Symposium on HTS Cable Applications

Kunming, China June.24-25, 2004.

Kunming Hotel, No. 52 Dong Feng Dong Road, Yunnan, China

Program

June 24, 2004 (Thursday),	
7:30 – 10:00am	***Visit Puji HSC Cable Substation***
10:00-10:30am	Congratulatory Speeches 1. Mr. Zhimin Chen Representative from Ministry of Science R&D Technology, National "863" program Key project for Superconductor Technology 2. Mr. Zelong Liao, Yunnan Electric Power Group. 3. Mr. Jichun Zheng, Beijing Science and Technology Committee 4. Dr.Jianhua Wang, Yunnan Provincial Science & Technology Department
Session A (Danxian Hall)	***Chair: Prof. Zhenghe Han***
10:30-11:10am	"Overview of HTS Power Cable Projects in the United States" "The SuperGrid: An Energy Vision for the World of 2050" Dr. Paul M. Grant Electric Power Research Institute, USA
11:10 -11:40am	"China's 33.5m,35kV/2kA HTS Cable System" Dr. Ying Xin, Innopwer Superconductor Cable Co., Ltd. China
11:40 -12:10am	"R&D of 22.9kV/50MVA HTS Transmission Cable in KOREA" Dr. Jeon-wook Cho, Korea Electrical Research Institute, Korea
12:10-2:00pm	Lunch Break (Furong Bar)
Session B (Danxian Hall)	***Chair :Dr. Paul M. Grant***
2:00 – 2:30pm	"Applications of HTS in China" Prof. Z. Han, Applied Superconductivity Research Center ,Tsinghua University, China
2:30 –3:00pm	"HTS Transmission Network will be the Key of 21st Century's Power Grid" Mr. Ryosuke Hata , Sumitomo Electric Industries, Ltd. Japan
3:00-3:30pm	"Max. Length of HTS Cables in the Future" Dr. K. Schippl , Nexans Deutschland Industries, Germany
3:30 – 4:00pm	"Research status of the manufacturing technology and application properties of HTS wires in

	Innost" Dr. Qing Liu, Innova Superconductor Technology Co., Ltd., China
4:00 – 4:20pm	"Development of a three phase 10.5kV/1.5kA HTS power cable" Dr. Yinshun Wang, Institute of Electrical Engineering, Chinese Academy of Science, China
4:20pm – 4:40pm	Break
Session C (Danxian Hall)	***Chair: Dr. Ying Xin***
4:40 – 5:10pm	"Development of HTS Fault Current Limiter at ABB" Dr. Makan Chen, ABB Switzerland, Corporate Research, Baden, CH-5405, Switzerland
5:10 - 5:30pm	"Development of Ho-123 Coated Conductors by PLD Method" Kazuya Ohmatsu, Sumitomo Electric Industries, Ltd. Japan
5:30 - 7:00pm	Discussion
7:00pm – 8:00pm	Dinner (Xizhu Hall)
June 25, 2004 (Friday)	
8:00am -6:00pm	Sight Seeing around Kunming- "Stone Forest"
6:00pm – 7:00pm	Dinner

I. Overview of HTS Power Cable Projects in the United States

II. The SuperGrid: An Energy Vision for the World of 2050

The idea of using superconductors for the transmission of electric power dates back to the period immediately following their discovery in 1911 by Kammerlingh Onnes and his coworkers. In those days, of course, the extremely poor critical state parameters – current and magnetic field – precluded any possibility of such application, their very low transition temperatures notwithstanding. During the decade of the 1950s, development of the so-called "type II" materials matured eventually enabling their application to high field electromagnets universally found today in medical and particle collider instrumentation. By the 1960s, these events also renewed hopes of using superconductors for power cable uses, with several theoretical papers on the subject appearing in a number of engineering and physics journals.

In the late 1970s, two United States National Laboratories undertook demonstration projects probing the technical and economic feasibility of advanced superconducting wire to power cables. One, at the Brookhaven National Laboratory, actually resulted in a technically successful cable carrying 1000 MVA of electrical power. Nonetheless, these achievements did not mature into commercial superconducting cables, primarily because of economic and

I. 美国超导电缆项目简介

II. 超导电网：2050 年世界能源远景展望

将超导材料应用于电力输送的想法可以追述到 1911 年 Kammerlingh Onnes 和他的合作者发现超导材料之初。当然，那时极端苛刻的状态参数——电流、磁场——排除了超导材料电力应用的可能性，更不用说需要极低的超导温度。上世纪 50 年代，终于成熟地发展了所谓的“二类”超导材料，使其可在高电磁场中使用，现在它们已广泛应用于医学设备和粒子对撞机中。到 60 年代，多种工程、物理期刊刊登了相关的数篇理论性文章，超导材料的进展重新点燃了它们应用于电力输电电缆的希望，。

70 年代末，美国两个国家实验室开始了试点项目，以探索将先进的超导带材用于输电电缆的技术、经济可行性。其中，Brookhaven 国家实验室，确实成功地制作出容量为 1000 MVA 的超导电缆。然而，此举并未形成成熟的商业超导电缆，这主要是由于当时的经济和社会状况...具有讽刺意义的是，成功的持续努力反而降低了预期载流能力的增

social factors that had evolved by that time...successful conservation efforts had lowered expected electricity load growth such that, ironically, the incremental efficiencies offered by superconductivity were no longer required at the cost involved...an important lesson in that the successful deployment of a technology often rests on factors unforeseen and outside its internal development.

The years from 1986 to the present witnessed the discovery of the copper oxide perovskite high temperature superconductors and their coming-of-age in practical wire form, engendering initially two, and now four, cable demonstration projects sponsored by the US Department of Energy underway in America. We will describe the current status of these projects and their relevance to those under consideration and in existence by the People's Republic of China. Finally, we will present a vision of a future energy economy, based on a symbiosis of nuclear, hydrogen and superconducting technologies for a planet free of carbon emissions and least invasive of the environment and ecology, which we believe deserves careful consideration by the Chinese people as their nation reaches toward complete industrialization by the mid-21st Century.

Vita

Dr. Paul M. Grant ,
Science Fellow
Senior Technical leader
Strategic Science and Technology

长，以至于超导电性缓慢增长的效率与其投入相比已不再需要了...这给我们一个重要的教训，一项技术的成功应用往往依赖于一些在其内部发展之外的未预见因素。

1986 年以来，发现了铜基钙钛矿结构高温超导材料，并成熟地制造出可应用的超导带材，这使得美国能源部资助了最初两项，目前四项超导电缆试点项目。我们将介绍这些项目的进展状况，以及它们与中国已有的和策划中的超导电缆项目的关系。最后，我们还将展望未来能源经济的远景。核电、水电和超导技术的共同使用将营造一个没有碳污染，最低限度生态环境破坏的星球。我们相信将在 21 世纪中页全面迈入工业现代化的中国人民一定会认真思考这些问题。

演讲者简介：

Paul M. Grant 博士，美国哈佛大学应用物理系博士，美国电力研究院 Epri 高级研究员，近年来多次在国际权威刊物上发表有关高温超导电缆技术的文章。

Installation and Trial Operation of 35kV/ 121MVA, HTS ac Power Cable

The China's first HTS power cable system, 3 phases of 33.5m, 35kV/121MVA, warm dielectric cables with terminations and cryogenic facilities was installed in the China Southern Power Grid at Puji substation of Kunming, Yunan province in March, 2004. Live-grid trial operation was started on April 19, 2004. This substation distributes electricity to 4 industrial customers (including 2 metallurgical refineries) and a residential population of about 100,000.

In this talk, we will introduce the project information, the detailed final design parameters of the system, and the installation highlight. Experimental data on ac current carrying characteristic of short cable models are presented and discussed. Various results from the 33.5 m system field tests and trial operation will be reported.

Vita

Dr. Ying Xin, General Manager, received a B.S. from Tianjin University in 1983, and a PhD from University of Arkansas in 1991. He has been working extensively on HTS material and applications for 15 years, during which he was for 8 years a senior researcher and lead scientist at the Midwest Superconductivity Inc., Lawrence, Kansas, USA. He holds six US patents in superconductor material and applications and has an impressive publication record. Dr. Xin assumed his present position at Innopower in 2001

35kV/ 121MVA 交流超导电缆的安装与试运行

2004 年 3 月中国第一组三相 33.5 米 35 千伏 121 兆伏安，具有终端和制冷设备的热绝缘超导电缆系统在中国西南电网云南省普吉变电站安装成功。2004 年 4 月 19 日开始挂网试运行。普吉变电站为 4 家工业企业（包括 2 家金属冶炼企业）和 10 万居民供电。

在此，我们将介绍项目的相关信息，详细的系统最终设计参数，并重点介绍电缆的安装。短缆样品交流载流特性的实验数据和 33.5 m 电缆系统的现场测试和试运行的结果也将在此介绍和讨论。

演讲者简介：

信赢博士，1983 年毕业于天津大学应用物理专业，获理学学士学位。1991 年毕业于美国 University of Arkansas 凝聚态物理专业，获博士学位(Ph. D)。 1991-2001 年就职于美国中西超导技术公司，先后任高级研究员、项目负责人及首席科学家。2001 年回国任北京云电英纳超导电缆有限公司总经理。信赢博士是高温超导材料的专家，特别是在铊系高温超导材料的材料合成、结构分析和块材应用技术上处于世界领先地位。主要研究成果包括六项美国专利，近 50 篇 SCI 或 EI 收录的科学论文，近 20 篇国际会议论文。

R&D of 22.9kV/50MVA HTS Transmission Cable in KOREA

The underground power transmission systems have to be expanded according to the increasing power demand in Korea, but it is almost impossible to construct new cable tunnels and ducts to install additional underground transmission lines in Seoul. HTS power transmission is one of the most feasible solutions for solving the power system problems. HTS power transmission cables appear to be the replacement and retrofitting of underground cable in Seoul areas.

The 30m long, 3 phase 22.9kV class HTS power transmission cable system have been constructed by Korea Electrotechnology Research Institute (KERI) and LG cable Co. Ltd. that is one of the DAPAS program of 21st century frontier project in Korea. DAPAS program (Dream of Advanced Power system by Applied Superconductivity technologies) is the name of the Applied Superconductivity Technology R&D program, which has been selected as one of the 21st Century Frontier R&D Program sponsored by Korea Ministry of Science and Technology (MOST).

The HTS cable consists of Ag/Bi-2223 tapes, high voltage insulation paper which is impregnated by LN2. The cables are rated at 22.9kV, 50MVA, and 60Hz and are cooled with pressured liquid nitrogen at temperature from 70 – 80K. The 30m 3-phase cable system is evaluating for system performance and long-term test.

韩国 22. 9kV/50MVA 超导输电电缆系统的研制

由于韩国电力需求的增长，地下输电系统必将得到拓展。但在汉城，新建电缆隧道及管路以安装更多的地下输电线路几乎是不可能的。高温超导电力输送是解决这一电力系统问题最切实可行的方案之一。高温超导输电电缆有望作为替代品取代汉城地区的地下电缆。

韩国电力技术研究所（KERI）和 LG 电缆公司共同制造了 30m 三相 22. 9kV 级的超导输电电缆系统，这是韩国 21 世纪前沿项目中 DAPAS 规划之一。DAPAS（Dream of Advanced Power system by Applied Superconductivity technologies）是应用超导技术研发项目的名称，被韩国科学技术部选作 21 世纪前沿科研项目的内容之一。

高温超导电缆由 Ag/Bi-2223 线材和高压绝缘纸制成，其中注入液氮。电缆的额定指标为 22. 9 kV、50 MVA 和 60 Hz，用压缩液氮冷却至 70-80 K。当前，30 m 三相电缆系统正在进行系统性能和长期运行的测试工作。

Vita

Jeonwook Cho earned his B.S. and the M.S. degrees in Electrical Engineering from Hanyang University in 1983 and 1985 respectively and the Ph.D. degree in Electrical and Electronic Engineering from Yonsei University specializing in the superconducting power cables in 2001. Since 1990 he has been a researcher in the Korea Electrotechnology Research Institute (KERI). He is involved with the development of power cables of high temperature superconductors and the superconducting energy storage system(SMES) at KERI. He is the project manager for the HTS power transmission cable project in KERI.

演讲者简介：

Jeonwook Cho，1983 年汉阳大学电子工程专业本科毕业，1985 年汉阳大学电子工程专业硕士毕业，2001 年 Yonsei 大学电子电力工程专业博士毕业，主要从事高温超导电缆方面的研究。1990—现在，韩国电工所研究员，从事高温超导和 SMES 系统的研发工作，现为电工所高温超导电缆项目负责人。

Applied superconductivity in China

Recently, the applications of superconductivity are increasing significantly in China. At the same time, energy shortage appears to be a serious challenge to the sustainable development. In this talk, we will review the progress of HTS power application in China and discuss the impact of HTS on the electrical industry. The potential of HTS power applications in China is great and international collaborations can promote the HTS applications.

Vita

Prof. Zhenghe Han, Graduated from Physics Dept. of Tsinghua University in 1982, and received his Ph.d degree from Copenhagen University in 1996.He studied and worked extensively in HTS research in Europe from 1986 to 2000.Now he is the derector of Tsinghua University's Applied Superconductivity Research Center(ASRC). Chairman of the Board of Innova Superconductor Technology Co., Ltd and Innopower Superconductor Cable Co.,Ltd.

高温超导在中国的应用

近年来，中国超导电性的应用研究有了显著的增长。与此同时，可持续发展却受到了能源短缺的严峻挑战。在此，我们将回顾中国高温超导电力应用的发展历程，并讨论高温超导技术对电力工业的影响。高温超导技术在中国的电力应用潜力是巨大的，国际合作将推动高温超导技术的应用。

演讲者简介：

韩征和博士，1982 年毕业于清华大学物理系。1986 年～1990 年，在瑞典皇家工学院固体物理系，访问学者，研制快冷软磁合金，高温超导（薄膜，块）。1990 年～1993 年，在瑞典 Likoping 大学技术中心，研究工程师，研制微波用高温超导薄膜。1993 年～1997 年，在丹麦 NKT 研究中心，研究工程师，高级工程师，负责高温超导导线研究。1997 年～2000 年，丹麦，NST，高级工程师，负责高温超导导线发展和生产线建立。2000 年 5 月回国，筹建清华大学应用超导研究中心并任主任。2000 年 9 月创建北京英纳超导技术有限公司任董事长兼总工程师。2001 年 7 月创建北京云电英纳超导电缆有限公司。

HTS Transmission Network will be the Key of 21st Century's Power Grid.

3 HTS Cable Demonstrations in Yokosuka (Japan), Copenhagen (Denmark) and Carrollton (US) were successfully implemented. After these successful milestones, the HTS Cable development has been entered to the 2nd stage. Also, HTS cable Projects are on-going in Korea and China. 3 Bi-based Cable projects, which are in the real network, have started in US under international collaborations. Big Innovation of Bi-based wire has been achieved. Ic, Mechanical Properties, Anti-Ballooning Properties and Yield of Bi-Based wires are simultaneously improved greatly. The innovation of the Bi-based wire is the turning point for the HTS application to the real application for it's user-friendly characteristics. HTS Cables with Large Transmission Capacity and Low Loss are Environmentally Friendly, hence Indispensable for 21st Century's Power Grid and the innovated Bi-based wire is leading the HTS cable!

超导输电网将成为 21 世纪电网的关键

Yokosuka（日本）、Copenhagen（丹麦）和 Carrollton（美国）成功安装了 3 套高温超导电缆系统。在这些里程碑之后，高温超导电缆的发展已经进入了第二个阶段。目前，中国和韩国的高温超导电缆项目正在进行之中。通过国际合作，美国启动了将接入实际电网的 3 项 Bi-基超导电缆项目。Bi-基超导线材已得到很大的改进。Ic、机械性能、防起泡和产量都同时得到了很大的改善。Bi-基超导线材具有使用方便的特点，它的改进是超导技术应用的转折点。高温超导电缆大容量、低损耗的特点有利于环境保护，因此在 21 世纪的电网中将是不可或缺的，而 Bi-基线材的改进将引领高温超导电缆技术的发展。

Vita

Mr.Hata majored in Electronics Engineering, Faculty of Engineering of Tokyo University and graduated in 1970. He joined Sumitomo Electric Industries, Ltd in a same year and started his carrier as a Production Engineer of Underground Electric Power Transmission Cables, out of which his efforts focused on Oil-Filled Self-Contained Power Cables. After that he transferred to Power Cable Division thereafter to R&D Group. He developed Polypropylene Laminated Paper (PPLP) as a new high performance insulation material, PPLP insulated AC 800kV OF cable, Optical-fiber incorporated submarine cable, PPLP insulated AC OF cable installed along bridges, PPLP insulated 500kV DC submarine cable, HTS cable system, Gas-insulated Transmission Line and so on.

His major experience in Sumitomo Electric is following:

1992: General Manager, Power Engineering Department, Power Cable Division

1998: General Manager, Power System Technology R&D Laboratories

2001: Senior General Manager, R&D Group and General Manager, Automotive Technology R&D Laboratories

2003: Executive Officer and Senior Vice General Manager, R&D Group

演讲者简介：

Hata先生1970年毕业于日本Tokyo大学电子工程专业，同年加盟Sumitomo Electric Industries, Ltd开始了地下输电电缆制造工程师的工作，致力于充油自封闭电力电缆的制造。此后，他先后调动至电力电缆部和研发组。他研制的层状聚丙烯纸(PPLP)是一种高性能的新型绝缘材料。PPLP可用于 800kV 交流电缆、海底光纤电缆、沿桥铺设的电缆、500kV 直流海底电缆、高温超导电缆系统、气密输送线等处的绝缘。

在Sumitomo Electric的主要经历如下：

1992：电力电缆部，电力工程分部经理

1998：电力系统技术研发实验室经理

2001：自动化技术研发实验室经理和研发组高级经理

2003：研发组执行官及副本部长

Max. Length of HTS Cables in the Future

HTS power cable are a novel technology for the future electric cable industry. There are a lot of new projects planned and running in the world. The max. length will be realized in the next future in the LIPA project with a cable length of 600 m.

There are different reasons for a limitation of the cable length:

1. Physical limitations:
   - Pressure drop, AC and heat loss reduce the max. length to a cooling station.
   - The necessary good insulation vacuum limits the max. length of the vacuum space.
2. Shipping limitations:
   - The requirement of transport reduce the max. cable length to a cable connection.
3. Maintenance and repair problems:
   - Maintenance and repair possibilities reduce the max. length of the vacuum space.

The technique for the manufacturing of long length cryogenic envelopes up to 2000 m length will be presented.

Vita

Dr. Klaus Schippl
Nexans Deutschland Industries,30179 Hannover, Germany

未来超导电缆的最大长度

高温超导输电电缆是未来电力电缆工业中的一项崭新的技术。世界上有许多计划中和实施中的新的超导电缆项目。LIPA项目在不久的将来将实现具有最大长度600m的超导电缆。

超导电缆长度限制的各种原因：

1. 物理限制：
- 压降、交流损耗和热损耗限制了制冷站能够支持的电缆最大长度。
- 必须的良好的真空绝缘限制了真空的最大长度

2. 运输限制：
- 运输需求限制了电缆的最大长度。

3. 维护和修理问题：
- 可能进行的维护和修理限制了电缆真空空间的最大长度。

我们将介绍长达2000m大长度制冷密封系统的制造技术。

演讲者简介：

Klaus Schippl 博士，耐克森公司德国有关超导技术方面销售负责人，对高温超导电缆技术有多年研究经验。

Research status of the manufacturing technology and application properties of HTS wires at InnoST

As the first company engaged in commercial manufacture of HTS wires in China, InnoST has devoted great efforts to improving the electrical performances and application properties of its HTS wire products. Based on huge amount of fundamental research work, the short sample can achieve I_c=110 A and J_c =12 kA/cm^2. Under strict quality control, InnoST's HTS wires can be manufactured reproducibly with length up to 1km, I_c over 90A and J_c over 9 kA/cm^2. Meanwhile, to demonstrate technical feasibility and reliability of HTS power apparatus, diversified wire-design has been carried out, including reducing AC losses and thermal conductivity, increasing insulation properties and so on. On the other hand, in order to further reduce the manufacturing cost, InnoST also intensified its effort in R&D to realize commercial manufacture of superconducting precursor powder.

InnoST公司超导线材的制造工艺和使用性能的研究现状

作为中国首家从事高温超导线材生产制造的公司，英纳超导有限公司为提高高温超导线材产品的电学性能和应用品质付出了巨大的努力。基于大量基础性研究工作，我公司生产的线材短样已达到I_c=110 A 和 J_c =12 kA/cm^{2}的水平。通过严格的质量控制，可稳定生产长度为1 km，I_c大于90 A，J_c大于9 kA/cm^{2}的高温超导线材。同时，为达到高温超导电力设备技术可行性和可靠性的要求，我们对超导线材进行了多种设计，包括减少交流损耗、降低热传导、增强绝缘性能的超导线材。此外，为进一步降低超导线材的制造成本，英纳公司加大了研发力度，以实现超导粉末前驱体的工业制造。

Vita

Dr. Qing Liu, Director and General Manager of InnoST.Graduated with a Bachelor of Science degree in Engineering at the Department of Metallurgy and Material, Chongqing University, China in 1984. In 1987 and 1991, Dr. Liu obtained his Masters and Doctor degree respectively, in Engineering at the Department of Metal Material and Techniques, Harbin Institute of Technology in China, whilst at the same time working as Assistant Lecturer at the faculty. In 1991, Dr. Liu conducted his post-doctoral research at the University of Science and Technology of Beijing, and was promoted to Associate Professor in the following year. Dr. Liu further pursued his advanced technological research and development in Denmark and in 1993, he acted as a Visiting Researcher and Senior Researcher at the Material Research Department of Risø National Laboratory in Denmark for about six years in respect of industrial materials processing and related research. Dr. Liu returned to China in 1999 and served as a Professor and Tutor of doctoral students at the Department of Material Science and Engineering of Tsinghua University in China since then. During the period from 1998 to 2000, Dr. Liu also acted as the chief representative in China for the Denmark-headquartered HKL Technology Company and was responsible for promoting the company's products. In March 2001, Dr. Liu widened his business exposure by attending the Executive MBA Program held by Guanghua School of Management Peking University.

Dr. Liu joined InnoST since 2000 as Director and General Manager. He is responsible for coordinating and monitoring the Company's production, overall operations, as well as the Company ' s strategic development and investment planning.

演讲者简介：

刘庆博士，1984年毕业于重庆大学冶金及材料工程系，1987年～1991年，哈尔滨工业大学获硕士、博士学位。1991年-1993年，北京科技大学博士后、副教授。1993年-1999年，丹麦Risφ国家实验室，材料研究部，高级研究员。1999年回国，清华大学材料科学与工程系，教授，博士生导师。2000年创建北京英纳超导技术有限公司，任董事兼总经理。刘庆博士是材料学及材料加工领域专家，是国际及国内多个学术机构及会议的理事及顾问专家。已发表科学论文80余篇。

Development of a three phase 10.5kV/1.5kA HTS power cable

A 10-m long, 3-phase, 10.5 kV/1.5 kA HTS power cable has been built and tested. The warm dielectric technology is chosen by using different winding schemes. The critical current of the cable is more than 2800 A and the total joint resistance of the conductor is less than 0.12 μΩ at 74 K. The AC loss measurements showed the losses is less than 0.85 W/m at 74 K and 1.5 kA_{rms} / 50 Hz. The cable was operated continuously many times, the results show that it is stable and reliable at rating current for more than 5 hours. Finally, the progress in 75-m, 3-phase 10.5 kV/1.5 kA HTS power cable system was presented.

10. 5kV/1. 5kA 三相交流高温超导电缆的开发

本文首先介绍10米10. 5kV/1. 5kA三相交流高温超导电缆的设计和实验。电缆绝缘采用热绝缘工艺。直流实验结果表明，临界电流超过2800 A，接头电阻在74 K小于0. 12 μΩ，交流损耗在74K和1. 5 kA_{rms} / 50 Hz小于0. 85 W/m。电缆连续多次运行，每次额定电流运行超过5小时，电缆运行稳定、可靠。最后，介绍了75米10. 5kV/1. 5kA 三相交流高温超导电缆的研究进展。

Vita

Yinshun Wang, male, obtained Ph.D in Applied Superconductivity Laboratory, Institute of Electrical Engineering, Chinese Academy of Sciences 1998. Then he did postdoctoral research in MAYO and MIT from 1998-2000, majoring in Micro-CT correction and HTS flux pump of next generation NMR high field magnet respectively. Since mid of 1995, he has being engaged in DC characteristics of HTS such as anisotropy, mechanical property (tension and bending), homogeneity, heat cycling, AC losses of HTS, contact-free methods for critical current and n value. On the other hand, he did research on stability of AC HTS magnet, winding technology, jointing, wrapping insulation , high voltage insulation in low temperature etc. At present, he is responsible for the "863" three-phases 1.5kV/1.5kA HTS power cable and take part in "973" applied basic research of HTS item. During recent years, he published about 30 papers and applied 5 patents in HTS application field.

演讲者简介：

王银顺，男 ，1998年中国科学院电工研究所应用超导实验室博士毕业。1998年—2000年分别在美国酶鸥和麻省理工学院做博士后研究工作，分别从事Micro—CT成象和下一代NMR高场磁体高温超导磁体磁通泵的研究工作。从90年代中期开始从事有关高温超导体直流特性、各向异性和交流损耗的研究，在铋系高温超导带材交流损耗、电磁特性、抗弯曲特性、热循环特性以及应力特性方面进行了系统的理论和实验研究，同时进行交流超导磁体稳定性方面、高温超导磁体绕制工艺、绝缘、低温高压等方面的研究。目前主持国家“863”高温超导电缆项目，并参与国家“973”高温超导应用基础研究项目。近年来在国际及国内学术杂志上先后发表了有关高温超导应用方面论文30余篇，申请专利5项。

The development of Superconducting Fault Current Limiter at ABB

ABB, the world leader in Power Technologies, is actively pursuing the High Temperature Superconductor (HTS) technology for power applications since its discovery in 1986. Presently, the focus is on the development of a SuperConducting Fault Current Limiter (SCFCL).

SCFCL represents an ideal fault current limiter, i.e. in normal operation the SCFCL is in its superconducting state and has negligible impedance. In the event of a fault, the transition into the normal conducting state limits the current very fast and in a passive way. SCFCL can enable novel design of electric grids, and bring added value to existing grids.

The SCFCL component is a composite structure consisting of layers of bulk Bi-2212 ceramic, resistive metallic electrical bypass and fibre reinforced composite. The employment of a robust bypass facilitates a uniform quench in the SCFCL component during a fault event. Depending on the level of prospective fault current, a fault current is typically reduced to around 10 times nominal current in the first current peak and further to 2-5 times after 50 ms into the fault.

In a case study carried with German Utility, RWE it was shown that a SCFCL can provide an ideal solution for grid-coupling.

In 1996, ABB installed the world first SCFCL demonstrator in a Swiss hydropower

ABB 公司超导故障限流器的研究进展

ABB 作为世界电力科技的领军企业，早在 1986 高温超导材料发现之初，就已经积极开展了高温超导技术电力应用的研究工作。目前，研究的重点是超导限流器。

超导限流器是一种理想的限制短路电流的电力设备。正常使用时超导限流器处于超导状，阻抗可以忽略；当发生短路时，超导态转变为正常态，从而迅速限制短路电流。超导限流器的使用可实现新型的电网设计，也可为现有电网带来益处。

超导限流器由多层 Bi-2212 块材复合体、阻性金属电流支路和纤维增强复合材料组成。使用通流能力强的电流支路，有利于短路电流发生时限流器内超导材料的均匀失超。根据限流器的预期使用要求，短路电流通常在头一个电流波峰内被减弱至正常电流的 10 倍左右，在 50ms 内减弱为正常电流的 2~5 倍。

在与 German Utility，RWE 进行的研究表明，超导限流器为电网的联网提供了理想的解决方案。

plant, representing the first HTS power installation worldwide. In 2000, ABB successfully developed and tested a single phase 6.4 MVA SCFCL demonstrator, based on a novel conductor geometry design and innovative Bi-2212 ceramic fabrication technology. Since then, the technology was further improved and performance and endurance testing was performed.

The development of the 6.4 MVA demonstrator, together with the application prospects of such Bi-2212 based SCFCL will be presented and discussed.

Vita

Makan Chen received his B.Eng. from Harbin Institute of Technology, China in 1984 and studied at University of Sheffield, UK where he received his Ph. D. in Materials Science in 1990. He was a Research Fellow at University of Cambridge, UK until 1995.

He joined ABB Corporate Research in Switzerland in 1995 to work on power applications of "High Temperature Superconductors" in department of Electro-Technologies. In 1999 he became the project leader for "Superconducting Fault Current Limiter" where he led the development of a world leading technology on HTS at ABB. In 2004 he joined the ABB Business Area "Semiconductors" as Senior Process Engineer.

He is the co-author of more than 50 publications and more than 20 patents in the area of materials engineering, development of HTS fault current limiters and power applications of HTS.

1966 年，ABB 在瑞士的一个水电站安装了世界上首台超导限流器，这也是世界范围内高温超导材料在电力上的首次应用。2000 年，ABB 采用新颖的导体结构设计，创新了 Bi-2212 块材制造工艺，成功地研制并测试了单相 6.4 MVA 超导限流演示器。此后，又进一步完善了超导限流器技术，并测试了其性能和持久运行能力。

在此，将介绍 6.4 MVA 超导限流器的研制过程，同时讨论以 Bi-2212 为超导材料的超导限流器的应用前景。

演讲者简介：

MaKan Chen ，1984 年于中国哈尔滨工程学院获工程学士学位，其后就读于英国 Sheffield 大学，并于 1990 年获材料科学博士学位。1990~1995 年，为英国 Cambridge 大学的科研工作人员。

1995 年加入 ABB 瑞士研究所电力技术部，从事高温超导体电力应用的科研工作。1999 年，成为高温超导限流器项目组长，并为 ABB 带队发展了具有世界先进水平的高温超导技术。2004 年，作为高级工艺工程师加入 ABB “半导体” Business Area.

曾在工程材料、超导限流器和高温超导材料的电力应用等领域合作发表文章 50 余篇，申请专利 20 余项。

Development of Ho-123 Coated Conductors by PLD Method

We have developed Ho-123 thin films by using pulsed laser deposition (PLD) method. Ho-123 shows high Jc up to 5MA/cm^2 in the case deposited on single crystal substrates such as sapphire and LAO. In this work, based on our PLD technique, Ho-123 coated conductors have been developed on flexible metal tape substrates. Oxide buffer layers such as YSZ and CeO_2 have been deposited by PLD method on textured Ni-alloy tapes. Buffer layer structure with several combinations of 1st and 2nd buffer layers were studied. Fine (001) oriented epitaxial growth of FWHM=9~10 ° was achieved for the homo-epitaxial buffer layers consist of CeO_2 and YSZ. Surface roughness was several nm and the surface was almost flat with few particles. Ho-123 film deposition was conducted on the buffer layers by PLD method. Sample less than 0.2 μm in thickness showed Jc (77 K, 0T) over 2 MA/cm^2. Sample with 1.4 μm in thickness showed Jc (77 K, self field) over 1MA/cm^2. In this sample, Ic was 153A-cm^w. X-ray (103) pole figure of Ho-123 shows in-plane texture of approximately 9°. This demonstrated fine epitaxial Ho-123 growth on YSZ / CeO_2 / textured Ni-alloy tape. SEM photograph of Ho-123 layer revealed relatively smooth film morphology with some particles. Furthermore, Jc-B characteristics at 4.2 K under the high magnetic field up to 30 T were evaluated. Ic (4.2 K, 30 T) was 220A-cm^w when the external magnetic field was applied parallel to the tape surface.

采用激光溅射制作 Ho-123 覆膜导体

我们采用激光溅射（PLD）的方法制备了 Ho-123 薄膜。在单晶蓝宝石和 LAO 基片上沉积的 Ho-123 薄膜 J_c 可高达 5 MA/cm^2。基于 PLD 技术，Ho-123 覆膜导体可以以柔性金属带材为基底。使用 PLD 可以在有纹理的 Ni 合金带材上沉积氧化物过渡层如 YSZ 和 CeO_2 等。我们研究了几种组合结构的一次、二次过渡层结构。获得了具有良好的（001）取向均匀外延生长的 CeO_2/YSZ 过渡层，其 FWHM=9~10°，表面粗糙度为几个纳米，非常平整，几乎没有颗粒。使用 PLD 在此过渡层上沉积 Ho-123 薄膜。样品厚度小于 0.2μm 时，J_c（77K, 0T）大于 2 MA/cm^2；样品厚度为 1.4μm 时（77K，自场），J_c大于 1 MA/cm^2，I_c为 I_c was 153A-cm^w。Ho-123 薄膜的 X-ray（103）极像图显示其层间平整度为 9°。这说明 Ho-123 在以 Ni 合金为基底，以 YSZ/CeO^2 为过渡层的带材上能够很好地外延生长。SEM 图显示 Ho-123 薄膜表面较为平整带有少量颗粒。此外，我们还研究了 4.2K 下磁场高达 30T 时 J_c-B 的特性，当这一磁场平行于带材表面时，Ic（4.2K，30T）为 220A-cm^w。

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Vita

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Born in 1959
Graduated from University of Tsukuba in 1983 (M. S., Material Science)
Entered Sumitomo Electric Industries in 1983
Over 20 years for superconducting wire development
1983-1986 Basic research of NbTi and Nb3Sn conductors
1987-1988 HTS material research and wire development of BSCCO
1989-1993 NbTi, Nb3Sn and Nb3Al conductor for AC use (Generator, Transformer, etc.)
1994-1998 BSCCO wire and Cable conductor, Magnet by using BSCCO wire
1999-2004 HTS thin film (Coated conductor, Large area film for FCL, etc.)

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1983 年毕业于 University of Tsukuba（材料科学硕士学位）
1983 年加入 Sumitomo Electric Industries 公司
从事了 20 多年超导线材的研究工作
1983-1986 年进行 NbTi 和 Nb3Sn 的基础性研究
1987-1988 年高温超导材料研究和 BSCCO 超导线材的研制
1989-1993 年 NbTi，Nb3Sn 和 Nb3Al 导体的交流应用（发电机、变压器等）
1994-1998 年 BSCCO 线材及其在超导电缆和超导磁体中应用研究
1999-2004 年高温超导薄膜（覆膜导体、限流器用大面积超导薄膜）