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NANORUCER

"Mapping the NANOtechnology innovation system of RUssia for preparing future Cooperations between the EU and Russia"

Overview of possible topics for cooperation:
A roadmap towards joint research activities

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Contents

Introduction and approach

This paper summarises core topics suggested for future cooperation between European and Russian groups in the field of nanotechnology and nanomaterial. The identification of these opportunities is based on various strands of NANORUCER research. We started with a performance analysis of R&D activities in nanotechnology and nanomaterial in European countries and Russia, using bibliometric and patent indicators. This analysis allowed to identify specialisation patterns of Russia compared to other regions of the world.

A second core activity within NANORUCER was the mapping of the Russian nanotechnology sectoral innovation system. Key actors of the nanotechnology innovation system could be identified and in particular their competences and interest in future cooperation could be elaborated. All in all 84 R&D organisations and 50 companies suggested topics for future cooperation.

Thirdly, the European situation in nanotechnology and nanomaterial R&D was analysed based on already available information from other projects and studies. Thereby European competences could be assessed in a SWOT analysis.

Fourthly, a very important contribution to the identification of future opportunities for cooperation was made by representatives of the Russian nanotechnology research communities during two NANORUCER workshops in Moscow held in January 2011 and April 2011.

A final strand of information was the assessment by European experts which was carried out during a workshop in Brussels in March 2011, followed by a series of personal interviews in order to assess cooperation opportunities.

In order to select core topics for future cooperation the following set of criteria was applied:

- Competences and capacities: Cooperation would only be meaningful if both partners could contribute required competences in the fields under consideration and also the needed capacities in terms of human resources, equipment and infrastructures.
- Synergies: Competences and capacities of cooperation partners should be combined in a way which allows to take advantage of synergies.
- Mutual benefit: The benefit from cooperation should not be one-sided but rather be generated for both parts of the cooperation in a comparable way.
- Competitive advantage: Via cooperation a position of competitive advantage should be achieved by the cooperation parties which for example should also consider the potential to secure knowledge by IPR.

- High impact: Cooperation topics should have the potential to contribute to handling grand challenges, thereby generating future economic, social or environmental impact.
- Different time perspectives: Topics should be differentiated along the timeline and include short-term (2-4 years), medium-term (4-6 years) and long-term (7-10 years) activities.

For describing the opportunities for cooperation a strategic framework was developed. Accordingly topics were mapped along three main dimensions:

- Innovation areas related to grand challenges
- The enabling dimension including components, process-means, methods, nano-structures and nanomaterials, tools, models and equipment
- Scientific disciplines.

Following this approach a total of seventeen core topics was identified which have been classified into seven fields. Each topic is described with a short one or two-page profile summarising the main features of the topic according to the described dimensions. Finally a roadmap is developed positioning the topics along the timescale and indicating short-term, medium-term or long-term opportunities for cooperation.

In this paper we first present an overview of the seventeen topics. This is followed by the individual profiles of the seventeen topics. Finally the roadmap summarises the time horizon of future opportunities for cooperation.

Overview of core topics

Area	No.	Topic
Nanometals	1	Plasma technology for production of metallic nanoparticles/ -structures
	2	Metallic nanoporous filters/membranes
	3	Nanometals for extreme conditions
	4	Superhard/-tough composites with superconducting properties
	5	Vacuum-tight X-ray transparent Beryllium components
Nanoceramics	6	Process technology for nanoceramics
	7	Electroceramics
	8	Coatings for high-temperature shielding
	9	Shielding materials for electromagnetic radiation
Carbon-based materials	10	Nanocarbon-based sensors (e.g. CNT, graphene)
Nanomagnets	11	Nanomagnets and their optimized production
	12	Electronics/electronic devices based on spintronics
Sensors and Instruments	13	Plasmonic sensors and devices
	14	Advanced UHV-setup for analysing and modelling surface reactions for nanoelectronic devices
Superconductivity	15	Theory for nanoscale enhanced high-temperature superconductivity
	16	Nano-analysis and applications for superconducting devices
Quantum computing	17	Theoretical models for quantum computing

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Profile of topics of interest between RF and EU

Topic No. 1	Plasma technology for metallic nanoparticles/-structures
Area	Nanometals
Characterization	Metallic nanoparticles (NP) are basic building blocks for coatings and bulk materials. Nanograins in metals and coatings show improved hardness, corrosion and resistance compared to microscaled materials. Generating nanoscaled metallic structures on surfaces e.g. by plasma technology will be more important in the future. Beside the high surface area of NP also optical, electronic/magnetic properties are of importance.
Relevance for grand challenges and potential impact	Topic has high relevance in the field of energy (bulk materials and coatings e.g. batteries, fuel cells, wear resistant coatings), health (biosensors) and ICT (metallic nanostructures on surfaces as sensors)
Main R&D needs and barriers	Plasma technology is established for NP production. Main R&D needs are better control of NP sizes by flexible methods for production, including process simulation/control based on modelling tools. Understanding transport properties of nanoclusters will also allow better process control.
Time scale *(short: 2-4 y, medium: 4-6 y, long: 7-10 y)*	Nanoparticle production methods can be optimized in short term, nanostructured surfaces in medium term
Synergies	RF has high competences in metals processing, plasma technology and modelling The EU is looking for upscalable production technologies for nanoparticles and /-structures
References	No projects/ activities between RF and EU in the field of plasma technologies for metals Interest of actors in RF is visible Possible dual use should be considered (e.g. explosives) RusNano-Project: Clean Nanopowder production (Ni, W, Mb, Co, Rh) with Mendeleev Tech. University, St. Petersburg State University etc.

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Topic No. 2	Metallic nanoporous filters/membranes
Area	Nanometals
Characterization	Nanoporous materials are useful for separation of low molecular weight compounds or even gases. Ceramic materials are used for these purposes in some fields. The brittleness of ceramics however can be detrimental in some cases. Metals show higher ductility at higher temperatures and can also be chemically or catalytically active for separation of various compounds. The control of pore sizes in the low nm-regime including their homogeneous distribution however was not shown for metals so far.
Relevance for grand challenges and potential impact	Topic has high relevance in environmental and energy applications working at elevated temperatures such as oil refineries, gas separation (CO_2), hot gas filtration, catalysis etc.
Main R&D needs and barriers	Metallic foams with pores above 100 nm are described, but nanoporous bulk metals with defined small pores and high flux density combined with good mechanical and thermal properties need more R&D especially as far as processing is concerned. Thin nanoporous metallic films on porous ceramic substrates might also be an option including the use of nanoparticles on ceramics as catalysts
Time scale *(short: 2-4 y, medium: 4-6 y, long: 7-10 y)*	First components with pores around 100 nm could be available short term (improved metal foam technologies), below 100 nm or even below 10 nm pore sizes will be available medium to long term
Synergies	RF has competences in the field of nanometals and also interest in components for high temperature use in power plants, oil refineries etc. EU competences in the field need to be explored in more detail, in general there is interest insuch materials.
References	Actors in RF visible, EU status in terms of ongoing R&D projects unclear RusNano-Projects in the field of nanoporous membranes only at low to medium temperatures so far.

Profile of topics of interest between RF and EU

Topic No. 3	Metals for extreme conditions
Area	Nanometals
Characterization	High surface/interface area in nanometals, composites and coatings can improve mechanical and chemical properties, which lead to higher service temperatures, longer service life (abrasive wear) and better corrosion resistance.
Relevance for grand challenges and potential impact	Topic has high relevance especially in the field of energy (including machinery, power plants, aviation, and thermal energy systems) in order to improve energy efficiency and service life.
Main R&D needs and barriers	Further research is needed for a better understanding of the nano-scaled effects on various properties. It is necessary to prove that lab scale results for nanoscaled materials can be implemented in indus-trial relevant processes. Process control of relevant properties (includ-ing modelling and optimization tools) is key topic.
Time scale *(short: 2-4 y, medium: 4-6 y, long: 7-10 y)*	First applications have been implemented, however cooperation with industry is necessary to further explore and transfer the technology more markets, which can be done on short to medium time scale.
Synergies	RF has high competencies and a strong interest in the field of metals, processing and modelling. The EU is also interested in advanced materials for extreme condi-tions, which gives good complementary competencies and interest.
References	Various RF actors available. Materials for extreme conditions including metals part of EU calls RusNano-Project with Kurchatov Institute: Multilayer nanostructured coatings by PVD for highly wear resistant coatings on metals (mechanical engineering, aviation industries etc.)

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Topic No.4	Superhard/tough composites with superconducting properties
Area	Nanometals
Characterization	Superconductors can find more applications for transmission of electricity if their mechanical properties (brittleness) could be improved. Metal matrix nanocomposites with superconductors use the high surface and interfaces in nanoscaled materials in order to combine excellent mechanical with electronic properties.
Relevance for grand challenges and potential impact	Mechanically robust (hard/tough) superconducting composites can be used for cryogenic techniques, wear resistive parts of superconductive devices and in microelectromechanical systems (energy, ICT). This topic could also be relevant for electric cables (processing of high-temperature superconductors) with improved mechanical properties.
Main R&D needs and barriers	R&D needs for this topic covers all areas from basic understanding/ modelling of the interface metal/superconductor up to processing.
Time scale *(short: 2-4 y, medium: 4-6 y, long: 7-10 y)*	Topic can be implemented only in medium time frame (4-6 years)
Synergies	RF has excellent competencies in the field of metals, superconductors and modelling EU interest in the field probably only modest
References	RF actors and interest visible EU: small markets, see also superconductivity in general.

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Profile of topics of interest between RF and EU

Topic No. 5	**Vacuum-tight X-ray transparent Beryllium components**
Area	Nanometals
Characterization	Beryllium is used as lightweight material in rocket parts, as window material with high X-ray transparency and in nuclear energy applications including fusion reactors. Beryllium nanopowders can be used to form bulk materials or foils with high transparency combined with good mechanical properties (plasticity, toughness).
Relevance for grand challenges and potential impact	Be is useful as X-ray transparent material for synchrotrons, X-ray equipment, free electron lasers, fusion equipment etc. Some of them are important for energy and healthcare (diagnosis) uses.
Main R&D needs and barriers	Processing of Be-nanopowders for bulk or thin components is not straightforward and more R&D is needed. Alternatives (Be-free materials) with the same performance are also looked for worldwide.
Time scale ***(short: 2-4 y, medium: 4-6 y, long: 7-10 y)***	Applications of Beryllium powders or composites have been described, but little research so far is dealing with the nanoscale enhancement of mechanical properties in order to be able to form thin components with good mechanical properties. Time scale would be medium.
Synergies	RF has competencies in the field and also strong interest. Politics of the EU not clear in this field, maybe interesting for new nano-infrastructure projects or fusion experiments (ITER) Small industrial relevant market
References	RF has projects in the field, Dual-use has to be checked

Profile of topics of interest between RF and EU

Topic No. 6	**Process technology for nanoceramics**
Area	Nanoceramics
Characterization	Ceramics with nanoscaled structures/grain sizes show improved mechanical and thermal properties. Coatings, bulk materials and composites are often based on processing of nanoceramic powders. Beside the production of nanoparticles, the proper processing in order to keep the nanoscale features intact until the final product affords special methods for thermal treatment (fast annealing and sintering processes, use of microwaves or laser systems). Chemical methods allow homogeneous doping of ceramics, distribution of sintering aids or processing of transparent ceramics.
Relevance for grand challenges and potential impact	Topic has high relevance to all areas where ceramics are used mainly energy, health and environment. The topic is also relevant for topic 7 (electroceramics) with uses in the field of ICT. Ceramic multilayer processing: see also thermal barrier coatings.
Main R&D needs and barriers	The basic principles and structure/property relationships for nano-ceramics are well known; however some processing techniques can so far only be used on small scale and have not been implementable in large scale production facilities (especially bulk ceramics). Upscaling processing techniques including chemical nanotechnologies are there-fore key areas.
Time scale ***(short: 2-4 y, medium: 4-6 y, long: 7-10 y)***	Topic provides a number of close to market applications and the optimization of processing could be realized on a short term time scale of 2-4 years for coatings, medium term for bulk materials.
Synergies	RF has high competencies in the field of powder processing (metals and ceramics), ceramic coatings, techniques for fast application of high energy doses are well known, and RF has a strong interest in the field. EU member states are also active in the field and therefore provide synergy potential.

Topic No. 6	Process technology for nanoceramics
References	Cooperations between RF and European countries on bilateral scientific basis have been active since quite some time. Projects/ activities between RF and EU: has to be checked. EU-calls have been published in the field, number of existing coopera-tions between RF and EU needs to be checked. RusNano-Project with Tomsk State University: Nano-Oxide coatings (micro-arc-technology) for metals (wear, corrosion protection); fur-ther RusNano-Project: Nanostructured ceramics for tribochemical, high friction (oil industries, metalworking industry) applications

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Topic No. 7	Electroceramics
Area	Nanoceramics
Characterization	Nanoscaled electroceramics (coatings, multilayers or composites) can lead to improved electrical and mechanical properties of various components (microelectronic substrates, transducers, sensors, actuators etc.). Piezoceramics without Pb (environmental concerns), electroconductive and ion conductive ceramics e.g. for use in fuel cells are also key areas.
Relevance for grand challenges and potential impact	Topic has high relevance in ICT and in some energy applications (e.g. detectors). Environmental contributions can be the replacement of Pb in piezoceramics and sensors for better control of combustion processes (power plants, automotive).
Main R&D needs and barriers	Influence of grain size and interfaces on electrical properties are complex and not completely understood especially in some multicomponent systems with a high number of additives which are used only in very small amounts. Homogeneous doping is possible by chemical nanotechnology. Understanding has to be improved and processing has to be optimized. Overlap/interference with topic 7 processing of nanoceramics.
Time scale ***(short: 2-4 y, medium: 4-6 y, long: 7-10 y)***	Topic provides close to market applications and some improvements can be realized on a short time scale.
Synergies	RF has various competencies (modelling and materials) and interest in the field. The EU is also active in the field. High interest in the EU due to applications in power plants, fuel cells, microelectronics and automotive industries.
References	Scientific bilateral cooperations between RF and EU countries are visible. COST No. 539 action “Electroceramics from nanopowders” with contribution from Russia has been funded in the past. EU-calls/projects have to be checked.

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Topic-No. 8	Coatings for high-temperature shielding
Area	Nanoceramics
Characterization	Coatings for shielding of metallic structures in power plants working at high temperatures using ceramic multilayers are called thermal barrier coatings TBC. Usually these systems are multilayers combining different functionalities needed e.g. mechanical robustness, thermal/corrosive shielding (of the metal substrate) and IR-reflectivity. Nanoscaled layers show improved functions in all these requirements and can therefore improve the whole system.
Relevance for grand hallenges and potential impact	Topic has very high relevance for energy (power plants). Every increase in processing temperature will increase the energy efficiency.
Main R&D needs and barriers	Products using TBC are available, but the actual use of nanoscaled materials has not been implemented to the extent possible. The multifunctionality (multilayers) must be translated into to a simplification in processing of the component in power plants. Processing and materials optimization are therefore key topics.
Time scale *(short: 2-4 y, medium: 4-6 y, long: 7-10 y)*	Time scale could be short to medium.
Synergies	RF has high competencies in ceramic coatings and also interest in the topic The EU will also be interested to improve TBC in power plants.
References	RF actors available. EU-call materials for extreme conditions probably partly covers the topic

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Topic No. 9	Shielding materials for electromagnetic radiation
Area	Nanoceramics
Characterization	For shielding of electromagnetic radiation (microwaves, electromagnetic compatibility) metallic or magnetic compounds or electronically conductive ceramics can be used. Electronically conducting nanoparticles, carbon nanotubes or magnetic nanoparticles can be implemented into nonconductive ceramic materials to form shielding composites, with high efficiencies even under high mechanical or thermal stresses. Also electronically conducting ceramics could be used as matrix.
Relevance for grand challenges and potential impact	Topic has high relevance for all components and devices used in various fields e.g. health, energy and ICT, due to the ever increasing density in microelectronic devices.
Main R&D needs and barriers	The combination of electromagnetic shielding capabilities with mechanical robustness of ceramics affords the implementation of nanoparticles in high amounts into ceramic matrices. The optimization of electromagnetic properties in combination with ease of processing is not solved in many cases.
Time scale ***(short: 2-4 y, medium: 4-6 y, long: 7-10 y)***	Proof of principle has been shown, optimization of processing could lead to solutions within 2-4 years
Synergies	RF has competencies in the field of metallic and magnetic nanostructures and also interest in the application field. The EU is also active especially in the field of electroceramics, which could provide synergies.
References	RF actors visible. There are no significant cooperations between RF and the EU visible in the field. Dual use has to be checked!

Profile of topics of interest between RF and EU

Topic No. 10	Nanocarbon based sensors (e.g. CNT or particularly graphene)
Area	Carbon-based materials
Characterization	Carbon-based materials such as graphene or carbon nanotubes (CNTs), possess unique characteristics making them very promising candidates for highly sensitive nanoscale sensors. They have a very high mobility at room temperature and hence a very high sensitivity and are recently discussed as very attractive ultra-sensitive and ultra-fast electronic sensor.
Relevance for grand challenges and potential impact	Such advanced sensors are relevant for chemical sensing functions (e.g. for smog/ gas detection in intelligent buildings) or biological/ biofunctional sensing (e.g. diagnostic devices). They are especially relevant for application fields like environment, safety and health.
Main R&D needs and barriers	R&D needs can be identified in materials and components development and advancing processing technologies. However fundamental understanding and the analysis of kinetics (non-equilibrium transport) of electrons in graphene is of importance and necessary in order to apply it to advanced nanotechnologies as well.
Time scale ***(short: 2-4 y, medium: 4-6 y, long: 7-10 y)***	Carbon-based sensors are expected to be a medium to long term issue with moderate to extreme importance, depending on the progress achieved and the application field to be used for.
Synergies	Graphene- and other carbon-related structures are assessed as very promising materials with the potential for setting up R&D cooperations: C-based nanomaterials research in general (e.g. also production of controlled amount of material) has been identified as a relevant field for Russian-European cooperation with a long term perspective. Devices based on nanotubes, graphene, etc. are regarded to be a principle research field with strength in Russia and need for cooperation in the EU. On a short term perspective also research on carbons (in particular graphene) for electrodes that are conductive but very soft (see workshop results) has been identified to be of interest. Graphene for use in nanooptics is supposed to be a field with moderate strength of Russia but stronger need for EU cooperation. Thermoelectric elements based on graphene has been identified as a field with particular strength of Russia but with moderate need for EU-cooperation In total, there is a strong competence and interest from Russian researchers and interest as well as synergy potential from EU. The impact in general is high due to the broad potential for applications addressing grand challenges.

Topic No. 10	Nanocarbon based sensors (e.g. CNT or particularly graphene)
References	The recent Nobel Price on graphene (by the Russian scientists Andre Geim and Konstantin Novoselov who are working in the UK) was mentioned as supporting the above notions and relevance of graphene (compare to further profiles).

Profile of topics of interest between RF and EU

Topic No. 11	Nanomagnets and their optimized production
Area	Nanomagnets
Characterization	Magnetic materials with a fixed set of magnetic properties (e.g. coercive force, remanent magnetization, etc.) are of interest to highly integrated devices (e.g. in spintronics) but have also a potential to be used as functionally designed particles, coatings or bulk materials for a broad number of applications. The optimization of production technologies for nanomagnets is of importance in order to develop new and improved (e.g. by function, efficiency) applications with a shorter time to market perspective.
Relevance for grand challenges and potential impact	Nanomagnets have the potential to contribute to applications in several fields, such as health treatment (e.g. magnetic nanoparticles for diagnostics), Energy (e.g. Nd-Fe-Pb high-energy magnets for electromotor in electric vehicles, generators for wind energy), environment (e.g. nanomagnets for removal of soil contaminants) and ICT (e.g. spintronic devices, sensors).
Main R&D needs and barriers	A number of research needs can be identified, where Russia is strong and EU cooperations would be helpful, such as R&D on size induced magnetism, low-dimensional magnets, nanostructured high-energy magnets, magnetic semiconductors, quantum-spin dynamics in molecular nanomagnets. The focus of the R&D efforts would be on methods and tools to develop and optimize production technologies for nanomagnets (in contrast to nanomagnets for electronic devices, where also materials/components and processing are addressed).
Time scale *(short: 2-4 y, medium: 4-6 y, long: 7-10 y)*	The topic is believed to be relevant on a medium term time scale with moderate to very high importance (depending on the subtopic). Commercial applications are not expected on a short term time scale. However in some subtopics and research activities (e.g. measurements on nanomagnets, sensors based on multiferroics) cooperations on a short term time scale could be realized. R&D on nanomagnets for health treatment has a medium term perspective.

Topic No. 11	Nanomagnets and their optimized production
Synergies	Nanomagnetism was suggested as a very good area for collaboration where Russian strengths could be brought in. Russia has much know-how and competencies in the field of nanomagnets and has interest in cooperation with the EU. The USA is said to be very active and a strong competitor. Thus, the need for cooperation is strong for Russia as well as the EU. Synergies between Russia and the EU could help to accelerate the joint development of the field. For example, Russia could support in explaining EU experimental results (medium term issue).
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Profile of topics of interest between RF and EU

Topic No. 12	Electronics / electronic devices based on spintronics
Area	Nanomagnets
Characterization	In contrast to conventional computing devices, which require electric charges to flow along a circuit, spintronic devices use both the charge (electric property) and the spin (magnetic property) of the electrons. Advanced spintronics, like molecular spintronics will enable the manipulation of spin and charges in electronic devices containing only one or more molecules. The recent evolution and progress at the intersection of spintronics and molecular electronics promises exciting fundamental discoveries and applications in the future. Magnetic (but also non-magnetic) molecules are considered very promising for spintronics, as they can store a bit of information in an extremely small volume. Different materials may be applied, such as magnetic alloys, molecular nanomagnets (e.g. single molecule magnets – SSM), magnetic molecules as well as metamaterials with artificial magnetism, organic spin materials and nowadays graphene. Geim and Novoselov (Russian scientists, Nobel Prize 2010) demonstrated the ability of graphene to magnetize in a way, making it a useful material for spintronics. Besides the above mentioned materials, multiferroics (piezo-/ferroelectrics and/or magnetics) define a further category of materials which should be mentioned in this context. Multiferroic materials are materials (e.g. BFO perovskite as lead-free piezoelectric material or Barium titanate) in which unique combinations of (ferro) electric and magnetic properties can simultaneously coexist and exhibit a strong coupling between the two phenomena. They are potential cornerstones in future magnetic data storage, spintronic devices and sensors if a simple and fast way can be found to turn their electric and magnetic properties on and off.
Relevance for grand challenges and potential impact	Applications for such devices are e.g. hard disk drive read heads, magnetoresistive random access memory (MRAM), spin transistors, spin quantum computing. Such devices may be even powered by harvesting energy exclusively from the environment. Spintronics enables smaller, faster and more energy efficient and (ultralow) power computers and other signal storing and processing devices (e.g. sensors, detectors, memories). The R&D field has a clear and pronounced relevance to the ICT sector; however, the resulting devices may be applied to several markets (e.g. healthcare sector, environmental applications, automotive, etc.).

Topic No. 12	Electronics / electronic devices based on spintronics
Main R&D needs and barriers	R&D is needed from advanced materials and components to processing, methods and the development of tools for fabrication and integration. Challenges are e.g. to develop devices that work at ambient conditions or the development of new physical principles of operation of micro and optoelectronic devices based on functional materials (e.g. multiferroics).
Time scale ***(short: 2-4 y, medium: 4-6 y, long: 7-10 y)***	The general topic has been identified to have a medium term perspective with moderate to very important relevance. However, due to strong activities in Russia potential cooperations (e.g. on sensors) could be realized on a short term already.
Synergies	Russia has strengths and competencies in fields, such as semiconductor spin manipulation, graphene, nanomagnets and multiferroics. Also, there is a strong interest from Russia and a need for EU cooperation.
References	To our knowledge to date there are no significant joint collaborations.

Profile of topics of interest between RF and EU

Topic No. 13	Plasmonic sensors and devices
Area	Sensors and Instruments
Characterization	Plasmonics is a new branch of photonics employing surface plasmon polaritons. These arise from the interaction of light with collective oscillations of electrons at metal surfaces. Light at the plasmon frequency excites electronic motions at the surface of metals, which act like antennas and create very strong local optical fields. Plasmon based devices have been used effectively in detecting and sensing applications, primarily due to their ability to locally concentrate light and due to their high sensitivity to changes in the background environment. Recent investigations on surface plasmon resonance (SPR) promise continuous enhancement of their sensitivity and their lower detection limit (e.g. through progress in the understanding and manipulation of localized SPR phenomena, optical transmission through nanostructures in metals, surface-enhanced spectroscopies, second harmonic interaction, etc.). Thus, surface but also volume plasmonic resonance sensors define a promising field for cooperation between Russia and the EU with the potential for a wide range of applications.
Relevance for grand challenges and potential impact	Effectively sensing the presence of molecules in gases, liquids or biological materials opens potential applications and markets in healthcare, environmental, ICT or further fields. Examples are carbon monoxide detectors (e.g. in private homes), sensors for measuring gases in catalytic nanoreactors and fuel cells, or the monitoring of biochemical processes (e.g. blood glucose sensors in the field of optical biosensing). Also, for many scientific and technical applications, ultrasmall and precise sensors are needed. Furthermore, plasmonics in PV has been pronounced by experts to be of high importance and a short term issue, which could profit from joint collaborations between Russia and the EU.
Main R&D needs and barriers	Detecting and sensing the presence of only small numbers of molecules requires strong amplifications, being able to detect small changes in sensor properties. Plasmonic effects in metal nanostructures are promising to do so, however still plasmonic sensors vary in size from several hundred microns to a few millimetres. This limits their potential for system integration. R&D on materials/components, processing and methods/tools is needed to further improve the sensitivity as well as integration and miniaturization of size of plasmonics sensors.

Topic No. 13	Plasmonic sensors and devices
Time scale *(short: 2-4 y, medium: 4-6 y, long: 7-10 y)*	Sensors and instruments are regarded as short to medium term (2-6 years) R&D fields with moderate to extreme importance, depending on the specific subject. Therein, plasmonics in nanoelectronics is regarded to be highly important and has a short term perspective. Surface and volume plasmonic resonance sensors may be subject for short term cooperations between Russia and the EU (e.g. due to emphasized interest and running research from Russia).
Synergies	Russia has some background and competencies in the field and for the EU a strong need for cooperation has been identified. Interest from Russia has been formulated as well. A high synergy potential as well as impact due to the relevance to broad application fields can be expected.
References	The RAS has proposed a project “Development of highly sensitive plasmic sensor for detection traces in gas and liquid mediums”. On the surface of a metal film of a plasmic sensor they generated 2-D and 3-D nanostructures and it helped to increase the sensor sensitivity. RAS is interested in collaboration with specialists who can give sorbents, selective to different substances. Application of selective sorbents will make it possible to create highly sensitive sensors for detection of traces equal to the dog’s ability to perceive smells (Source: Deliverable D3.1).

Profile of topics of interest between RF and EU

Topic No. 14	Advanced UHV-setup for analysing and modelling surface reactions for nano-electronic devices
Area	Sensors and Instruments
Characterization	Ultra-high vacuum (UHV) is necessary for a number of surface analytic techniques for microscopy/ spectroscopy such as STM, AFM, SEM, SPM, etc. in order to reduce surface contamination and to improve imaging and atomic resolution. UHV-technology setups on a laboratory level may be combined with one or more such microscopes (also combined with modelling and simulation approaches) to study and manipulate chemical surface/ interface reactions of nanostructures and nanostructured components to create and model electronic devices. The goal would be to develop advanced sensors and instruments as enabling technologies for nanotechnology.
Relevance for grand challenges and potential impact	The topic is relevant to the ICT-sector. Advanced devices, sensors and instruments may also be used for environmental, healthcare or other application fields. Furthermore, improved equipment and analytic techniques are of importance for the researchers themselves to gain more insights and a better understanding of the studies nanomaterials and -structures.
Main R&D needs and barriers	R&D needs focus on improved methods and tools as well as the development of common approaches for the measuring in nano-dimensions.
Time scale ***(short: 2-4 y, medium: 4-6 y, long: 7-10 y)***	Sensors and instruments as a whole are regarded as short to medium term (2-6 years) R&D fields with moderate to extreme importance for Russian and European cooperation, depending on the specific subject. The above topic may be suitable for a medium term perspective.
Synergies	Russia is regarded to be strong in this field and there is a substantial interest from Russian organisations to cooperate with the EU. There is believed to be a strong need for EU cooperation in the field as well. Thus, there is a potential for broader synergies. The impact of the topic is supposed to be moderate due to the indirect relevance to application fields via improved instrumentation.
References	To our knowledge there are no joint projects, programs or activities running between Russia and the EU. The topic has a short term perspective for the cooperations themselves due to existing equipment and background of the researchers at several Russian organisations and laboratories.

Profile of topics of interest between RF and EU

Topic Nr. 15	Theory for nanoscale enhanced high-temperature (high-T) superconductivity
Area	Superconductivity (SC)
Characterization	Superconductors have no resistance and conduct electricity with 100% efficiency making them attractive for a broad number of energy applications. However, they work only at extremely low temperatures. Thus, high-temperature superconductors (especially with transition temperatures above 77K or −196°C, the boiling point of liquid nitrogen) are of much interest for affordable applications. In the past few years there has been some progress in the field, with the discovery of mercury barium calcium copper oxide as high-T superconductor at 135 K in 2009. However, a unified theory explaining high-T superconductivity and a full understanding of this phenomenon is still out of reach.
Relevance for grand challenges and potential impact	Promising future applications for high-T superconductors (apart from current applications as e.g. in medical imaging), where nanotechnology could play a role, include energy transmission, conversion and storage (e.g. smart grid, electric power transmission lines, transformers, storage devices). Also, nanoscale superconductors would be useful in ICT-devices such as superconductive transistors and eventually in ultrafast, power-saving electronics, e.g. by using superconducting multicomponent thin films.
Main R&D needs and barriers	Theoretical models for explaining (nanoscale enhanced) high-T superconductivity are needed to provide more insights and potential progress in the field.
Time scale ***(short: 2-4 y, medium: 4-6 y, long: 7-10 y)***	The topic has a medium to long term perspective with slight to extreme importance (depending on the progress and applications which may be realized).
Synergies	R&D cooperation on high-T (advanced) superconductors is very important. The EU can benefit from the strong competence and interest from Russia and synergies can be expected to be high.
References	There are some cooperations established (e.g. in developing superconducting devices): The L.D. Landau Institute for Theoretical Physics RAS develops the theory of superconductivity in highly disordered superconducting films since a number of years together with experimentalists from laboratory under the direction of Mark Sankers (Marc Sanquer) at the French research centre CEA-Grenoble.

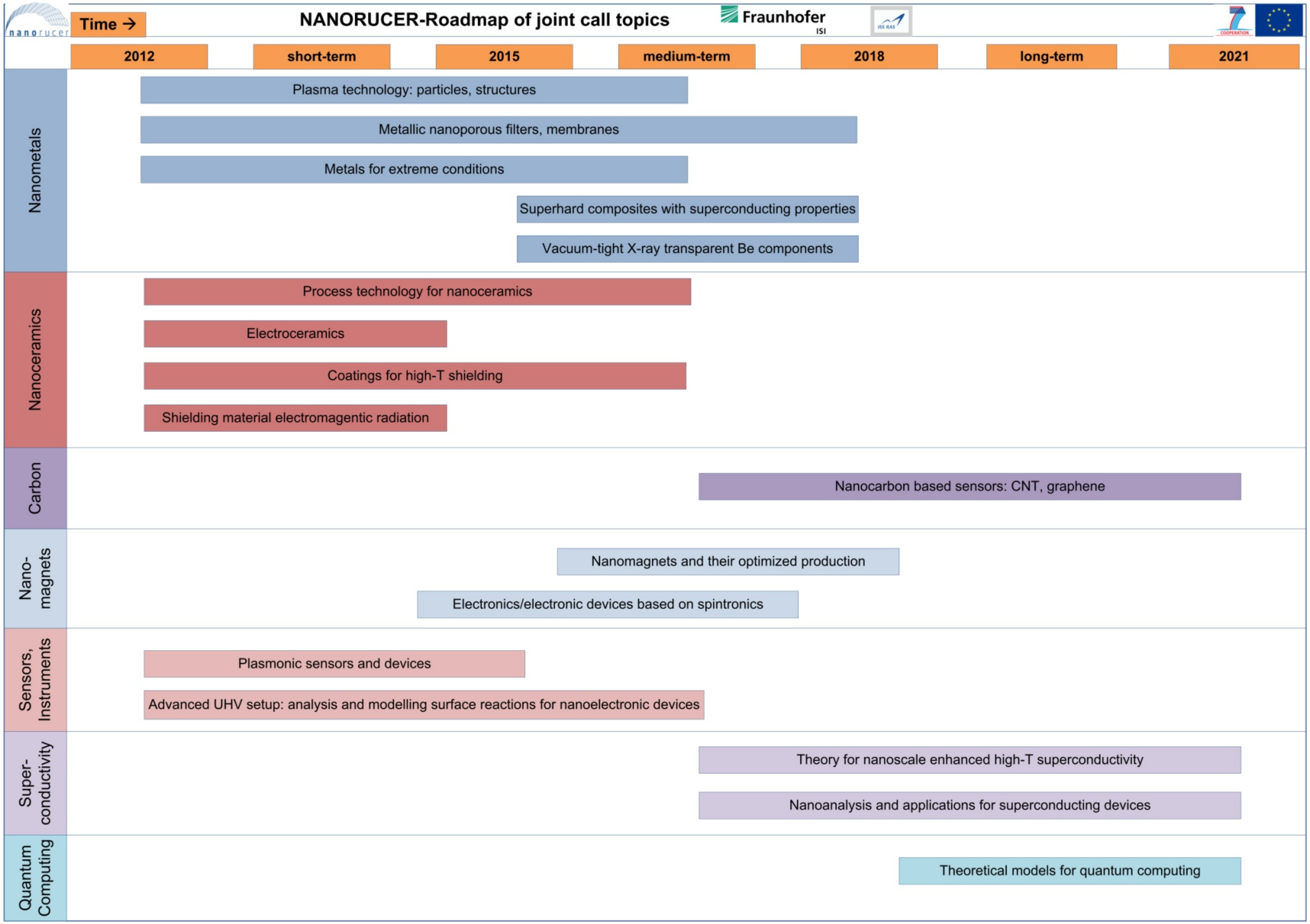
Profile of topics of interest between RF and EU

Topic No. 16	Nano-analysis and applications for superconducting devices
Area	Superconductivity (SC)
Characterization	Superconducting devices are of interest due to their potential to lead to highly efficient and sensitive applications (no energy loss, no electric resistance). For example, superconducting (SC) tunnel junctions (e.g. SC-ferromagnet heterostructures or SC/metal/SC structures) using the proximity effect or Andreev reflection are of interest for spintronics and quantum computing, superconducting quantum interference devices (SQUIDS) may serve as sensor for magnetism (e.g. for medical devices, in geology for measuring the magnetic field of Earth, non-destructive measuring, etc.), superconductivity in graphene and other artificial nanostructured materials (with an increased set of properties) may enable further new electric devices, or superconducting nanostructures may be used to realize THz-sensors. On the other hand, analytical tools for analyzing superconducting behaviour on the nanoscale are needed, in order to better understand the phenomenon and help developing new and advanced superconducting devices.
Relevance for grand challenges and potential impact	Superconducting devices are relevant to applications in the ICT-sector, in particular to spintronics and quantum computing (compare to the respective profiles). Also, superconducting materials with an increased set of properties, can lead to new or improved sensors and electrotechnical devices for medical, health, environmental, energy and further application fields.
Main R&D needs and barriers	R&D needs are identified for improving analytical tools as well as models and theories to understand the physical phenomena and being able to tailor new kinds of superconducting devices.
Time scale ***(short: 2-4 y, medium: 4-6 y, long: 7-10 y)***	The topic has a medium term to long term perspective for applications with slight to extreme importance, depending on the concrete subtopic and potential application addressed.
Synergies	Nanoelectronics with superconducting devices have been identified as a very important topic with a short term perspective for cooperation between Russia and the EU. Russia has strong competencies and interest, such that synergies with the EU (e.g. by combining theoretical work from Russia with experimental work from EU) may be exploited.
References	Some cooperations between Russian and European researchers are already established.

Profile of topics of interest between RF and EU

Topic No. 17	Theoretical models for Quantum Computing (QC)
Area	Quantum Computing (QC)
Characterization	A quantum computer is a device for computation that makes direct use of quantum mechanical phenomena, such as superposition and entanglement, to perform operations on data. Various concepts exist to create such a quantum computer (e.g. based on trapped-ions, photons, superconductors with SQUBITS, quantum dots, graphene, nanodiamonds, etc.).
Relevance for grand challenges and potential impact	Quantum computers could be used e.g. for breaking computer security codes and are therefore of interest in the context of security and defence. Researchers believe quantum simulation to be one of the most important applications of quantum computing (e.g. to test quantum mechanics and explore new physical phenomena by studying problems in various fields including condensed-matter physics, high-energy physics, quantum chemistry, etc.
Main R&D needs and barriers	Besides the challenges of stabilizing the decoherence-time or increasing the number of entangled qubits in such systems, also new theoretical models have to be developed, which can be applied to new promising concepts or candidate systems (e.g. currently graphene based QC is under discussion) in order to realize quantum computers.
Time scale *(short: 2-4 y, medium: 4-6 y, long: 7-10 y)*	The topic has a long term perspective.
Synergies	Solid state Quantum Information Processing (QIP) and Quantum Computing (QC) have been identified as a very/extreme important topics with a short to medium term perspective for cooperation between Russia and the EU. Quantum computing (in particular with use of graphene but also nanodiamonds) is extremely important with a medium to long term perspective for cooperation (single cooperations between Russian and European researchers are already running). Furthermore, the study of quantum-coherent phenomena in superconducting nanostructures, implementing devices for quantum calculations based on superconducting nanoelectronics, implementing detectors for the conditions of quantum bits, interference effects and geometric phases in superconducting systems have been suggested as potential topics for cooperation by Russian experts. There are strong competences and interest from Russian researchers in the field (mainly in theory), providing synergy potentials with European research activities (e.g. on experiments).

Topic No. 17	Theoretical models for Quantum Computing (QC)
References	-



NANORUCER-Roadmap of joint call topics
Time →
2012
short-term
2015
medium-term
2018
long-term
2021
Nanometals
Plasma technology: particles, structures
Metallic nanoporous filters, membranes
Metals for extreme conditions
Superhard composites with superconducting properties
Vacuum-tight X-ray transparent Be components
Nanoceramics
Process technology for nanoceramics
Electroceramics
Coatings for high-T shielding
Shielding material electromagentic radiation
Carbon
Nanocarbon based sensors: CNT, graphene
Nano-magnets
Nanomagnets and their optimized production
Electronics/electronic devices based on spintronics
Sensors, Instruments
Plasmonic sensors and devices
Advanced UHV setup: analysis and modelling surface reactions for nanoelectronic devices
Super-conductivity
Theory for nanoscale enhanced high-T superconductivity
Nanoanalysis and applications for superconducting devices
Quantum Computing
Theoretical models for quantum computing