Detector Coatings Research Leads to ESS Production Facility in Linköping

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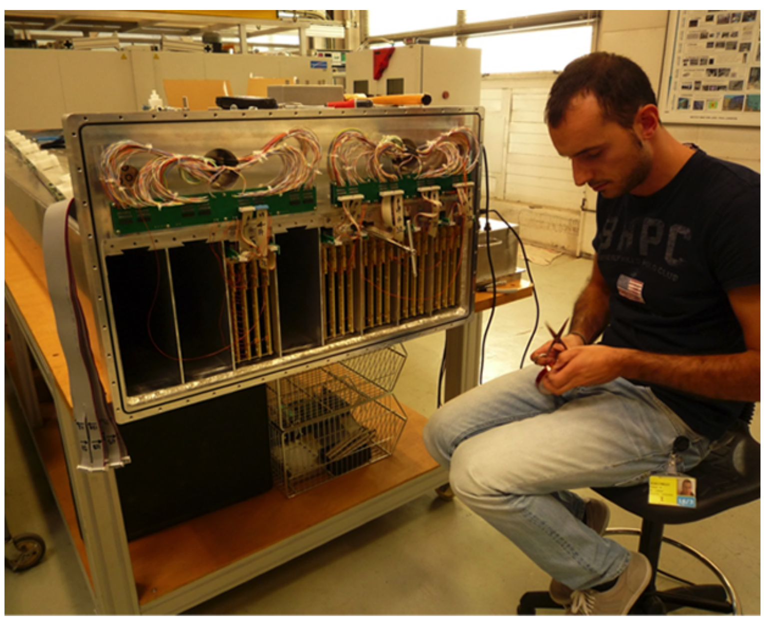
The little building with the forgettable name has the attention of neutron science facilities across Europe.

LUND, GRENOBLE, LINKÖPING — The European Spallation Source (ESS) and Linköping University (LiU) are holding a ceremony to inaugurate the ESS Detector Coatings Workshop in Linköping, Sweden, today. It is a production facility used to apply thin films of boron-10 carbide ($^{10}B_4C$) onto neutron detector substrates, such as aluminum. The use of boron carbide film is a new technique for detectors, and the coated aluminum plates will serve as the neutron impact point on the new *MultiGrid* detector designed at Institut Laue-Langevin (ILL) in Grenoble, France. This is the design ESS intends to use for its first large-area detectors.

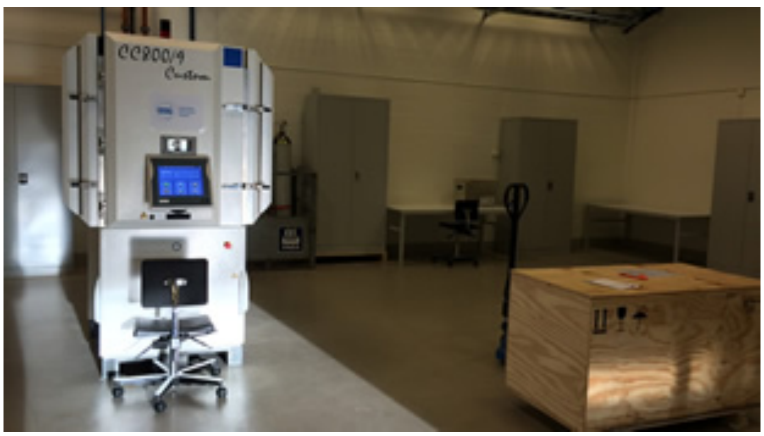


Francesco Piscitelli (ESS/ILL) working on the large *MultiGrid* detector prototype (3 m x 0.8 m) at ILL, which includes the 10B4C-coated plates produced by ESS and LiU. Provided courtesy of ILL.

The coatings production facility is about the size of a large home and includes a single off-the-shelf, industrial-scale sputtering machine. It has the capacity to produce 1000 square meters of coated plates annually. This will be enough to supply ESS with its estimated requirement of around 5000 square meters by 2020, when its first instruments and their detectors will go online. Dr. Carina Höglund, a neutron detection researcher in the detector group, and Linda Robinson, a coatings production engineer for ESS, will manage the facility.

Five years ago, ESS and ILL began to take a serious look at possible solutions to the so-called helium-3 (^{3}He) crisis. Helium-3 is the helium gas isotope that for the last 30 years has been used in neutron detectors worldwide. Once plentiful as a by-product of nuclear weapons development, its supplies have dwindled to critical levels and existing stockpiles are now closely controlled by foreign governments for domestic use. The price on the free market has become unpredictable, and ESS's needs alone exceed available supplies.

For the time being, facilities with existing detectors can recycle and dilute their remaining helium-3 supplies. ESS, however, will build its detectors from scratch and has an urgent need for a substitute technology. ILL felt similar urgency based on the fact that it hosts dozens of instruments using a wide variety of detector types, all using helium-3 tubes as the medium for detection. It has been recognized for some time that the replacement could be boron-based, but complications concerning what form the boron should take and how it could be integrated into detector designs required dedicated research.



The ESS Detector Coatings Lab in Linköping, Sweden. The machine on the left is the sputtering machine.

The vital seed was planted by former ESS Science Director Christian Vettier at a break in the 2009 MaxLab user-meeting in Lund. '[Vettier] was near me having coffee and saw my name tag that said 'Thin Film Physics, Linköping University'. He said something like, 'Can you make boron films?' We didn't know each other, though I knew who he was. I asked why he wanted them and he said we need this boron-10 coating." This is how Prof. Jens Birch of LiU's highly regarded Thin Films Physics division describes the origins of the university's involvement in the project. 'Without Christian Vettier, there would be no boron coatings today."

LiU's Thin Films Physics division typically works to solve problems that arise when new applications for thin films are proposed. This often leads to more fundamental, not obviously related studies, and researchers there already had several years of work on boron films under their belts. Birch himself had previously developed a similar boron carbide coating now used widely in x-ray mirrors. What LiU knew for certain was that using an enriched boron-10 coating, highly desirable as a detector coating due to its purity, was out of the question. 'We had tried this, it was extremely difficult, you can't make it. No, I told [Vettier], we cannot make boron-10 films for you but we can make boron carbide, which is much better." In this sense, LiU already had the solution, but applying the film to substrates for industrial scale production was another story.

'Our primary goal was always the ESS project," says Prof. Richard Hall-Wilton, detector group leader at ESS. 'The boron carbide coating is clearly a world-leading technology, and we had to find a way to increase the scaling and reduce the cost of production. Our investment cost will be recouped many times over."


Prof. Jens Birch (provided courtesy of Paul Birch); and Dr. Carina Höglund, preparing samples at LiU.

Birch met with ILL's head of Neutron Detector Service, Dr. Bruno Guérard, at ESS a week after his discussion with Vettier. A larger group of researchers from ILL visited LiU a couple of months later. The collaboration was in full swing. ILL's original goal was to retrofit their existing helium-3 detector tubes with a thin film coating. When it became clear that coating the inside of a narrow tube would require years of R&D—time ESS did not have—the solution was to engineer a new detector with a flat surface that could be coated, in principle, using existing sputtering techniques. The now patented ESS/LiU deposition process for boron carbide was developed specifically for this design. The detector's mechanics and electronics would be developed by the team at ILL, including Jean-Claude Buffet, Jean-Francois Clergeau, Jonathan Correa (now at Desy), Sylvain Cuccaro, Mathieu Ferraton, Bruno Guerard, Jerome Pentenero, Francesco Piscitelli (now at ESS), Charles Simon, and Patrick Van Esch.

Dr. Höglund, a PhD graduate from LiU's Thin Film Physics division, was asked to head up the coatings project for ESS and its Detector 'group" was born. LiU provided the necessary research infrastructure, and

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by late 2010 Höglund had found a solution to coating aluminum substrates with boron carbide: heat. 'We started in June 2010 to make the first depositions and they were quite bad, I would say," says Höglund. 'We had what we called the 180-degree test: if you turned the plate over 180 degrees and the film fell off, it was no good."

'By the end of the year we realized that if we go up in temperature then we could get really good quality." By locking the aluminum substrates in a heated vacuum during the sputtering process, Höglund found that within a range of 300-400 degrees Celsius, not only did she get high quality, uniform adhesion of the boron carbide to the aluminum, but the materials and their environment were cleansed of many impurities, making the films more efficient neutron detectors. Several months more of research resulted in an optimal mix of temperature, substrate, film thickness, and sputtering environment, and a production method was settled.

Meanwhile, the ILL team designed and built a large prototype of its *MultiGrid* detector that was then fitted with the boron carbide-coated aluminum plates produced by ESS and LiU. The tests were conducted using ILL's IN6 time-of-flight spectrometer, and were a success. This collaboration was organized under the EU's innovative CRISP (Cluster of Research Infrastructures for Synergies in Physics) cooperative project that encourages institutional collaboration in areas like accelerators, instruments and detectors. The success of the ESS/ILL/LiU cluster and its synergy means that there is now a new standard for the future of neutron detector technology.

'The joint *MultiGrid* project demonstrates the feasibility of building a boron-10 detector with the same efficiency, and at a comparable cost, as the equivalent helium-3 detector," says Dr. Charles Simon, associate director and head of the Projects and Technique division at ILL. 'In the context of European neutron science, the construction of many new instruments provides a great opportunity to use this new concept in the future."

There is much more work to be done in Linköping, the nerve center for tailoring thin films to specific applications. 'The critical focus has been on very large detectors," says Höglund, 'but there are also maybe 10 other labs we are working with to develop the process for other types of detectors and substrates." Some smaller detectors use fiberglass or plastic substrates, for instance, which cannot tolerate the temperatures aluminum can. Other detectors require the coatings to be applied to more complicated shapes. 'There we have a very big challenge to find the solutions." The production facility's proximity to LiU's labs and researchers will allow for an efficient transition from process development to production.

In this image of the ILL demonstration detector, the $^{10}B_4C$ layers are horizontal and neutrons arrive from the top. The 6 modules of 16 grids each form an assembly of 360 gas-filled tubes, 24 tubes wide and 15 deep, which are visible on the front side. Each tube is read out by an anode wire. Provided courtesy of ILL.

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