ABB’s partnership with MIT and Leaders For Manufacturing program

ABB Corporate Research has a tradition of working with many leading universities around the world. Typically, these collaborations help keep the company up to date with emerging science and technology, which can then be adapted for the development or enhancement of ABB products, services and solutions.

Over the past few years, ABB has been benefiting from the knowledge and practices of manufacturing operations experts in academia. One such important collaboration is with the Massachusetts Institute of Technology (MIT). Through its manufacturing technology program, ABB is closely associated with MIT’s Leaders For Manufacturing (LFM). This is a two-year graduate-level academic and research program in which students have the opportunity to become ‘bi-lingual’ in management and engineering sciences and leads to two master’s degrees: one in engineering and one in management.

LFM in a nutshell

LFM was launched in 1988 in response to the needs of American companies to become more competitive. It is an active partnership comprising MIT’s School of Engineering, Sloan School of Management, and industry. This partnership is dedicated to addressing the broad issues of manufacturing, such as product development, marketing and the supply chain. Together the partners develop, design, implement, and participate in a cutting-edge, integrative engineering and management program that gives them the knowledge, tools, and support they need to strengthen, lead and transform industry.

Through its academic structure, its research, and its outreach to other universities around the globe, LFM strives to integrate the total manufacturing enterprise with customers, suppliers, government and the community. The course tutors generally have connections to major companies, and can see first hand certain business practices and technology – both new and emerging – at work. LFM participants include a diverse mix of students and alumni, senior executives at companies such as Intel, ABB and Ford, and faculty from MIT’s Sloan schools of management and engineering. Such a mix ensures that many of the students participating have solid credentials in engineering or science.

In addition to classes and lectures focused on improving manufacturing in the context of case studies and personal experience, students have an opportunity to apply these principles in real-world factory settings through several plant tours. They are offered a chance to comment on the running of the facility, often giving valuable input on how to improve certain processes within the plant. In 2003, a 16 day ‘cross-country’ plant tour included facilities at Kodak (Rochester, New York), Hamilton Sundstrand (Rockford, Illinois), Ford (Detroit), General Motors (Detroit), Agilent Technologies (San Francisco), Boeing (Los Angeles), Dell (Austin), and Honeywell (Baton Rouge).

ABB’s commitment

The LFM program is dedicated to discovering the principles that produce world-class manufacturers and leaders, and translating those principles into teaching and practice. It ideally fits with ABB’s Manufacturing Technologies program, which aims at introducing world-class manufacturing methods to ABB factories. This involves improving the speed, inventory levels and quality at ABB factories as well as supporting IT solutions and products for ABB manufacturing. To help it achieve these goals, ABB decided to join MIT’s LFM program in spring 1999 as a managing partner, becoming one of the very few European companies to participate in the LFM.
As a managing partner, ABB plays a critical role in LFM program governance, overall program policy and operations, and internships. The most visible part of the partnership is perhaps that with internships. The LFM program includes a 26-week research internship at a partner company, during which students undertake a research project that exposes them to real manufacturing concerns. This takes place during the second year (usually between June and December).

Rafael O. de Jesús, leader of the University relations project within the manufacturing technologies program, (and a former LFM program student) coordinates activities with key universities. One of the tasks within this project is the coordination of LFM internships at ABB. Every year, between two and four LFM students complete their 26-week internship at various ABB sites. To date, 14 LFM students have completed internships within ABB business areas in Finland, Switzerland, Germany, USA and Ireland. Some of these students afterwards joined our company.

Being already very experienced, those attending the course tend to be given big projects, allowing ABB to benefit enormously from the results. Those on internship at ABB apply their know-how and experience to solving ABB problems. In addition, these people become aware of what ABB has to offer in terms of services and solutions, and this can be of benefit to the company they work for.

The research projects assigned to the students have varied. One student was given the task of investigating the application of Industrial IT technologies developed for process industries, such as pulp and paper, in a discrete manufacturing environment. The resultant feasibility study for a small instrument transformer plant in Finland led to a full pilot project in a much larger plant in Germany.

In 2002, following up on this work, another student was assigned to analyzing the findings of various Industrial IT project teams in the USA, Germany and Finland. These teams were working on the development of Industrial IT solutions for discrete manufacturing applications in ABB’s Power Technologies division. Primarily, the student’s task was to:
- Create a model for sharing acquired knowledge from pilot projects being developed within the company.
- Put together guidelines for rolling out future pilots.

In addition, the student had to come up with a business strategy for developing a marketable product from the results, and also for identifying areas of research needed to apply Industrial IT in shop floor and manufacturing execution control systems.

On a larger scale, faculty from MIT and students from the LFM program will work together on a recently commissioned ABB future factory project. Business areas within ABB are continuously
working to define a model of operational excellence. Within manufacturing, for example, certain activities are concerned with defining a manufacturing improvement methodology and IT integration standards for 34 factories. The future factory project will assist in these activities by producing a comprehensive research-based framework that will improve and accelerate the development and deployment of manufacturing operations excellence programs for all the business areas in ABB.

As well as offering internships to students, ABB is currently sponsoring one of its employees in the LFM program. The student in question is now completing her internship at Dell Incorporated in Austin, Texas. Her project is concerned with determining the optimal end-to-end order fulfillment process, from scheduling to shipping, which will result in maximum customer experience with minimum logistical cost.

Those who graduate from the program are very well qualified in both engineering and management. As one recent graduate said, “Because of the LFM course, I get the chance to wear many different hats. One day I am sitting with managers discussing business concerns, and the next day I am working with engineers on the shop floor solving technical problems.”

**Give and take**

As a large decentralized company with hundreds of companies in different stages of operational excellence, ABB has been able to provide the LFM program with many challenges – most concerned with finding ways to effectively improve a global corporation and its manufacturing operations. For students, internship experiences at ABB allow them to apply what they’ve learned at MIT to real-world problems. ABB employees have the opportunity to interact with LFM students, transferring knowledge to them, and vice versa.

As well as providing the challenges, ABB has benefited, as has MIT, enormously from the results of the various projects and research activities while contributing to a program that promotes the growth of future industry leaders.
ABB is currently working on the development of a new contact film which possesses a unique set of properties well suited for contact and wear applications. The compound, \( \text{Ti}_3\text{SiC}_2 \), bridges the gap between ceramics and metals.

An article in *ABB Review* 2/2003 called *Nanotechnology: from small dimensions to big business* [1] described ABB’s activities in the area of nanotechnology and its growing importance to the company. It was explained that the strategy of ABB’s nanotechnology program, in existence since 2000, is to focus on areas of nanotechnology and advanced materials – like electrotechnology, nanocoatings and nanosensors – which are less exploited and have direct relevance for ABB. The program secures technology transfer from the scientific community to ABB while helping ABB to find business opportunities. Biased towards applications rather than material development, the program aims to add new or improved functionality based on nanotechnology solutions to existing ABB products. The primarily short-term research activities target use in real products.

Within electrotechnology, the idea is to expand the electromagnetic property windows of essential materials and components in ABB products. This will lower the losses in electrical transmission and distribution network components, and reduce the weight and cost of systems. Important areas are thermal conduction, electrical insulation and contacts. It is the latter area – contacts – that is the focus of this article.

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To understand why this is so, consider that under any force mechanical contact surfaces only touch at a limited number of discrete points, called a-spots. Since most metallic surfaces (with the exception of gold) are covered with a native oxide, the true electrical contact is only a fraction of the mechanical one. Now consider that a contact should maintain low contact resistance over the lifetime of the product, with only limited degradation of the electrical contact properties. All this, despite the contacts being exposed to high temperatures due to current constriction, different chemical environments and wear due to thermal cycling and magnetostriiction of the materials. Some contacts used in circuit-breakers must even withstand different sliding wear and current arcs that can cause local melting of the contact interfaces.

Soon, it may be possible to provide many of those ideal contact properties mentioned earlier. Through its nanotechnologies program, ABB is currently involved in the development of a new contact film which possesses a unique set of properties well suited for contact and wear applications. The material is a compound known as \( \text{Ti}_3\text{SiC}_2 \) – a member of a group of nanolaminar materials that bridge the gap between ceramics and metals. In other words, these materials exhibit metallic properties such as ductility.
MAX-phases

The nanolaminar materials are known as MAX-phases. These compounds have a layered crystal structure and can be described as ternary carbides (compounds made up of carbon and any other element other than hydrogen) or nitrides. The carbides and nitrides are present as nano-sized layers and are bonded to each other through considerably weaker Me-A bonds. The compounds have the general formula $M_{n+1}AX_n$, where $M$ is an early transition metal, $A$ is an element in group 13–15, $X$ is carbon or nitrogen and $n = 1, 2$ or 3 (see periodic table). Currently, 60 different MAX-phases are known.

Even though the first MAX-phases were synthesized more than 30 years ago, their properties have hardly been investigated. The discovery that $\text{Ti}_3\text{SiC}_2$ displayed properties which are typically both metallic and ceramic is a recent one, and credit for this goes to a research group at Drexel University in the USA.

Under the leadership of Professor Michel W. Barsoum, the group found that $\text{Ti}_3\text{SiC}_2$ has high thermal and electrical conductivity (better than pure Ti) and exhibits one of the lowest friction coefficients of any solid measured to date. They also discovered that the compound has a high stiffness value combined with low density and a very high damage tolerance. Furthermore, it seems to maintain these properties at high temperatures and is also highly resistant to oxidation and thermal shock. A surprising property of $\text{Ti}_3\text{SiC}_2$ is that it is easy to machine, making it possible to produce different kinds of complex components.

$\text{Ti}_3\text{SiC}_2$ is an unusually tough ceramic even at room temperature, because microcracking, delamination, crack deflection, grain motion and buckling of individual grains act as energy-absorbing mechanisms during deformation. This behavior has been attributed to the particular structure of the compound, enabling basal plane slip and giving it the ability to form kink bands under applied loads. $\text{Ti}_3\text{SiC}_2$ is stable up to $1800 \degree C$ in an inert atmosphere and decomposes at temperatures above $2300 \degree C$. The resistivity of $\text{Ti}_3\text{SiC}_2$ at room temperature is $23 \mu \Omega \cdot \text{cm}$, nearly half that of pure titanium, and the thermo-power (EMF) is zero over a wide temperature range, which means that equal quantities of electrons and holes contribute to conduction. Its thermal conductivity, at $57 \text{ W/mK}$, is good. In addition, oxidation properties are excellent and $\text{Ti}_3\text{SiC}_2$ is considered to be more oxidation resistant than...
chromium (Cr). Due to the limited mobility of silicon, a thick oxide layer is not formed at the top surface, allowing for a better electrical contact.

Due to the promising properties of Ti$_3$SiC$_2$, a project was initiated, within the nanotechnology program, at Linköping and Uppsala University in Sweden to investigate if Ti$_3$SiC$_2$ could be synthesized as a coating using a deposition process that could be adapted to industrial production. Using sputtering (ejection of material through energetic ion bombardment – a physical vapor deposition technique), initial attempts showed that a single crystal Ti$_3$SiC$_2$ could be synthesized above 700°C, and a compound with good contact properties is formed at lower temperatures.

Applications

Applied to a vital part of a low-voltage product, Ti$_3$SiC$_2$ has shown excellent low friction and wear properties, and the next aim is to implement it in the product. A range of different ABB products is under investigation to see if the new contact layer contributes to new functions, prolonged lifetime and cost reduction.

Looking to the future

In the near future, Ti$_3$SiC$_2$ will undergo extensive tests to determine its long-term properties as a contact material in selected applications and/or products.

Also, in order to secure commercial usage of the material, a company called Impact Coatings AB is collaborating with the group. Its task is the commercial upsaling of the deposition process for the MAX ceramics. This partnership is of special interest as the process of converting the research into a product (normally started after the research has been completed) is now taking place in parallel, with the intent of saving substantial time to market.

In addition, new combinations of MAX ceramics will be tested in an attempt to lower the contact resistance and so enable them to be used in low force applications. Ti$_3$GeC$_2$ has already been synthesized and tested, with promising results, and the next step is to replace Ge with Sn, whose native oxides have semiconductor properties and are easily penetrable. The final aim is to be able to tune the properties of the MAX-phase to obtain the optimum coating.

Reference