.

- Biological research is stimulated by access to high-throughput, high-resolution characterisation techniques at LSFs and access to, respectively synergies with, micro- and nanofabrication research groups as well as by access to state of the art techniques.
- Methodological development at LSFs is stimulated by biological research not only by new technical challenges that have to be addressed, but also because biology provides new perspectives and research fields for in-house research.

Researchers will take advantage of the focused infrastructure at LSFs and the associated NanoBio labs – experimental expertise on-site, stimulated and maintained by in-house research, as well as established standards for sample preparation and measurement conditions. One key issue will be that the NanoBio labs will also have to provide infrastructure for the production and handling of biological samples on-site that are sensitive to transport (particularly living cells) and storage conditions, or import permit declarations. The increasing awareness of risks and security implications of biological samples make on-site sample production attractive, or even necessary.

3.2 Synergies with other NFFA-facilities

Synergies with micro- and nanofabrication facilities, material growth facilities, molecule- and nano-manipulation facilities and nanolithography stations

A central motivation for establishing a NanoBio-laboratory in an NFFA facility are the possible synergies between biological research and nanofabrication facilities in a scientific environment. The significance and the options arising from synergies with micro- and nanofabrication facilities, material growth facilities, molecule- and nano-manipulation facilities and nanolithography stations are partially outlined in the respective Task reports (e.g. Task 3-2, soft lithography, Task 3-3, intelligent surfaces, lab-on-chip). Scientific cooperations between NanoBio-labs and labs with focus on research and development of micro- and nanodevices will be much facilitated by the vicinity of the labs, the mutual stimulation by LSF-based research and the possibility for joint involvement in LSF-user experiments.

The interaction of biological systems with micro- and nanostructured artificial and/or inorganic interfaces is very relevant for nanomedical research and in emerging fields such as (nano)toxicology. Nanoscale interfaces are also relevant for climate research, for studying chemical reactions at interfaces of micro-/nanoparticles like fine dust, industrial and natural aerosols or colloidal aggregates in water and soil. Research on toxicology, ecotoxicology and climate research has lately experienced increasing support and attention in Europe, as can be seen from the public funding policies and the founding of dedicated institutions and research groups. Research on nanoscale phenomena was recognised as an important precondition to address the challenges in these fields and will have an increasing demand for LSF based experiments in the future.

Classical biology, molecular biology and proteomics will increasingly profit from cooperation with disciplines like chemistry, nanoscience and -technology, not only by the development of new experiments and applications, but also by new research topics. One prominent example for the significance of the interaction of biological systems with artificial interfaces is the interaction between living cells and artificial surfaces, such as prosthetics and other implants in regenerative medicine. Micro- and nanotechnology provide the opportunity to control or mimic specific interface properties. This enables to study and improve e.g. the compatibility of stents in the aorta [1] and the use of peptide scaffolds as template for the growth of a functional nerve cell network [2]. An example from the field of materials engineering is the use of protein self assembly and bacterial S-layers [3] as templates to generate nanostructures of inorganic material that can be functionalised. Other techniques that involve interactions of biological and inorganic nanostructures and are relevant for nanomedical applications, are the design and synthesis of drug delivery systems, like mesostructured or hybrid nanoparticles [4], particles with tailored surface and the design of magnetic particles for diagnostic applications [5].

Thin film- and biochip fabrication are technologies required for the design of lab-on-chip applications, biosensor technology and other analytical devices based on the assembly of biological and nanotechnological components. The development of such devices has made rapid progress during the last few years, so that they can now be used for detection of enzyme activity [6] and clinical biomarkers [7] in medical applications, but also for highly sensitive environmental monitoring [8].

Synergies with an advanced general Metrology facility

The crucial parameters determining the interaction of nanoscale structures with biological systems seem to be predominantly geometrical ones, like size, shape, surface area or -charge. Nanomedicine and nanotoxicology are therefore research areas that have an urgent need for means to identify and characterise nanoscale structures and to quantify these parameters, in order to generate reproducible conclusions in issues as the biocompatibility of medical devices or the toxicity of a pollutant. Collaboration with a general Metrology facility is necessary to develop the methodology and standards for such measurements.

4. RELEVANT TECHNICAL CRITERIA

NanoBio research is a very diverse field, different perspectives and contexts and the fast developments in this research area require most of all flexibility and adaptability of the infrastructure as a precondition for long term success. On-site expertise of the concerned people is also important in the technical context, but not, in a strict sense, a technical criterium and will therefore be discussed below (section 5). Technical specifications may vary between different research sections, but there is a strong potential for synergies with other NFFA labs/facilities. For example, some instrumentation can be shared between biological and 'non-biological' research fields if flexibility for sample environments and specialised setups is permitted. Some of the infrastructure of the NanoBio-facility may even benefit from being located inside a clean (room) area, if mutual contamination can be avoided. Even though the focus is on the same, shared small scales, biological samples are diverse and will require diverse environments.

Irrespective of user access policy (section 4.1), scientific collaborations etc., two lab categories will have to be distinguished:

i) User facilities with standard equipment and state of the art instrumentation, providing on-site access to specialised complementary characterisation techniques and sample preparation infrastructure, available at all centres (sections 5.1, 5.2) and

ii) Labs run by research groups that establish and enhance on-site expertise and that maintain the state of the art by providing the driving scientific motivation for the methodological development (see section 5.3: In-house research sections - NanoBio Labs). This infrastructure will be provided according to the scientific focus of the respective NFFA-site.

Research groups are also able to develop the synergies with other related research facilities, establish internal and external collaborations and can act as an integrating platform between the research communities. A prominent example for the importance of those functions of in-house research is the Molecular foundry / Berkeley lab (http://foundry.lbl.gov/).

4.1 Mode of operation and access

Experiments involving biological samples will often be non-standard and require experience with the particular sample and background knowledge in the respective field as well as experience with the instrumentation. A scientific collaboration between the external users and the on-site staff may be required in these cases. Some techniques may require dedicated scientific staff doing research in the field or on the technique itself to keep the facility at the cutting edge of technology.
A certain critical number of technical and scientific staff will be necessary to maintain also a basic biological infrastructure at a level that is scientifically state-of-the-art and good practice regarding safety.

The access for users to equipment of the NanoBio lab should be organised in three main modes, depending on cost and robustness of the equipment and the scientific needs of the experiment.
Open access equipment implies that the LSF users are enabled to operate the equipment themselves. Expert staff will still be required for proper maintenance of the equipment and training of the users.
Limited access to equipment implies that only users with frequent use of the tools over a long time (e.g. PhD students or researchers permanently located at the site) are allowed to operate the equipment.
Remote access is the mode of operation for equipment that, due to a high degree of sensitivity and risk of damage by improper use, is only operated by dedicated staff.

4.2 Required environment

Specifications and regulations for Biolabs overlap partially with cleanroom specifications, possible synergies with other NFFA labs also exist for the environments required for samples and instrumentation.

Specifications and regulations for Biolabs, storage and handling of biological samples
i) Bio-certified staff, lab- responsible person, according to regulations

ii) Lab environment according to regulations for Biolabs. A separate, closeable room is required for cell culture, to avoid contamination of the cells with other organisms.
iii) Environmental conditions for biological samples should be controlable, during the LSF experiments as well as in the lab environment: control of the lab climate for sample requirements, installation of a 4°C room, and the possibility to produce extreme conditions for measurements, when required.
iv) Equipment (and staff) for handling and disposal of biohazardous materials (located at a specialised NFFA facility).

5. TECHNIQUES AND REQUIRED INFRASTRUCTURE

The key for exploiting the full potential of a LSF associated lab facility will be in creating a research environment in which not only the vicinity of a lab to a beamline (by means of a direct or effective physical connection) creates advantages and new experimental options. The labs and beamlines should (on the basis of organisational infrastructure and scientific interdisciplinarity) be in the position to develop experiments that reach much further by exploiting the potential provided by the availability of several complementary techniques for one experiment, like e.g. for observing complementary chemical and structural processes at several scales. To create a fruitful and dynamic research environment that attracts groups with interesting and significant research ideas with the need for such experiments, it will be necessary to not only establish a good scientific cooperation between the NFFA facility and the LSF, but also to be embedded in the scientific environment of the LSF, the universities and science parks. The research should, of course, relate to the scientific and instrumentational emphases of the associated LSF and with already existing user communities (like e.g. a proteomics community) and their expertise, standards and infrastructure for *in-situ* experiments. At NFFA centres with specialised biological research labs, the scientific emphases should be chosen to make an optimal complement and to find common interests for collaborations with research facilities and groups that are located in the region. Research themes with increasing significance and a strong LSF - affinity are:

- Biointerfaces, Biomimetics
- Biosensor devices
- Nanomedicine, Toxicology
- Proteomics, Protein crystallography

Even at NFFA centres that have their emphasis not in a biological research area, there will be the need for a basic infrastructure also for sample preparation and characterisation of biological samples. This includes support labs (as provided by many LSFs) as well as characterisation tools that will be provided for other research areas and require only some adaptability, some precautions and suitable environmental conditions to be also useable for tasks with a biological component. How this basic infrastructure can be provided and how such adaptability or precautions might look like specifically, will depend on the actual situation and the scientific focus of the centre. At this stage only general suggestions can be made. A consideration of possible biological tasks to be integrated in the framework of the research program of the site, at an early stage of the planning and set-up of the infrastructure, should provide such adaptability and can help to avoid costs and shortages in the future.

5.1 Support labs

User facilities with standard equipment that can be accessed by users for purposes of sample preparation and handling and that are maintained by technical staff (according to regulations, s. biolab safety).

Chemical lab: Standard chemical lab equipment, chemical synthesis facility (includes: fume hood, heating/stirring plates, microcentrifuges, ultrasonic processor, microscope with CCD camera, glove box with

controlled atmosphere, standard chemical lab supply). A chemical support lab will also be useful for other NFFA-facilities

Microfluidics lab: Stopped-flow- / rapid mixing equipment, automated, high throughput facilities for biological samples.

Bio-lab: Standard equipment includes a biological safety cabinet, laminar-flow box, CO_2-Incubator with inverse microscope with CCD camera, autoclave. The basic layout of the Biolab should provide sufficient space/infrastructure to allow an upgrade of the biological safety level and the installation of additional equipment.

5.2 Characterisation and Analysis labs

Providing access to state of the art instrumentation for sample characterisation, with techniques that give complementary information to the experiments that are carried out at the LSF, is one of the main purposes of the NFFA project. Some of the instrumentation required for biological research will also be necessary for other groups and can be part of the general metrology of an NFFA facility. In some cases specialised setups and add-ons may be required and in many cases specialised expertise for the application of a method for the respective biological sample will be required – including the suitable preparation of the sample and the interpretation of the data. This may require scientific collaboration between users and on-site research groups. Scientific staff that is integrated in on-site research may be required for further technical development of non-standard, emerging techniques and particularly for development and adaptation of applications that are specifically important for the needs of the NFFA facility at which they are located.

Although the speed, at which technical development of the techniques is progressing, makes it difficult, at the stage of a design study, to foresee future possibilities, some examples of important characterisation infrastructure can be given. Special requirements for biological research may be:

Confocal (fluorescence) microscopy and *in-vivo* fluorescence imaging are typical techniques with increasing importance for biological research on cell- and tissue level. Super-resolution microscopes (e.g. STED Leica, STORM Zeiss) allow cell imaging below the diffraction limit (down to <10 nm) and will be much asked for tools for nanobiological research in the future.

A very useful microscopical technique (not only for NanoBio-research, but generally for avoiding vacuum effects) is Field-emission environmental scanning electron microscopy (FE-ESEM). Samples (*e.g. humid samples, cells, biofilms...*) can be observed in low-vacuum mode (without the need for sputtering) or in environmental humidity conditions. With suitable sample stages (temperature control) and sufficient space provided in the sample chamber for experimental *in-situ* setups, experiments at different temperature and humidity can be carried out while directly observing the sample [9, 10]. Specially designed devices also allow the observation of humid or even living (for a short time) samples by TEM. *E. coli* cells have e.g. been observed using a microchip with SiO_2 nano-membranes [11]. (Micro-) Spectroscopy (Raman, UV-VIS, IR) and X-ray fluorescence / absorption spectroscopy are Synchrotron-based methods with increasing relevance for biological research [12].

Instrumentation that will be very interesting in the future for biological research and that needs research groups for development, would be:

(NMR-) Spectroscopy (particularly when applied on biological samples) and other non-standard spectroscopical methods would benefit from a dedicated research section. Scientific collaboration is necessary for special research fields with new kinds of samples or for further technical development of spectroscopical methods.

Cryo lab: Cryo- Electron microscopy / -tomography provides a possibility to study biological samples without the preparation artefacts common for non-cryo SEM/TEM techniques, but at a spacial resolution that is

comparable and complementary to the size range at which X-ray experiments give information. They provide a possibility to directly observe (at least frozen snap shots of) processes happening inside cells and solutions. Cryo technologies are not yet widely distributed and therefore have both, a large research and development potential, and have to be maintained by a research group. (The potential of cryoEM embedded in a research group can be assessed by the respective department of the TU/Eindhoven (http://www.cryotem. com).)

5.3 NanoBio Labs - In-house research sections

Biointerfaces, Biomimetics

Biological mechanisms at the nanoscale are both, a rich source for 'bioinspired' and 'biomimetic' technological development and an important research field for medicine, toxicology and environmental science. Promising future research areas in this field include:

- Biochemistry of micro- / nanomaterials (nanotubes, semiconductors, oxide thin films, nanoparticles)
- Immobilisation (electro-, photochemical, selective binding, self assembly)
- Bio-/inorganic interfaces with amino acids, peptides, enzymes, cells, etc., that retain functionality
- Hard/soft interface formation and stability
- Biomineralisation
- Control of (bio-)functionalisation (tunable selectivity)

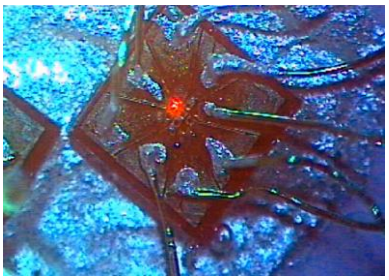

Figure 1 T3-6: ***Nuclear Label*** *- A single cell nucleus emitting light from red and green fluorescent probes used to detect cellular abnormalities.* (*© Cardiff University*)

Biosensor devices

Biosensors are an assembly of biological recognition elements and signal conversion elements and are therefore probably the best (at least the most prominent) example for a successful fusion of micro-/nanotechnology (electronics, thin film technology, …) on the one hand and molecular biology and proteomics on the other hand. They provide the opportunity to design tailored, highly sensitive and specific tools for complex medical and environmental diagnostics.

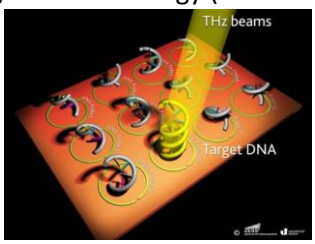

Figure 2 T3-6: *Vision of a biochip: Array of 3x4 ringlike resonators, ca. 0,7mm x 0,9mm in size.* (*Univ. Siegen/THz Biosensorik*)

Nanomedicine

The combination of nanotechnology (particularly the production of micro- and nanostructures) and molecular biology (cell-, tissue research, molecular recognition and binding, …) is a precondition for the development of nanomedical applications, for the design of nanodevices for a controlled, specific release of substances for detection, analysis and treatment of deseases. Typical applications that benefit from combined LSF/nanolab access are e.g. functional surfaces (prostetics, lab-on-chip, ..) and nanoscale drug delivery devices (nanoparticles, liposomes, cubosomes, shells ...).

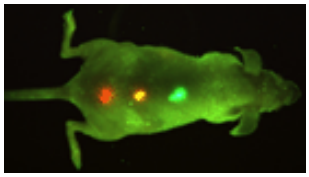

Figure 3 T3-6: *Mouse with fluorescent labels*

Toxicology

Nanoscale particles can have an adverse impact on health and environment, as known for e.g. airborne particles and nanofibres from natural or industrial sources. A toxicological risc assessment throughout the lifecycle of engineered and unintentionally produced artificial nanoscale particles is made necessary by the increasing distribution of these products. Studies on the properties of nanoparticles and their aggregates, on their behaviour in various environments and their effects on living systems requires access to both, LSF techniques and specialised labs. Advanced toxicological research will require cooperation with biological or medical institutes close to the LSF. A close cooperation with nanofabrication facilities and characterisation facilities could provide an environment for integrating a first toxicological assessment of new nanoscale products already at the development stage.

Proteomics, Protein crystallography

The proteomics research community is well established and organised at LSFs, an integration of this field (see Task 3.7, cooperation with existing facilities) into technological and applied research will be a main feature of a LSF-associated NanoBio lab. Proteomics research itself will gain access to techniques and equipment that provide complementary information on the functional and (micro-) environmental context, e.g. by kinetic (*in-situ*) studies mimicking biological processes. Cooperation with micro- and nanofabrication labs will be particularly interesting for protein crystallisation studies, by providing tools for (*in-situ*) experiments on seeding and nucleation, crystallisation and growth on surfaces or in tailored (e.g. confined, functionalised) environments.

TABLE 1 gives an overview of equipment, infrastructure, collaborations and LSF based techniques that will be necessary or useful for a successful in-house Nano-Bio research program in the above listed areas

TABLE 1: Methods and Infrastructure interesting for in-house NanoBio - research

	Methods at NFFA facilities / NanoBio lab	**LSF based techniques**	**Environmental requirements / collaborations**
Biointerfaces, Biomimetics	Surface characterisation (AFM), Confocal (fluorescence) microscopy, In-vivo fluorescence imaging, (Near-field-) optical microscopy, (Environmental-)SEM, TEM, NMR-Spectroscopy	X-ray and Neutron diffraction and (inelastic) scattering, (Micro-) Spectroscopy (Raman, UV-VIS, FTIR)	Clean room, Biolab with standard equipment
Biosensor devices	Surface characterisation (AFM, Spectroscopy), Brewster-angle microscopy, Ellipsometry, SPR-, electrochemical, optical (bio-) sensors Microarrays and read-out systems Micro-/nanodeposition systems	X-ray and Neutron diffraction / (grazing incidence GI -) Scattering, Spectroscopy ...	Chemistry lab, standard Biolab facilities, Thin film production and patterning facilities (*printing, spinning, coating, dipping, Langmuir Blodgett troughs*...), µ-/nanofabrication (*lithography, evaporation , etching*..)
Nanomedicine / Toxicology	Biolab with standard equipment Microfluidics (Stopped-flow, rapid mixing), High-throughput systems, Microfabrication, Microarrays, Printing (InkJet)	X-ray and Neutron diffraction/ Small angle scattering, Spectroscopy, (Protein-) crystallography	Chemical laboratory with standard equipment, Chemical synthesis facility, Clean room Synergies with Micro- and Nanofabrication, Nanolithography, Molecule and Nano-manipulation, Material growth facilities,
Proteomics / Protein crystallography	High-throughput systems Protein separation, Protein purification (Chromatography), Surface-enhanced laser desorption/ionization (SELDI), 2D gel electrophoresis	(Protein-) crystallography / Image analysis through standard protein databases, Small angle X-ray scattering	Chemistry lab, standard Biolab facilities, Synergies with Micro- and Nanofabrication

6. COST ESTIMATE

Characterisation equipment and support labs that are necessary for basic, frequently asked for biological research purposes will be available at all NFFA-centres. Additionally, each Nano-Bio facility will provide specialised equipment and expertise for biological applications in the framework of the research focus of the respective NFFA site. TABLE 2 refers to such a basic infrastructure, the staff numbers (technical and scientific staff) are an estimate of the critical number of people necessary to provide i) state-of-the-art scientific standard of user support, ii) third party funded research projects and iii) good lab practice. TABLE 3 gives an estimate for additional costs of an NFFA site with focus on biological research. It is not decided at this point of the design study, how many of such infrastructures will exist, therefore the given numbers refer to one specialised facility, co-located with a general "Common Metrology" facility and a complementary Nanofabrication/-manipulation facility that will have a comparable number of staff and equipment that will be shared in the framework of joint research.

TABLE 2: Estimate for the basic Nano-Bio Infrastructure present at all NFFA-centres (numbers for 4 centres).

		Investment per centre	**Maintenance (total)**	**Technical & Scientific Staff**
Support labs (standard equipment)	Chemistry lab, chemical synthesis facility	20 - 150 k €	100 k€ /a	8
	Biolab (safety cabinet, laminar-flow box, CO_2-Incubator, PCR)	100 - 200 k €	100 k€ /a	12
	Microfluidics lab (stopped-flow, rapid mixing)	100 – 200 k €	400 k€/a	8
Additional equipment*	Spectroscopy UV-VIS spectrometer	20 – 50 k €	400 K€/a	4
	(Near-field-) optical microscopy, Confocal (fluorescence) microscopy, In-vivo fluorescence imaging,	250 - 1000 k €	400 K€/a	4
	Protein separation, Protein purification Chromatography	20 - 50 k €	100 k €/a	4
	Surface-enhanced laser desorption/ionization (SELDI), 2D gel electrophoresis	25 - 35 k €	100 k €/a	
	Mass spectrometry HPLC	150 k € 50 - 150 k €	100 k €/a	
* Examples for Equipment used frequently for Bio-purposes. Some of the tools will be present as "Common Metrology" (s. T3.4). The actual number of equipment must be decided according to the needs of the site / the respective research program. Therefore the **Investment** numbers are per instrument resp. per site. Numbers for **Maintenance** and **Staff** refer to four centres.				
Support lab in cooperation with Nanomanipulation facilities:				
Optical tweezers, Single particle chemistry on biological macromolecules		100 - 500 k €	400 k €/a	8

TABLE 3: Estimate of additional costs of one Nano-Bio Lab at an NFFA-centre with emphasis on biological research

		Investment	Maintenance	Technical & Scientific Staff
Support labs (standard equipment)	Chemistry lab			1
	Biolab (safety cabinet, laminar-flow box, CO_2-Incubator, PCR)			1
	Microfluidics lab (stopped-flow, rapid mixing)			1
Characterisation labs **NanoBio****	Spectroscopy UV-VIS spectrometer			1
	In-vivo fluorescence imaging, STED super-resolution microscope	250 - 1000 k € ~ 1 M€	100 K€/a	1
	Protein separation, Protein purification Chromatography	10 - 50 k €	25 k €/a	1
	Surface-enhanced laser desorption/ionization (SELDI), 2D gel electrophoresis	25 - 35 k €	25 k €/a	
	Mass spectrometry HPLC	150 k € 50 - 150 k €	25 k €/a	
	(Environmental-)SEM	450 k €	25 k €/a	1.5
Characterisation labs **shared Metrology*****	TEM	250 - 1000 k €	200 k €/a	2
	X-ray lab (SAXS/WAXS/GISAXS)	300 - 600 k €	40 - 70 k € (10-20/unit)	3
	AFM, Surface characterisation	60-300 k€	20 k€/a	2
	Brewster-angle microscopy, Ellipsometry	35-100 k €	10 k€/a	1.5
** Nanobio Metrology (used frequently for Bio-purposes) that should be best located (physically) inside the Nanobio facility and could be accessed by other users if no conflicts arise from mutual contamination or similar reasons. *** shared Metrology that will also be used extensively by other Labs and could be located in a Metrology facility, but considering the restrictions given above.				
Specialised Characterisation/Support labs with shared Metrology:				
Cryo lab (CryoEM, plunge freezing, Cryo microtome)		~ 600 k € - 4 m €	50 - 100 k€/a	3
Optical tweezers, Single particle chemistry on biological macromolecules		100 - 500 k €	100 k €/a	1 (additionally)
NMR-Spectroscopy lab		80 - 1000 k€	100 k€/a	3
In-house research sections				
Biointerfaces, Biomimetics			75 k€	4
Biosensors, Thin film technology			75 k€	4
Nanomedicine, Toxicology			75 k€	4
Proteomics, Protein crystallography			75 k€	4

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