Extra June, 2013 Date of Issue: June 3, 2013

Superconductivity Web21

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What's New in the World of Superconductivity (April, 2013)

초전도 뉴스 –세계의 동향-

超导新闻 -世界的动向-

chāo dǎo xīnwén - shìjiè de dòngxiàng-

Yutaka Yamada, Principal Research Fellow
Superconductivity Research Laboratory, ISTEC

★News sources and related areas in this issue

▸Power Application 전력응용 电力应用 [diànlì yìngyòng]

Breakthrough High-Temperature Superconducting Technology for Next-Generation Power Generation

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GE Power Conversion (April 3, 2013)

GE Power Conversion has successfully completed trials of Hydrogenie, a power generator that incorporates groundbreaking technologies to enable the efficient production of electricity in a relatively small space. The Hydrogenie utilizes superconductors for the rotor windings and operates at 43 K. The device was tested late in 2012 and was shown to be capable of operating well beyond its full rated load of 1.7 MW spinning at 214 rpm, thereby meeting expectations and design predictions. Marin Ingles, the Hydrogenie project manager at GE Power Conversion, commented, "This technology is a true breakthrough. It could radically improve the efficiency of equipment producing electricity from water and from wind and may also be suitable for further applications down the road." The most recent superconductors are made by depositing a superconducting layer of ceramic onto a relatively cheap base metal, producing a wire wit a cross-section around 2 % of a convention copper wire winding. This smaller size enables more winding to be fit within an electromagnet coil, resulting in a higher power magnet that is substantially smaller and lighter than conventional magnets. Thus, superconductivity offers significant advantages in efficiency and weight reduction, compared with conventional machines. GE Power Conversion performed much of the development of the Hydrogenie 1.7-MW, 214-rpm HTS generator as part of a European Union Framework Programme 6-funded project that ran between 2006 and 2010. The successful completion of this project will create a framework for continued research and development in the study of superconducting machines, such as upgrades to existing run-of-river power plants.

Source: "GE Successfully Trials Breakthrough High-Temperature Superconducting Technology for Next-Generation Power Generation"
GE Power Conversion press release (April 3, 2013)
URL:
http://www.genewscenter.com/Press-Releases/GE-Successfully-Trials-Breakthrough-High-Temperature-Superconducting-Technology-for-Next-Generation-3ef3.aspx
Contact: Masto Public Relations, information@mastopr.com

Progress in Energy Device Demonstration Projects

SuperPower Inc. (April 8, 2013)

SuperPower Inc. and its project partners for a number of device development and demonstration programs have announced important progress toward the realization of market-ready devices, with SuperPower reporting the delivery of its high-performance superconductor for the fabrication of SMES, wind turbines, and fault current limiting transformer prototype devices to be on schedule and fully meeting expectations. First, the U.S. Department of Energy is supporting the development of a 28 MVA, three-phase superconducting fault current limiting (SFCL) transformer project that will include two years of in-grid operation at the Southern California Edison Smart Grid substation in Irvine, CA. This transformer will have a smaller footprint and safety benefits in that it requires non-oil cooling, as well as the added FCL feature that enables the device to rapidly react to and passively limit surges at high power levels. Recent results regarding conductor performance tests for AC loss in perpendicular fields have generated excitement, and further validation of the results should provide a pathway toward a very low loss transformer with a simpler

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cooling system.
Another program to develop a superconducting magnetic energy storage (SMES) system is being funded by the U.S. Department of Energy's Advanced Research Project Agency – Energy (ARPA-E). The goal of this program is to develop a competitive, fast response, grid-scale MWh SMES as demonstrated by a small-scale 10 -kW, 1.7 -MJ prototype with a direct connection power electronics converter. The development team includes ABB, Brookhaven National Laboratory, SuperPower, and the University of Houston. All the coils for this project have now been built and final tests are presently underway. A novel superconducting bypass switch has also been built and tested, the power electronics converters, have been built and tested, and the capabilities of a new plasma-assist MOCVD superconductor deposition system have been successfully demonstrated as part of this project.
In a second ARPA-E program, SuperPower is working in partnership with the University of Houston, TECO-Westinghouse, Tai Yang Research Company, and the U.S. National Renewable Energy Laboratory to develop high-performance and low-cost superconducting wires and coils for high-power wind generators. The University of Houston is working toward a four-fold improvement in the HTS wire current density at device operating conditions (30 K, 2 T). Haran Karmaker, R&D Principal Engineer at TECO-Westinghouse, commented, "…the only viable technology for high power direct drive wind turbine generators for offshore applications in the 10-20 MW power range includes the use of HTS wire field excitation to reduce size and weight to practical levels. The HTS wire specifications from SuperPower with the projected 4X performance improvement has been used to design a 10 MW direct drive generator. Detailed design studies including electrical, mechanical and thermal performance modeling for commercial applications are being investigated in the program."
As an important component of each of the above-mentioned programs, the ongoing development of second-generation HTS wire is being continued at the University of Houston under the leadership of Dr. Venkat Selvamanickam, M.D. Anderson Chair Professor of Mechanical Engineering, who commented, "We have already made significant progress in the development of high-performance HTS wires including a 65 % enhancement in critical current at the operating condition of wind generators by engineering nanoscale defects in the HTS films in the ARPA-E REACT project. In the ARPA-E SMES project, we have achieved the highest-ever critical current in HTS films of less than two micrometers made by a chemical process through the development of a novel HTS film deposition system. We will be developing multifilamentary HTS wire technologies in the DOE Smart Grid FCL transformer project and the ARL SMES project to achieve significant reduction in AC losses."

Source: "SuperPower and Program Partners Announce Progress in Energy Device Demonstration Projects"
SuperPower Inc. press release (April 8, 2013)

URL:
http://www.superpower-inc.com/content/superpower-and-program-partners-announce-progress-energy-device-demonstration-projects
Contact: Traute F. Lehner, tlehner@superpower-inc.com

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Super Wind Turbines by Superconducting Technology

CORDIS (April 23, 2013)

SUPRAPOWER, a European Union-funded project, is working to produce a powerful, reliable, and lightweight superconducting offshore wind turbine. The 4-year project is utilizing the expertise of nine partners from industry and science working under the coordination of Tecnalia (Spain). The group believes that the application of superconducting technology will enable significant reductions in operation and maintenance costs, compared with conventional technology, enabling the construction of an efficient, robust, and compact wind power plant with a 10-MW superconducting generator. Such an application would enable substantial savings in energy and raw materials and extend the service life of the turbine. Iker Marino Bilbao, an assistant to the project coordinator at Tecnalia's Energy and Environmental Division, commented, "Our main objectives for the first year is to validate the modular rotating cryostat concept. We will then produce a conceptual design of the superconducting scale generator. As well as design, construct, and test superconducting dummy coils for the construction of generator (500-kW scale generator) coils in 2014." These breakthrough solutions are expected to reduce the turbine head mass and overall size, thereby reducing manufacturing costs by 30 %.
Wind power is expected to make a major contribution to improving the efficiency of energy production across Europe, and the European Union has set a target of reducing emissions to 20 % below the 1990 levels as part of its effort to reduce greenhouse gas emissions and enhance energy security.

Source: "Super wind turbines represent a major technological breakthrough"
CORDIS press release (April 23, 2013)
URL: http://cordis.europa.eu/fetch?CALLER=EN_NEWS&ACTION=D&RCN=35671
Contact: For more information,
SUPRAPOWER http://www.suprapower-fp7.eu/
Tecnalia http://www.tecnalia.com/en
Karlsruhe Institute of Technology (KIT) http://www.kit.edu/kit/english/index.php
European Commission – Energy http://ec.europa.eu/energy/efficiency/index_en.htm

▸Electronics 엘렉트로닉스 电子应用 [diànzǐyè yìngyòng]

Launch of its U.S. Commercial Quantum Computing Company

D-Wave Systems Inc. (May 2, 2013)

D-Wave Systems Inc. has announced the formal launch of its U.S. commercial quantum computing company. Robert "Bo" Ewald, an industry expert and supercomputing veteran, will lead the U.S. business as President and will head the global customer operations as the company's Chief Revenue Officer. The company has opened new offices and R&D facilities in Palo Alto, California. Vern Brownwll, CEO of

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D-Wave Systems Inc., commented, "Bo Ewald joining us is huge validation of our business. Bo is a legendary figure in the supercomputing industry. His knowledge and influence reach a wide array of sectors, where he has delivered state-of-the-art high performance solutions for research, defense and intelligence, energy, manufacturing, financial services and genomics. Throughout Bo's career he has been dedicated to helping organizations solve their most difficult challenges, which perfectly matches the mission of D-Wave. Today we launch our formal presence in the U.S. and will start to expand our business globally. It is gratifying to have Bo at the helm." Ewald added, "The quantum computers being developed by D-Wave and the applications that will be used by our customers will be an even more revolutionary step than I've seen in the industry. People will be able to solve problems that they can only dream about today, on systems that are turning science fiction into science fact."
D-Wave's flagship product, the D-Wave One™, is based on a novel type of superconducting processor that uses quantum mechanics to massively accelerate computation. Its first unit was purchased by Lockheed Martin in 2010, marking the world's first sale of a commercial quantum computer.

Source: "Quantum Computing Firm D-Wave Systems Launches U.S. Business; Industry Veteran Bo Ewald Will Lead U.S. Business and Global Customer Operations"
D-Wave Systems Inc. press release (May 2, 2013)
URL: http://www.dwavesys.com/en/pressreleases.html#investment_2012
Contact: Janice Odell, jan@fordodell.com

▸Medical Application 의료응용 医疗应用 [yīliáo yìngyòng]

Actively Refrigerated Ascend™ Aeon Magnet for Novel NMR System Independence from Cryogen Supply

Bruker (April 15, 2013)

Bruker has introduced new Ascend™ Aeon 600 and 700 superconducting, nitrogen-free magnet systems featuring a fully integrated helium reliquefaction system. The novel Aeon technology enables long-term care-free operation without the need for user maintenance. By eliminating the need for liquid helium and nitrogen refills, the new 600- and 700-MHz magnets will enable user convenience and substantial independence from cryogen supplies. Additionally, Bruker is now offering actively refrigerated Ascend Aeon 400 and 500 magnets that are nitrogen-free, have very low liquid helium evaporation rates, and require liquid helium refills only every 18 months. Bruker has already installed close to 20 Ascend Aeon 400 and 500 magnets in customer laboratories around the world. As Bruker provides scheduled refrigeration maintenance service for these systems, customers can expect to operate the devices in a care-free manner for years. Bruker views the introduction of the new Ascend Aeon technology, which incorporates an advanced, proprietary refrigeration design featuring an integrated low-vibration cryocooler, as a response to worldwide concerns regarding helium shortages and the rising cost of helium. Dr. Werner Maas, President of Bruker BioSpin, commented, "While already available in hundreds of our preclinical MRI magnets for years, the extreme demands for stability and spectral purity of high-resolution NMR had until recently

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prevented us from introducing this active refrigeration convenience for NMR magnets. Thanks to several proprietary technological breakthroughs and further magnet and refrigeration systems integration optimization over several years, our magnet engineers have now made the 'care-free' Ascend Aeon option available also to our high-resolution NMR customers."

Source: "Bruker Introduces Actively Refrigerated Ascend™ Aeon Magnet Produced Line"
Bruker press release (April 15, 2013)
URL:
http://www.bruker.com/news-records/single-view/article/bruker-introduces-actively-refrigerated-ascendTM-aeon-magnet-product-line.html
Contact: Dr. Thorsten Thiel, thorsten.thiel@bruker.com

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World Project Now for Superconductor

Save Earth by Superconductor

This year ISTEC has started the special feature on the current world projects for HTS superconductor and its application.

This June issue, Profs. Xavier Obradors and Teresa Puig of ICMAB-CSIC, Spain, introduce the EU activity, especially newly started EUROTAPES project. This is the largest ever in EU for HTS, and we can expect further progress in HTS wire and applications.

ISTEC
YUTAKA YAMADA
(Japanese version translated by Yamada will be appeared in July issue.)

KEIRIN
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Coated Conductor Research in Europe

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Campus de la UAB, 08193 Bellaterra, Catalonia, Spain

ABSTRACT
This manuscript reports about the different initiatives being active at present in Europe towards the development of coated conductor (CC) for applications. We first summarize the different partners which have been recently involved in any aspect of the R&D required to build up coated conductors, then the largest effort existing so far in this area in Europe, i.e. EUROTAPES project, is described in more detail. The overall objectives of this project, involving 20 partners from 9 countries, is to create synergy among academic and industrial partners to go well beyond the state of the art in several scientific issues related to CC's enhanced performances and to develop engineered CC's with reduced costs, using high throughput manufacturing processes which incorporate quality control tools and so lead to higher yields. Three general application targets are considered which will require different conductor architectures and performances and so the strategy is to combine vacuum and chemical film deposition approaches to achieve the targeted goals. A few examples of such approaches are described related to defining new conductor architectures and shapes, as well as vortex pinning enhancement through novel paths towards nanostructure generation. Finally, we briefly summarize the most outstanding power application projects being active at present in Europe.

1. Introduction and overview

While the discovery of high temperature superconductors raised an unprecedented scientific challenge, the development of practical conductors based on the most promising HTS material, i.e. $YBa_2Cu_3O_7$ (YBCO), was delayed by the requirement of achieving a practical methodology to surmount the grain boundary problem. Second generation (2G) tapes based on biaxially textured YBCO films boosted a huge interest worldwide during the last decade in the new opportunities to develop practical conductors for power applications. Many research programs were established around the world (USA, Japan, Korea, Europe) to follow up this new opportunity. Europe closely followed the international trend and many R+D efforts were established, both at the national levels and through international cooperation projects supported by the European Union. Among them we could mention SOLSULET and HIPERCHEM devoted to chemical solution approaches, EFECTS to ink jet printing techniques, SUITABLE, HIPERMAG, NANOFEN and NESPA to several aspects of nanoengineering conductors. However, the largest European project related to superconductivity ever launched was only recently initiated: "European development of Superconducting Tapes: integrating novel materials and architectures into cost effective processes for power applications and magnets" (EUROTAPES, 2012-2016) [1]. The project involves 20 partners from 9 countries (see the map in Figure 1 and Table I), with 12 members from the academia and 8 industrial partners and a total cost of ~ 20 M€. The scientific coordinator is Prof. Xavier Obradors from ICMAB-CSIC.

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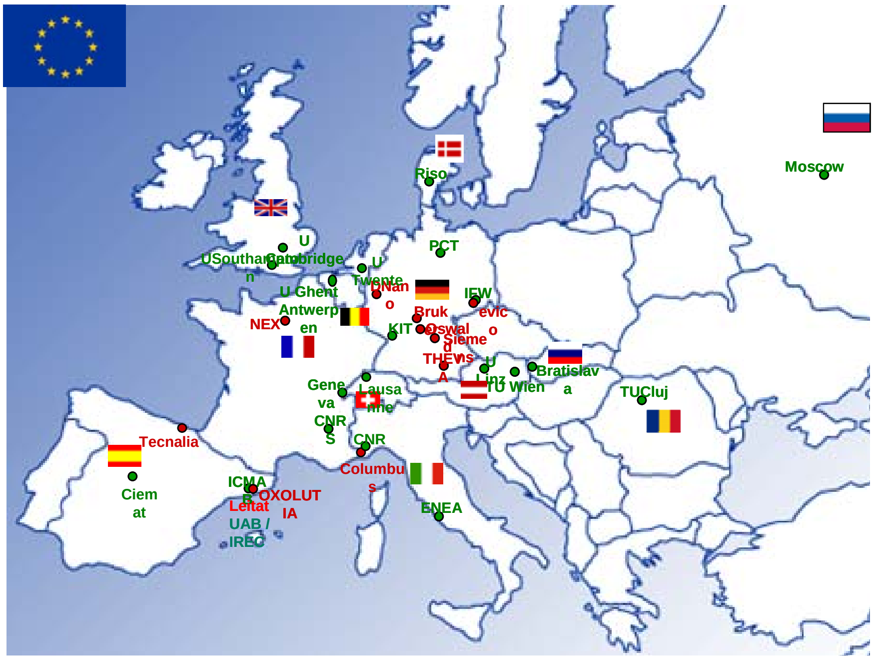

Fig. 1 European map including the main players in superconductivity research and superconducting power applications in Europe, particularly those involved in EUROTAPES are signaled.

Table 1 Participant of EUROTAPES Project

Participant No.	Participant	Country
1 (Coord)	Institut Ciència Materials Barcelona, ICMAB - CSIC	ES
2	Bruker HTS GmbH	DE
3	Italian National agency ENEA	IT
4	Institute of Electrical Engineering, IEE Bratislava	SK
5	La Farga la Cambra, LFL	ES
6	Leibniz Institut für Festkörper und Werkstoffforschung, IFW	DE
7	Nexans SA	F R
8	Oxolutia, SL	ES
9	PerCoTech AG	DE
10	Technical University of Cluj-Napoca, TU Cluj	RO
11	Vienna University of Technology	AT
12	Institute Neel, CNRS Grenoble	FR
13	University of Antwerp	BE
14	University of Cambridge	UK
15	University Autonoma de Barcelona, UAB	ES
16	University of Ghent	BE
17	Evico	DE
18	Nexans GmbH	DE
19	Leitat Technological Center	ES
20	Theva	DE

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The final objective of the project is to deliver long lengths (+ 500 m) of CC's at pre-commercial costs (~ 100 €/kA m) and to select the most promising technological choices for power applications. Three range of magnetic fields were targeted which require to use the tapes working at different temperatures (Figure 2). First, the low magnetic field range (< 1 T) suitable for cable and FCL systems which could work at around 77 K. Second, a high magnetic field range (3 - 5 T) which then would require placing the CC's at temperatures in the range of 30 - 60 K. Power systems which could be generated with these conductors would be mainly rotating machines and SMES. Finally, ultra-high magnetic fields (> 15 T) to build magnets which could only be achieved cooling at lower temperatures (~ 5 K). The technical performances which should be achieved are the following: I_c (77K, sf) > 400 A/cm-w, F_p(60 K) > 100 GN/m^3 and I_c (5K, 15 T)> 1000 A/cm-w . Additionally, the strategy of the project is to take into account that the required conductor lengths for each power application, and so also the fraction of HTS wire relative to the total system cost deeply differs. For instance, while in magnets the wire cost is in the range of 5 - 15 %, in transmission-distribution systems (cable, FCL, transformer) typically the wire cost rises to 20- 25 % of the total cost. In rotating machinery the wire cost could be also as high as 30 % of the total system cost. This wide span of cost relevance forces the need of developing different conductor architectures, having different production costs, and so it is advisable to investigate on different types of CC's characterized by specific performances under the corresponding working conditions and allowing to achieve a certain spread in the final production costs. In the second half of the project (30 to 42 months) the emphasis of EUROTAPES will be in developing high throughput processing with high yield and performance and the industrial partners will assume an enhanced leadership in order to demonstrate the scalability of the chosen CC manufacturing approaches.

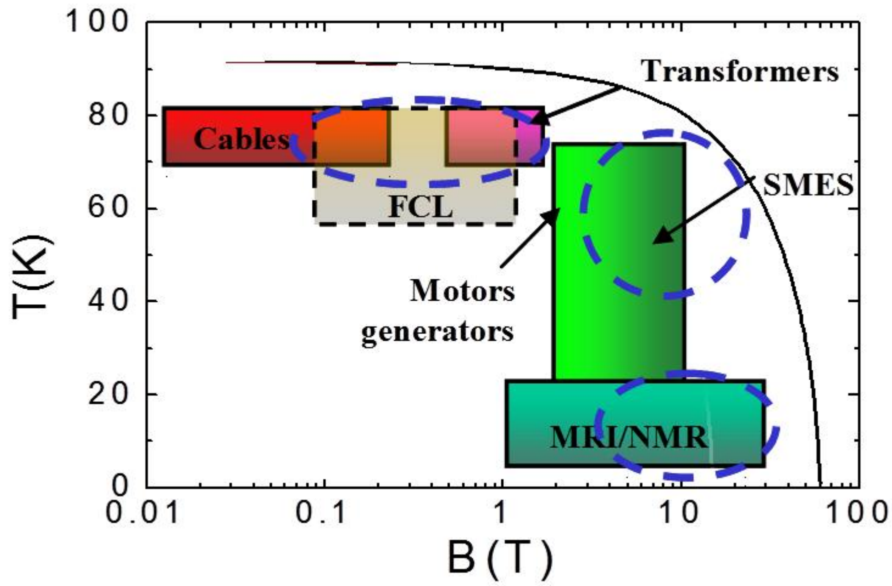

Fig. 2 Operating magnetic fields and temperatures where the YBCO coated conductors have performances adapted to the different indicated applications. Three targeted regions of EUROTAPES are highlighted.

We should here mention, however, that while EUROTAPES includes most of the main R&D players in Europe, there are still some additional research groups which are also active in other specific aspects of the CC's field and which will keep a certain degree of collaboration with the project. We should mention for

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instance, Kalsruhe Institute of Technology (KIT) with a large program on conductor and cable shaping together with advanced characterization, Deutsche Nanoschicht (D-Nano, formerly Zenergy, Germany) is also very active on industrial development of CC's using chemical solution deposition (CSD) methodologies on RABiT substrates and Riso National Laboratory (Denmark) perform research on growth of buffer and superconducting layers based also on chemical solution methodologies. Finally, we should also stress that Russia has recently deployed an extensive research program on CC's development as well as on power system development.

2. Coated conductor architectures

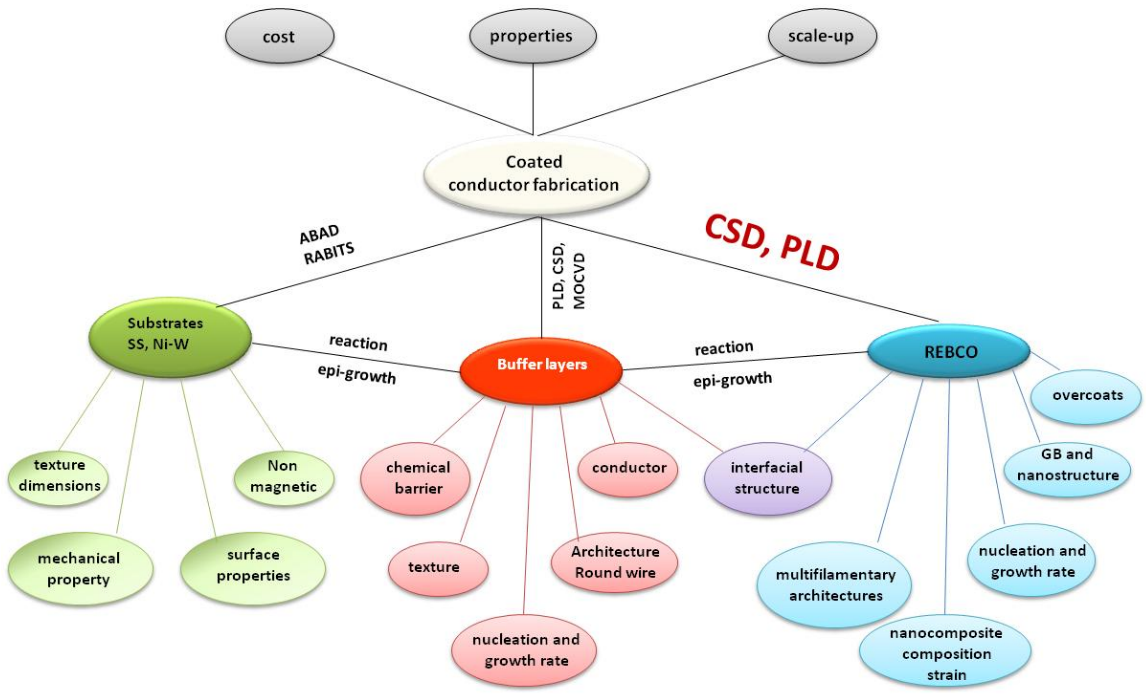

Fig. 3 General layout of the scientific and technological issues involved in the development of coated conductor production. EUROTAPES properly consider all these issues to achieve an integrated approach for industrial production.

The colossal "tour de force" for materials scientists to develop CC's may be summarized in the schema shown in Figure 3 where it is visualized how many relevant parameters need to be combined in unique ways to achieve high performance while cost-effectiveness is enhanced. EUROTAPES has decided to explore, in a first step, how to combine at best the existing knowledge in Europe in the areas of metallic substrate production and vacuum and chemical deposition methods. Scientific knowledge on metallurgical development, epitaxial growth, solution chemistry, surface chemistry, film nanostructuring and manufacturing methodologies including in-situ control tools will be used to select the best conductor architectures and processing methods for CC's industrial production (Figure 4). Three main conductor architectures will be investigated in EUROTAPES as they are shown in Figure 5.

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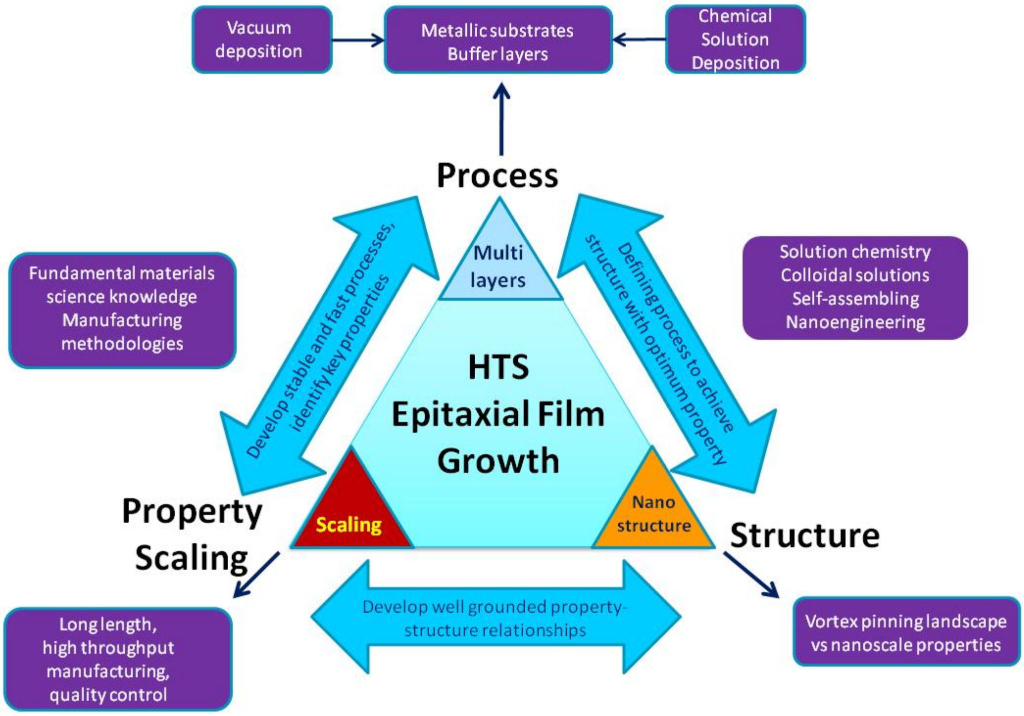

Fig. 4 The scientific core of coated conductor development is the scientific knowledge on epitaxy and nanostructure development and the main challenge is to properly implement in an integrated way the techniques to prepare multilayered materials and nanocomposites adapted to metallic substrates. EUROTAPES strategy is to combine at best the vacuum and chemically based thin film deposition approaches in order to manufacture long lengths of CC's with a high yield at a high throughput.

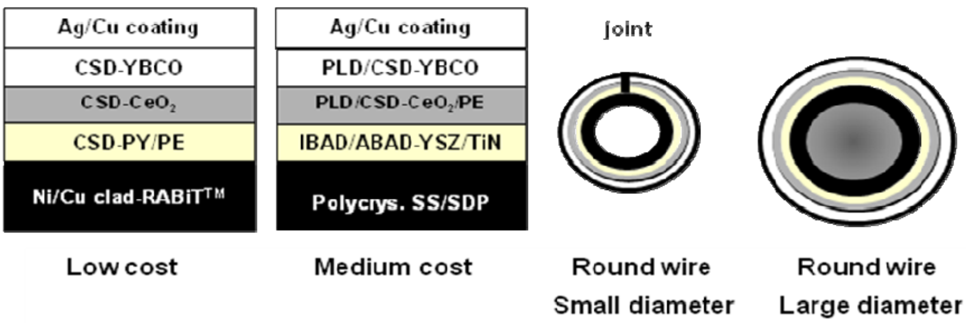

Fig. 5 Sketch of the three types of conductor architectures envisaged for development within EUROTAPES.

The RABiT approach will be investigated relying mainly in the search for new non-magnetic substrates (Ni and Cu based) to reduce ac losses and novel buffer layer combinations having as a final objective to achieve high performances at low cost based mainly on CSD methodologies. On the other hand, polycrystalline metallic substrates (SS) will be also investigated using ABAD as a route to produce textured templates. The main oxide to be investigated is YSZ, a template widely used by Bruker HTS showing to be

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very robust, but also the capabilities of TiN as a template layer will be explored. In both cases a particular effort will be made to develop methodologies intended to reduce production cost, such as Solution Deposition Planarization (SDP), as well as buffer layers by CSD. Finally, the potential of one new conductor architecture will be also examined within the consortium i.e. that of round wires based on 2G tapes. The interest of this geometry relies on its practical interest for the fabrication of power cables where the use of space should be optimized at the same time that manufacturing is simplified as it has been demonstrated by Nexans [2]. Summarizing, in Figure 6 we display the different CC's combinations that are being explored as potential industrial enablers, either within EUROTAPES or by other European players (D-Nano).

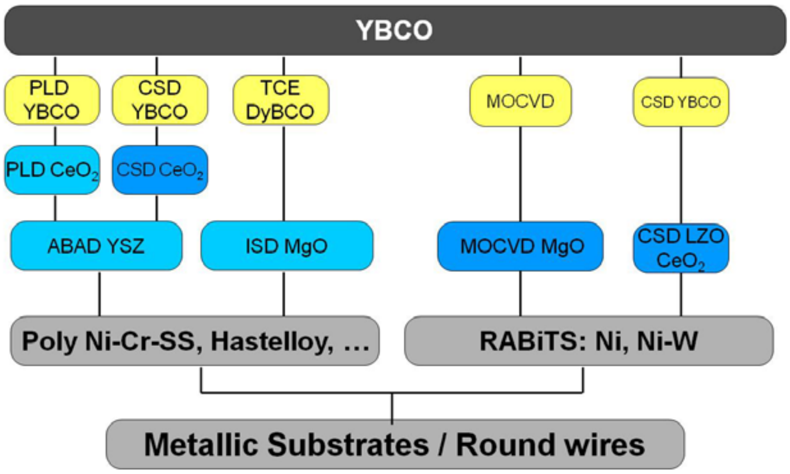

Fig. 6 Schema of the main coated conductor architectures being developed at present within Europe, including both those being investigated within EUROTAPES and by other industrial companies outside the consortium.

The synergy that will be generated among partners within EUROTAPES is very high (see Figures 7) because groups having expertise in metallic substrates (Bruker, IFW, Evico, Lafarga, ENEA) will be associated to groups with a large background on oxide buffer growth by CSD (Ghent, CNRS Grenoble, ICMAB), MOCVD (Percotech) or PLD (Bruker, IFW, Enea). On the other hand, the growth of superconducting layers themselves will be based on two main lines: PLD (Bruker, IFW, Enea, Cambridge) and CSD (ICMAB, Oxolutia, TU Cluj) [3]. In the second case novel, more eco-friendly, low-Fluorine formulations adapted to Ink Jet Deposition to achieve enhanced film thicknesses will be investigated [4]. In both cases a particular effort will be made also to develop novel nanostructuration approaches leading to enhanced vortex pinning properties, as it will be described in certain detail below. Concerning the round wire development, the main player will be Nexans while CNRS - Grenoble, Percotech and Oxolutia will support them in the materials development. Performances in terms of ac losses will be investigated by the group of Bratislava and the development of multifilamentary stripes to reduce ac losses will be investigated by Cambridge and Oxolutia based on Ink Jet Deposition [4, 5]. Finally, the groups of Vienna and Antwerp will provide general support to advanced physical and microstructural characterization respectively, Theva will contribute to testing buffer layer qualities by low temperature growth of YBCO layers and to the development of quality control tools, finally, Leitat will be responsible of performing a life cycle analysis for all the partners.

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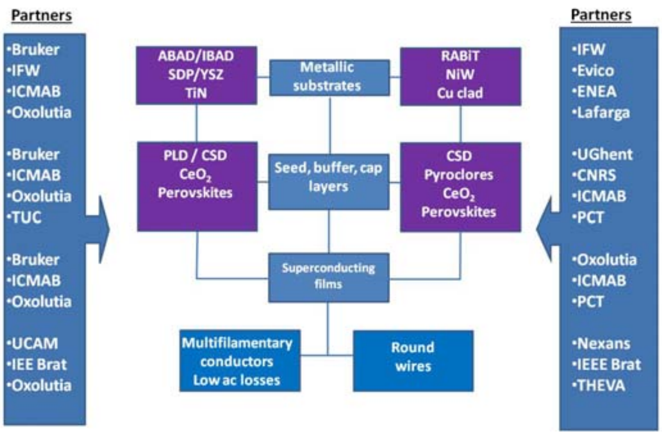

Fig. 7(a)

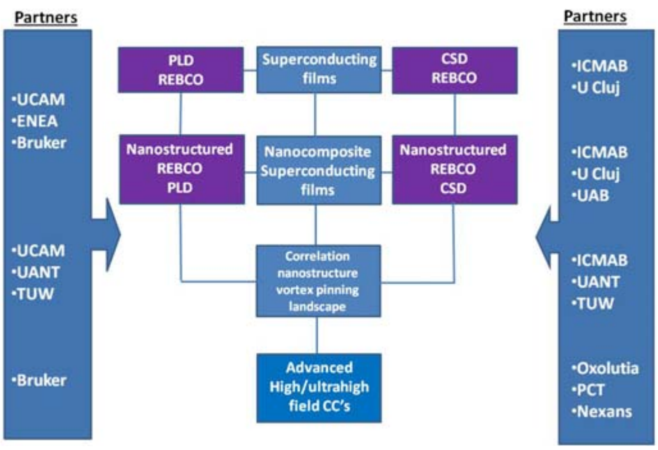

Fig. 7(b)

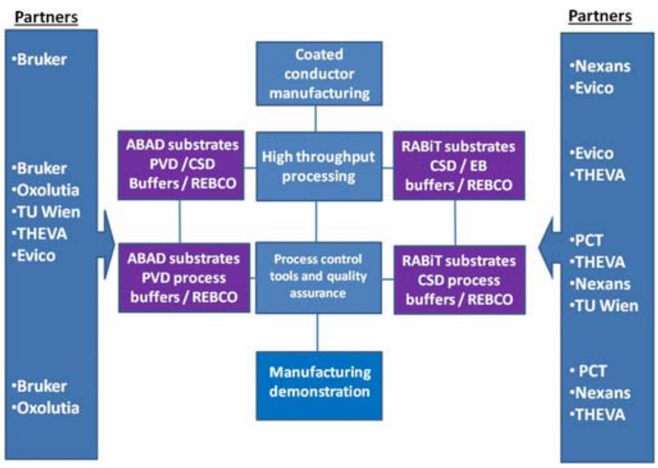

Fig. 7(c)

Fig. 7 General schema of the scientific and technological approaches being investigated within EUROTAPES, including the partners involved in each topic.

(a) Basic layout of the conductors
(metallic substrates, buffer layers, superconducting films and low ac losses structuring);
(b) General approach to producing nanostructured films and conductors for enhanced vortex pinning;
(c) Issues involved in the large scale manufacturing of coated conductors and quality control tools.

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3. Metallic substrates and buffer layers

As we have mentioned above, two different types of metallic substrates are considered for a full development of CC's within EUROTAPES. On one hand polycrystalline SS with YSZ biaxially textured templates grown by a modified ion beam deposition approach (Alternating Beam Assisted Deposition, ABAD) is being produced by Bruker in lengths exceeding 200 m at present. This templated metallic substrate is being used as the basis for the high rate PLD (HR-PLD) growth approach followed by Bruker (CeO_2 and YBCO layers) and also by ICMAB and Oxolutia for its approach based on CSD deposition of the cap layer ($Ce_{1-x}Zr_xO_{2-y}$, CZO) and the superconducting YBCO layer. Typical thickness of YSZ layers are 1.0 - 1.5 μm while that of CeO_2 and CZO are 50 and 20 nm, respectively. An appealing feature of this metallic substrate is its high mechanical strength and its robustness against high temperature annealing conditions (for instance CZO growth can be performed at 900 ºC in oxygen atmosphere). In both cases the final texture quality of the cap layer is fairly good, as well as the surface planarity (> 70 % and rms roughness ~ 1.2 nm), and thus the substrate is perfectly suited for long length deposition and growth of YBCO layers. The main objective within EUROTAPES is to define strategies to reduce ABAD production cost through the use of Solution Deposition Planarization (SDP) and to extend the substrate width above 40 mm. The technique of SDP has been found to make possible IBAD deposition in the case of MgO but its suitability for YSZ is still to be analyzed.

The potential of an additional IBAD alternative, TiN layers, will be also investigated in the scope of EUROTAPES based on the same SDP planarized SS substrates. The suitability of TiN as a biaxially textured template has already been demonstrated by IFW and it appears as an appealing alternative to reduce deposition cost due to the small thickness required to achieve highly textured films. Several oxide buffer layers (perovskites, MgO) will be investigated by TU Cluj to find a suitable multilayered structure for this novel conductor architecture.

The second option as metallic substrates to be used within EUROTAPES is based on the RABiT approach. Commercial production of Ni5%W is already available from Evico and so this substrate will form the basis for the most standard studies in this area. An objective of the project is, however, to make available non-magnetic substrates allowing to reduce ac losses. Here the first objective is to achieve highly textured Ni9%W substrates, an issue that will be handled by IFW and Evico. IFW also will further pursue its research on defining appropriate S surface templates on RABiT substrates to control the buffer layer nucleation process. Three main players will be involved in the search of improved buffer layers for NiW RABiT substrates based on CSD approaches, U Ghent, CNRS - Grenoble and Enea, while Percotech will follow MOCVD. The objective is to use IJP as an industrial approach to produce the buffer layers for these metallic templates and to reduce the total cost through selection of the simplest architecture and the most reliable growth process. Several oxide phases will be thoroughly tested, pyrochlores, fluorites, NaCl-like structures, etc. The final goal of this research is to select a simplified architecture to implement it on long length manufacturing of RABiT templates.

Within the scope of searching for non-magnetic RABiT substrates, the consortium will analyze the suitability of using Cu-based substrates mechanically reinforced through a cladding process. The study of this alternative will be carried out by Enea and Lafarga and in what concerns the definition of adequate buffer layers, Enea and ICMAB will provide its know-how on the use of PVD and CSD approaches. The advantage of this metallic substrate lies, besides of its non-magnetic behavior, on the high quality of the texture for wide substrates and its low cost, however it requires the development of robust protective buffer layers.

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Both, ABAD and RABiT based metallic substrates are in principle suitable for the round wire development to be investigated within EUROTAPES under the leadership of Nexans [2]. This novel idea is based on the fact that the fragile YBCO ceramic is accurately placed on the neutral axis of the tape where there is minimal tension during bending. The project will consider in detail all the issues related to the development of this novel approach to build more compact cables, from wire tooling and deposition of buffer and superconducting layers to electrical and thermal protection, mechanical properties and ac losses. All types of available CC's will be tested for this purpose.

4. Superconducting layers

Superconducting layers growth and optimization of their properties is for sure the core technology in coated conductors. For many years, many groups worldwide have devoted much effort in demonstrating the feasibility of these layers to transport large currents and several growth techniques have emerged as the most promising. In Europe, and also in EUROTAPES, two key technologies are foreseen: Pulsed Laser Depositions (PLD) and Chemical Solution Deposition (CSD) and $YBa_2Cu_3O_7$ and mixed $(Gd,Y)Ba_2Cu_3O_7$ are the mostly studied phases. We should also mention the distinguished effort from Theva, in Germany, in the growth of $DyBa_2Cu_3O_7$ on their Inclined Surface Deposition (ISD) approach based on reactive electron beam evaporation which have allowed them to enhance the film thickness up to 7.5 μm.
At industrial level, PLD is adopted by BRUKER and CSD by D-Nano and Oxolutia. The academic laboratories pursuing these methodologies are U Cambridge, IFW and Enea for PLD growth and ICMAB, TU Cluj, U Ghent, IFW and Enea for the CSD growth. Univ. of Ghent is involved in aqueous fluorine free solutions for YBCO growth, while the others are mostly concerned with the so called Trifluoracetates route (TFA) [3]. ICMAB and TU Cluj are the main players within EUROTAPES for the YBCO growth by CSD and their main objectives are to develop low fluorine solutions capable to be decomposed without cracking at large thickness keeping high superconducting performances at high growth rates.
The knowledge acquired in CSD YBCO growth is still limited and EUROTAPES is taking the lead within EUROPE for this matter. Nucleation and growth control as separate processes, correlation between solution precursor formulations and physical properties, the capacity to go to high thickness (~ 2μm) with minimum number of coatings, understanding of the pyrolysis process to be able to strongly fasten it and increase decomposed single layers thickness, evaluate growth rates and increase them, optimize and understand the oxygenation process, are the main issues that should be investigated within EUROTAPES. In addition, all this effort needs to be adapted to CeO_2 cap layers and to ABAD substrates from Bruker within EUROTAPES by ICMAB and TU Cluj and be transferred to Oxolutia who should demonstrate continuous mode in 10-100 m lengths. In addition the scaling up layer deposition technique adopted within EUROTAPES is ink jet printing technology.
At the industrial level D-Nano has already proved that ink jet printing is a promising, reliable and low cost methodology and they are able to achieve 10 m tapes based on NiW RABiT substrates using an "all chemical" approach. Very promising performances have been already demonstrated (I_c = 160 A/cm-w in short lengths and I_c = 105 A/cm-w in long lengths). Enhancing long length production and performance, achieving high yield, processing wider tapes and achieving higher growth rates and higher I_c (through larger film thickness) are the main issues to be undertaken by D-Nano and Oxolutia using RABiT and ABAD substrates, respectively.
On the other counterpart, PLD growth basics is still investigated by IFW Dresden mostly concerned on

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growth at high frequencies. Bruker, as the main industrial partner, has developed the multi plume high-rate PLD for large area and at present is able to have reproducible results at the level of 250 A/cm-w at 77 K. EUROTAPES should serve Bruker to go beyond these values with longer tapes and at a reduced cost.
Finally, we should mention the strong effort that SuperOX in Rusia is undertaking since few years ago. They are pursuing the MOCVD growth for the superconducting layers and they have already reached ~100 A/cm-w on 1m RABiTS tape and over ~300 A/cm-w on 10 m IBAD substrates.

5. Vortex pinning strategies

One of the main missions of EUROTAPES project is to find best/novel sources of pinning centers that should account for the three magnetic field regimes of interest mentioned earlier (i.e. low, high field and ultrahigh fields). Both technologies, PLD and CSD, are foreseen. The main initial path is the nanocomposite route where nanoparticles of a non-superconducting phase are embedded in a superconducting matrix. In the PLD case, epitaxial nano-inclusions (nanoparticles, nanorods) are expected to directly account for vortex pinning and so Bruker, U Cambridge and Enea will closely collaborate to implement it at the industrial scale [6, 7]. On the other hand, for CSD, randomly oriented nanoparticles are searched to stimulate the generation of 3D random network of additional defects and strain to pin vortices [8, 9].
The strategy is to push nanocomposites up to the limit, evaluate their pinning strength at the different magnetic regimes and model vortex pinning to be able to further approach the departing current limit.
Main efforts in PLD within Eurotapes follow the previous works where single or mixed phases have shown to control the nanorods size as well as interaction between nanoparticles and nanorods [10]. However, a full analysis in the temperature-magnetic field regime where these inclusions are effective pinning centers is to be undertaken so to foresee the need to search for other point pinning defects for ultra-high magnetic field and low temperature applications.
In CSD, the control of nanoparticles size, avoid agglomeration and coarsening are identified to be the main issues. Strong efforts are being done in this respect within this project in order to modify the growth process and keep nanoparticles in small sizes (< 10 nm) throughout the full heat treatment. Importantly this project also includes the pre-fabrication of nanoparticles to be suspended in the YBCO precursor solution as a route to control and design the final microstructure, so called ex-situ growth of nanocomposites. This effort has been pursuit for many groups and researchers without success because the highly ionic and alcoholic YBCO precursor solutions induce nanoparticles precipitation. Recently, EUROTAPES players (ICMAB, UAB, U Ghent, TU Cluj) have been successful to stabilize some of the already synthesized nanoparticle phases in the YBCO solution and a systematic analysis of the potential of this novel route in the growth of nanocomposites will be carried out in EUROTAPES. All this effort has to be transferred to the RABITs and IBADs tapes at large thickness and long lengths.
To undertake these challenges, the consortium holds specialized groups in electron microscopy (U Antwerp, ICMAB) and advanced physical characterization (TU Vienna, ICMAB, IFW) to pin the correlation between structural defects and vortex pinning.
Finally, the best options need to be demonstrated in reel-to-reel systems and end-to-end performance achievements need to be reached at high thickness.

6. Beyond I_c : ac losses, mechanical strength

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Issues related to what has been called "beyond I_c" like filamentary conductors, Roebel conductor, ac-losses, shunt resistance, final conductor architecture, mechanical strength, are very relevant issues when getting a conductor into the market, and EUROPE is working in few of them. In particular, ac-losses evaluation for the different architectures and scalable processes to obtain thin stripes for low ac-losses applications are objectives of EUROTAPES. Effort is being done in the direction of using ink-jet printing methodology to grow stripes in the tapes developed in the project and evaluate the robustness of this methodology. This work is a continuation of the EFFECTS European project which successfully evaluated ink jet printing for the deposition of the YBCO layers in CC and within EUROTAPES U Cambridge and Oxolutia will continue this development.
Other groups in EUROPE (KIT) are using picoseconds YAG infrared lasers to generate striated strands (up to 120) which demonstrated reduced ac losses [11]. These strands were used to build up Roebel cables which were then assembled as Rutherford cables for fusion magnets, as well as first demonstrations of structured tapes for undulators. Also strong effort is being done in EUROTAPES (IEE Bratislava) and at KIT to evaluate ac-losses in the different conductor architectures taking into account the ferromagnetism of the different substrates and also when structured for practical applications (FCL, motors). Additionally, within EUROTAPES Enea will also investigate and model the thermal stability of the conductors under diverse experimental configurations. On the other hand, the electromechanical properties are an important topic being strongly investigated in the ECCOFLOW European project devoted to FCL development. Finally, under the auspices of the European Fusion Development Agreement (EFDA) it has been deployed an activity of testing of CC's for fusion applications, i.e. mainly the determination of anisotropy of critical currents at high fields (12-16 T) and low temperature (T ~ 20–50 K), the electromechanical properties, ac losses analysis, thermal stabilization, study of irradiation tolerance, joint manufacturing, etc.. This activity includes 6 different partners (TU Wien, U Lausanne, KIT, ICMAB, ENEA and the Catalan Institute of Research on Energy, IREC).

7. Power applications projects

There are many important programs of development of power systems in Europe at present, even if most of them are not based on 2G CC's. A summary of the existing projects three years ago was reported by Tixador [12] and a more updated report was prepared by Noe [13]. Actually as a mean to quantify the present interest of European partners in superconducting power applications we can mention that European partners contributed with ~20 % to the large scale presentations in the Applied Superconductivity Conference 2012. Also in Russia an ambitious program (Rosatom) is now running since 2010 [14]. Here we will only mention some of the most outstading and recent activities in the different areas.
First of all, we should mention the German project Ampacity devoted to set up a 1 km ac cable together with a FCL in the city of Essen. It is a medium voltage (10 kV) , three phase cable with a total power of 40 MVA. The cable is based on BSCCO 1G tape while the FCL is a resistive model built by Nexans based on bulk BSCCO ceramics. The project is leaded by the utility RWE with the participation of KIT, Nexans and the cable should be installed at the end of 2013. Two other cable projects also exist in Russia corresponding to 20 kV - 50 MW with a lenght of 200 m (ac cable) and 2.5 km (DC cable).
In the area of FCL applications there exist several projects leading to demonstrators, the most outstanding effort comes, however, from the EU project ECCOFLOW, leaded by Nexans and with 13 partners involved, 5 of them utilities. The final goal is to have a resistive FCL based on 2G CC's with the following characteristics: 24 kV and 1 kA. The demonstrator should be installed during 2014 in the grid, first in Spain,

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and then in Slovakia where it will become permanent. Other resistive FCL development projects are active at present in Italy and Russia based on 2G CC's and with scheduled powers of 3.4 and 2.2 MVA, respectively.
Concerning rotating machines there are several initiatives being strongly active in Europe. On one hand, Siemens continue with his program of developping large synchronous machines (> 4 MW). These motors are based either on 1G or 2G conductors and they have been widely tested succesfully. Also in Germany Ostwald Motoren has been always very active in designing and building intermediate power range motors (100 - 2000 kW). Finally, a new project has been recently initiated sponsored by the EU (SUPerconducting, Reliable, lightweight, And more POWERful offshore wind turbine, SUPRAPOWER) to design a wind generator of 10 MW class based on MgB_2 conductors which should be cooled with cryocoolers. The project involves industries with a well established background on the wind energy sector (Acciona, Spain), tape manufacturers (Columbus, Italy) and research centers (Tecnalia - Spain, KIT, IEE Bratislava, U Southampton).
Research on the development of transformers has been maintained mainly at KIT in collaboration with ABB where a 1 MVA current limiter transformer has been demonstrated using 2G CC's. Finally, magnetic energy storage is a topic which has been investigated at CNRS Grenoble (800 kJ SMES based on BSCCO-2212) and at KIT (hybrid liquid H_2 and SMES storage based on MgB_2 wires) based on national projects.
Besides those power application projects there is a continuous development of HTS systems for use in High Energy Physics, mainly leaded by CERN and involving several academic and industrial partners. We should particularly mention the development of current leads for LHC and high-current electrical transfer lines for the future upgrade of LHC.
Summarizing, there's around Europe a large interest in using CC's for many power and large scale applications and so it will be extremely beneficial to further develop the industrial capacity of CC's manufacturing.

8. Conclusions

In conclusion, research in superconductivity, superconducting materials and its applications has a long tradition in Europe and, consequently, industrial development initiatives have also been widely spread, particularly those based on HTS materials. Since the discovery of CC's many national and European level supported projects have been active. Usually the European projects involved 5 - 8 partners from academia and industry and so there exists a strong tradition of cooperating actions. In 2012 a much larger R&D project has been launched, EUROTAPES, involving a total of 20 partners covering a wide spectrum of topics and techniques related to CC research and development. The main objective of this new project is to use at best all the wide know-how existing in Europe to give a definitive push to the industrial development of these emerging materials. Both, physical and chemical based deposition methodologies, will be combined in different conductor architectures to achieve CC's designed for specific applications intending to achieve high performance and reduced costs. The project will be very active in creating new scientific breakthroughs as well as in implementing scaling approaches for CC's manufacturing. It is expected that the European industry of CC's and of superconducting power systems will strongly benefit from the extended synergy created within this project.

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