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From Reactive to Predictive: Smart Manufacturing in the Semiconductor Industry – The MADEin4 Initiative

Introduction to the MADEin4 project: Metrology Advances for Digitized ECS Industry 4.0

O. Kievit
Senior Business Developer
TNO, Industry, Delft, Netherlands

Abstract

The MADEin4 project started in april 2019, with a consortium of 47 partners from 10 countries connecting the full range of the supply chain. Partners include semiconductor equipment manufacturers and system-integrating metrology companies, RTOs and organizations working on key application areas such as the automotive industry.

The objective of MADEin4 is to develop next generation metrology tools, machine learning methods and applications in support of Industry 4.0 high volume manufacturing in the semiconductor and automotive manufacturing industries. Addressing a broad range of electronic components and systems (ECS) technologies, MADEin4 aims to demonstrate Industry 4.0 manufacturing productivity improvement by developing advanced, highly connected metrology cyber physical systems, combining metrology data analysis and design with machine learning methodologies and digital twinning.

The project has entered its third and final year and we are beginning to see the first results. This presentation will highlight some of those results, and introduce the topics which will be addressed in more detail in other presentations in this session.

Biography

Olaf Kievit graduated in 1990 for his MsC in Chemical Engineering and obtained a PhD in Aerosol Technology at Delft University of Technology in 1995. He worked at 3M Corporation for 6 years, developing new technology for air filtration. Olaf joined TNO in 2001 as a research scientist. Moving more and more to project management, he has been active in the field of Semiconductor Equipment Development for over 10 years. Since 3 years Olaf is working as a senior business development manager, setting-up new projects and managing customer relations.

MFIG: a Mass Filterd Ion Gauge for heavy hydrocarbon detection

N. Koster
principal scientist
TNO, Nano Instrumentation, Delft, Netherlands

Abstract
The MFIG sensor is especially developed to detect heavy hydrocarbon contamination in high vacuum systems. This type of contamination can be responsible for carbon growth on surfaces of interest in equipment which utilize energetic particles like ions, electrons and photons. The carbon growth is responsible for yield loss on wafers causing bad dies or erroneous measurements for instance in CD-SEM metrology. The MFIG sensor is designed to detect these contaminants before they reach critical levels in equipment. As a result preventive action can be taken to prevent damage or yield loss. This could be to reject a dirty wafer or start a cleaning action in a metrology tool. The sensor gives a real time signal and is easy to interpret in contrast to spectra as obtained with residual gas analyzers. The sensitivity of the sensor for very small partial pressures is also further enhanced.
In the Madein4 project TNO has redesigned the MFIG to be able to fulfil industry needs. We will report on the design upgrades and show some preliminary results of the assembly and initial testing at TNO. Once the sensor is fully assembled and tested we expect to ship the sensor to interested partners in the Madein4 consortium for benchmarking and testing on relevant equipment.

Biography
Norbert Koster is Principal Scientist at TNO in the group for Nano-instrumentation, he has worked in vacuum technology and EUV lithography since 1992. After graduation he worked at the former FOM Institute for Plasma Physics Rijnhuizen. There he was involved in the fabrication and optimization of Multilayer Mirrors for EUVL applications and space astronomy as well as the improvement of the deposition tools. In 1999 he started at TNO as vacuum engineer. Together with ASML and partners he stood at the birthplace of the EUV Alfa demo tools and their successors. During his career he developed interest in vacuum engineering, systems engineering and contamination control. As Principal Scientist he is involved in projects for EUV Lithography, plasma technology, contamination control, nuclear fusion (ITER).He was deeply involved in the realization of a new EUV exposure facility (EBL2) for EUV optics lifetime research at TNO in Delft.

MetalJet – a New Key Module for Enhanced Metrology Capabilities

S. Laza
Research Project Manager
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Abstract

A real challenge for any metrology or inspection technology is to achieve not only the required sensitivity, precision and accuracy but also to enhance its productivity in terms of sample rates, cycle times and economic sustainability.

X-ray techniques are gaining traction due to intrinsic resolution and 3D capability where, e.g., optical metrology tools are running out of steam. However, all the various X-ray techniques share one fundamental challange: the X-ray source must be powerful enough to enable enough throughput or precision for high volume manufacturing (HVM).

The MetalJet X-ray sources developed by Excillum (Fig 1 and 2) are a promising solution since they have the possibility of significantly higher power loading (Fig 3) resulting in faster measurement times.

As pioneers of the world's brightest microfocus X-ray sources (Fig 3), Excillum is relentlessly pushing the limits of X-ray source technologies, to enable new breakthroughs in manufacturing, science and medicine and therefore a perfect key module provider for metrology companies.

Within MADEin4, Excillum have identified, together with Bruker, the needs for an X-ray source to be successful for HVM µXRF applications. Excillum's developments have addressed specific key module innovations needed for enhanced capabilities and throughput, in order to gain SEMI market acceptance for the MetalJet technology.

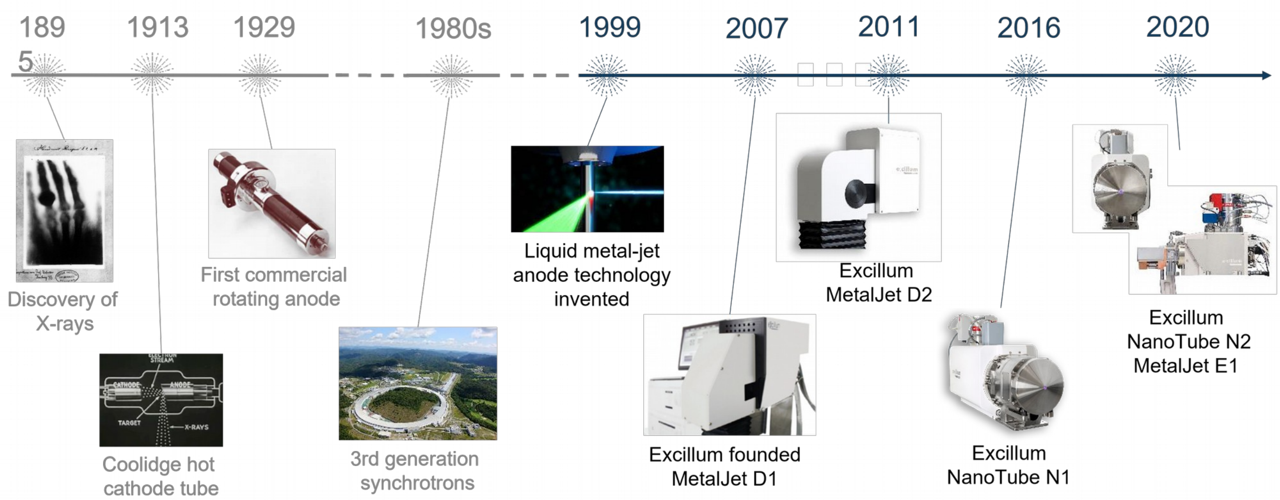


Fig 1. History of X-ray sources

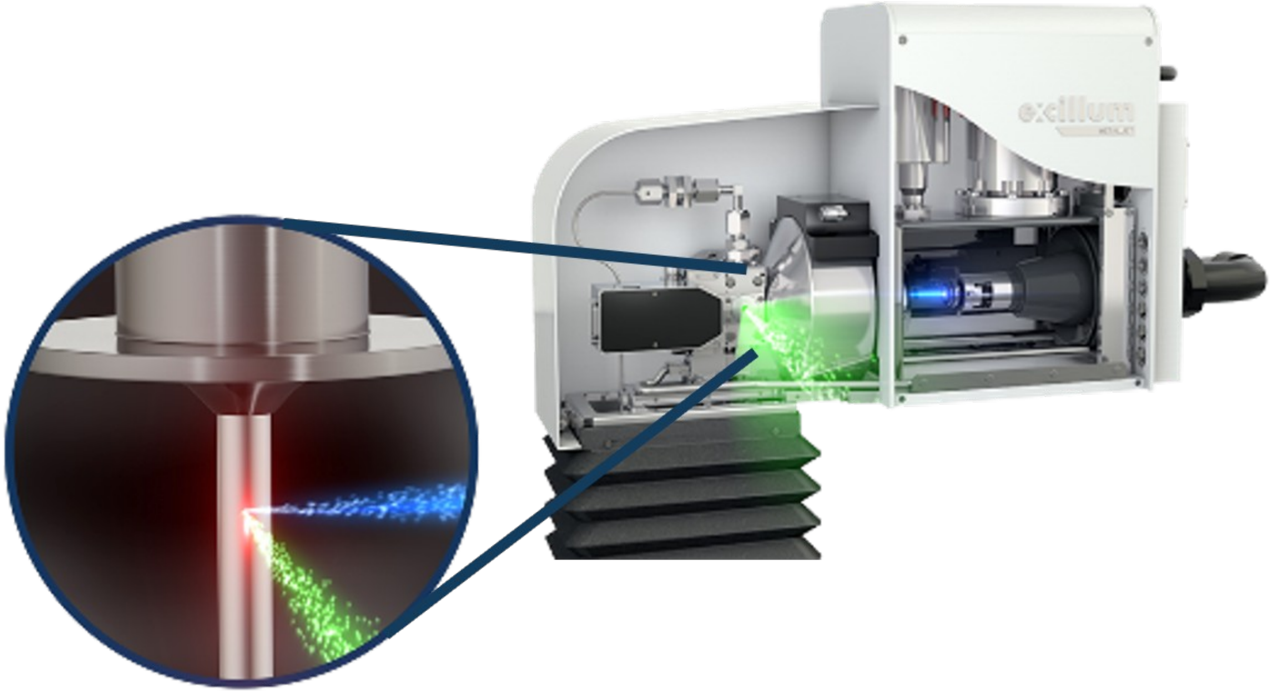
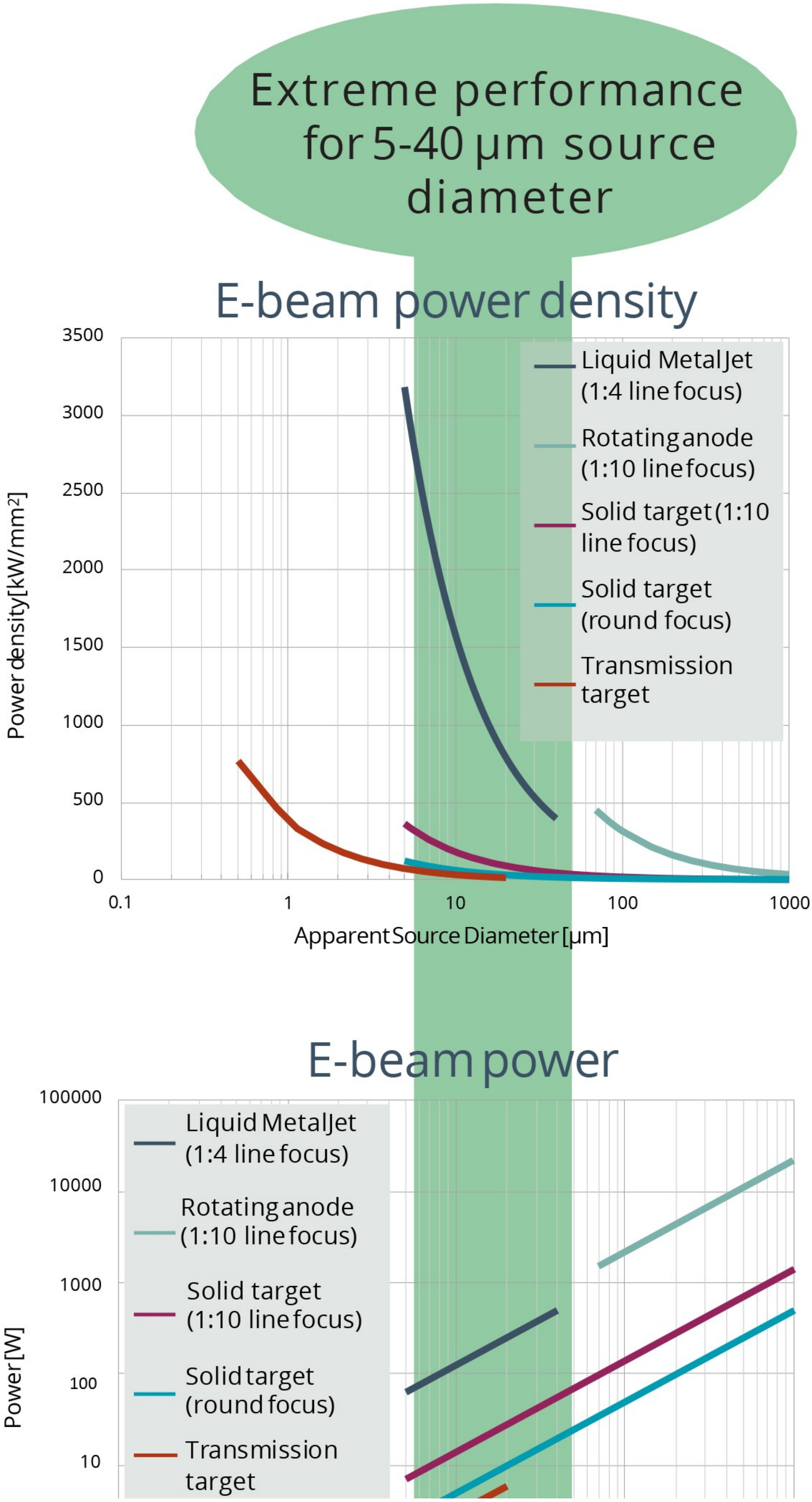


Fig 2. Liquid Metal Jet Anode X-ray source



Extreme performance for 5-40 µm source diameter
E-beam power density
3500
3000
2500
2000
1500
1000
500
0
Power density [kW/mm2]
0.1
1
10
100
1000
Apparent Source Diameter [µm]
Liquid Metal Jet (1:4 line focus)
Rotating anode (1:10 line focus)
Solid target (1:10 line focus)
Solid target (round focus)
Transmission target
E-beam power
100000
10000
1000
100
10
Power [W]
Liquid Metal Jet (1:4 line focus)
Rotating anode (1:10 line focus)
Solid target (1:10 line focus)
Solid target (round focus)
Transmission target

Fig 3. Brightness of X-ray sources

Biography

Simona Laza, is the Research Project Manager responsible for the publicly funded projects at Excillum AB since 2019. She is a senior R&I professional with background in nanotech research, holds a PhD in Physics from University of Pisa (Italy), and has experience in complex collaborative projects (from FP7 CSA actions on Future internet PPP, to H2020 IA in the field of smart grids, ECSEL JU initiatives, EURAMET and EUREKA projects) in which she has represented universities, research centers and companies from different European countries.

Advances in X-ray Metrology under MADEin4

J. van der Meer
Product Marketing Manager
Bruker, Semiconductor, Karlsruhe, Germany

Abstract

Micro X-ray Fluorescence (µXRF) is a well-established technique to measure metal and alloy film thickness and composition of semiconductor structures. It is a fast, non-destructive method with a small-spot size and capable of measuring pattered wafers and is widely adopted in high-volume manufacturing (HVM). However, with the advanced nodes, the structures and films of interest are continuously shrinking, challenging the tools to keep up with sensitivity and throughput. Bruker is collaborating with eXcillum under MADEin4, to assess the performance of latest generation of Liquid Metal Jet X-ray sources for this application.
Bruker has also achieved significant improvements in the Total Reflection X-ray Fluorescence (TXRF) tools for metal contamination monitoring, especially in terms of light element sensitivity and throughput.
In this presentation we will discuss the advances made and key results from the MADEin4 collaboration.

Biography

2015-present: Bruker Semiconductor, Karlsruhe, Germany. Product Marketing Manager XRD and TXRF. Coordinator EU collaborations.

2008-2015: Bruker AXS, Karlsruhe, Germany. Application scientist XRF and thin film metrology.

2003-2008: PhD in thermodynamics at Utrecht University, the Netherlands; post-doc in surface chemistry at CEA Marcoule, France

Privacy Preserving Amalgamated Machine Learning (PAML) in the Fab, and machine learning workflow in the MADEin4 project

T. Ashby
Senior Research Engineer
IMEC vzw, ExaScience, Leuven, Belgium

Abstract
This talk will cover two main topics. The first is privacy preserving machine learning in the fab. The second is recent machine learning results in the MADEin4 project relating to the BEOL data of the TITAN platform. In the first part we will illustrate the main concepts behind PAML and how they would apply in a fab setting, with a worked example for illustration. In the second we will report on the application of machine learning to the analysis of metrology and associated data in the experimental workflow that has been developed at Imec for the project, including some recent results in the development of automatically learned models.

Biography
Thomas Ashby received his PhD from the University of Edinburgh on computational and computer science, focusing on the programmability and performance of computational solvers for scientific computing, in particular for Quantum Chromodynamics, incorporating algorithmic analysis, use of high level languages and compiler optimisations. He joined Imec (Leuven, Belgium) in 2007 as a research engineer and has worked on parallel programming tools, machine learning, and HPC. His research interests include applying machine learning to privacy sensitive data in fabs, and general machine learning work flows in the semi-conductor and materials engineering space.