## 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.

# MetalJet – a New Key Module for Enhanced Metrology Capabilities

S. Laza
Research Project Manager
Excillum AB, Kista, Sweden

**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.
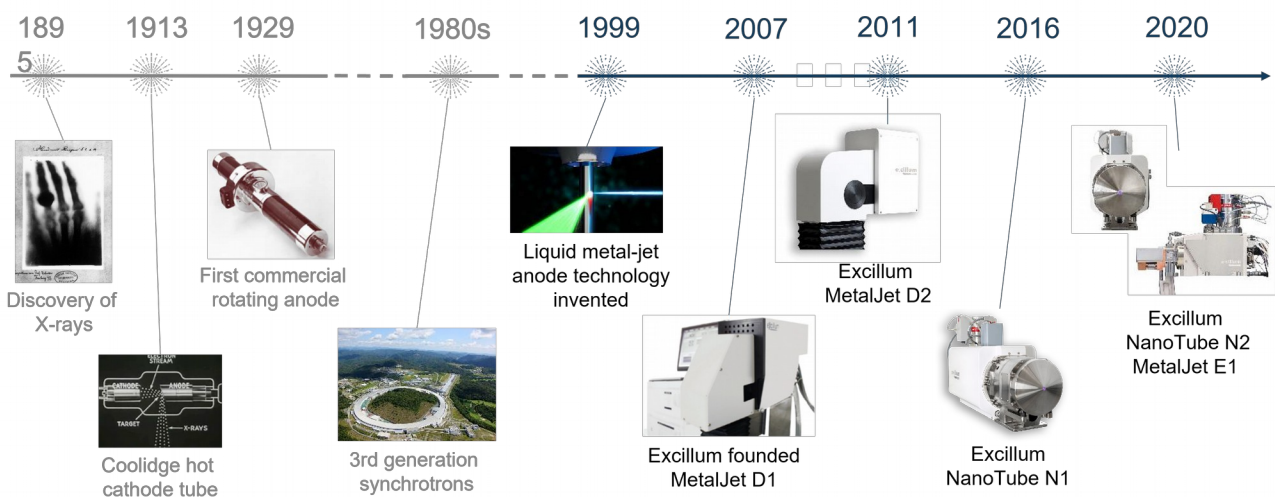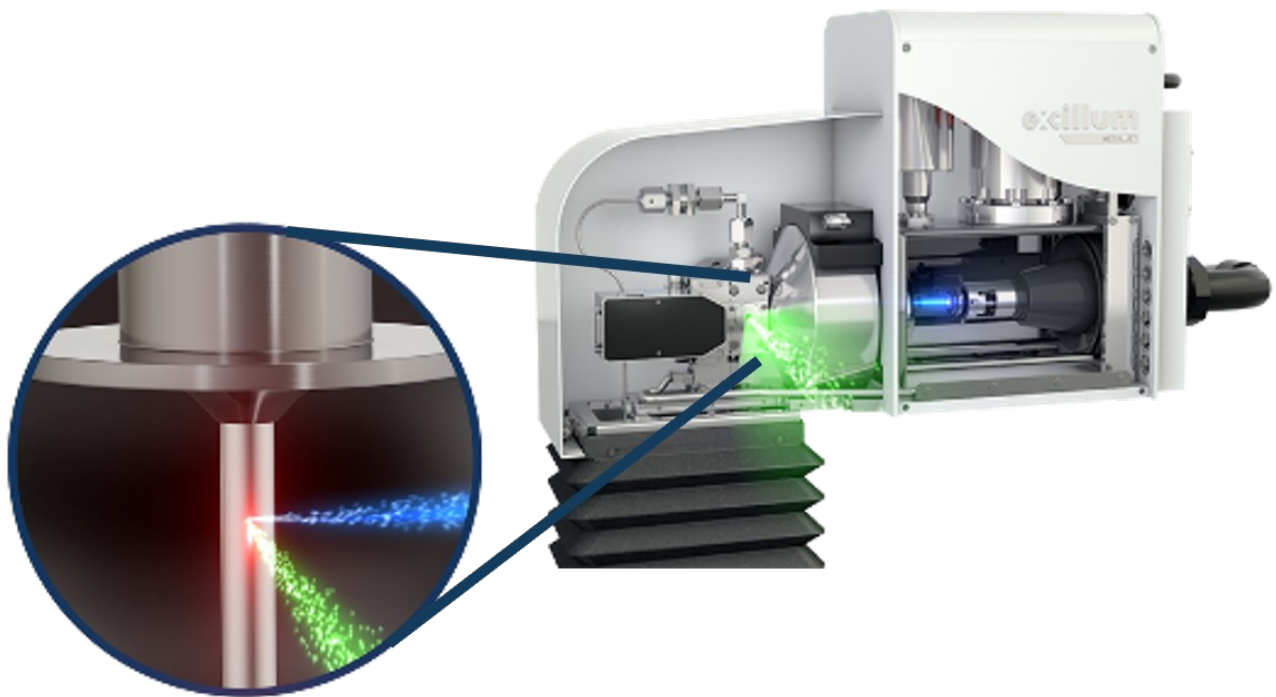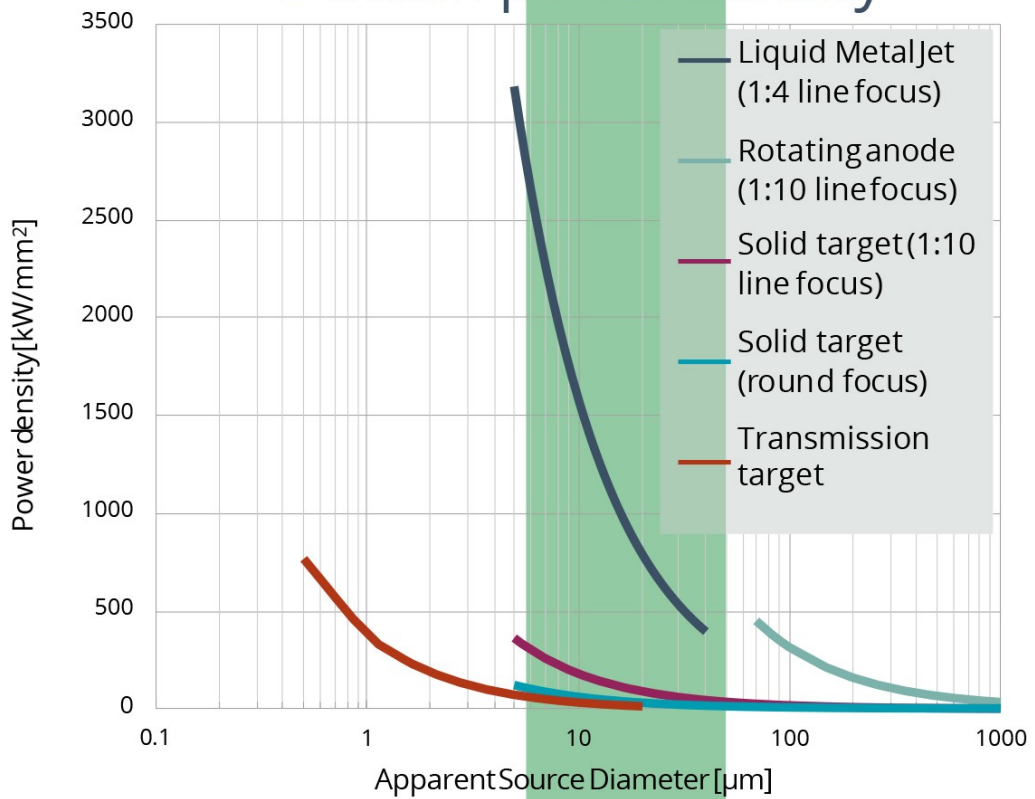
Fig 1. History of X-ray sources

Fig 2. Liquid Metal Jet Anode X-ray source

## Extreme performance for 5-40 µm source diameter

## E-beam power density

Power density[kW/mm²]

3500
3000
2500
2000
1500
1000
500
0

- Liquid MetalJet (1:4 line focus)
- Rotating anode (1:10 line focus)
- Solid target (1:10 line focus)
- Solid target (round focus)
- Transmission target

0.1    1    10    100    1000

Apparent Source Diameter [µm]

## E-beam power

100000
10000
1000
100
10

Power[W]

- Liquid MetalJet (1:4 line focus)
- Rotating anode (1:10 line focus)
- Solid target (1:10 line focus)
- Solid target (round focus)
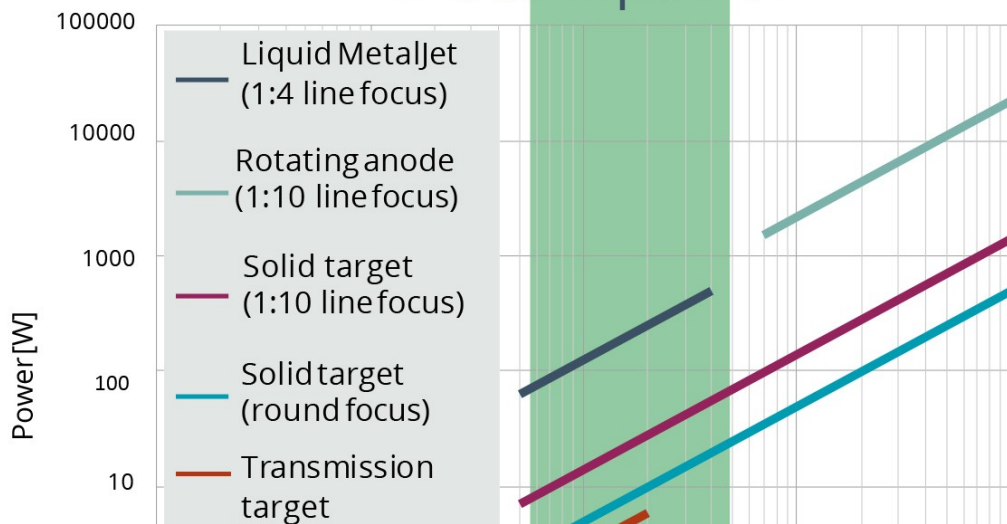- Transmission target

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
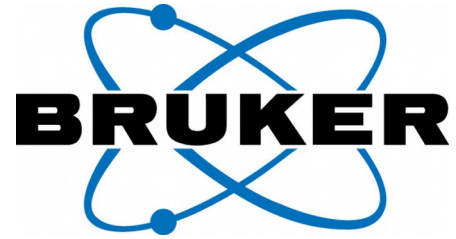
## Abstract

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.

# Next Generation Defect Inspection Computing Challenges - MADEin 4 project

L. Yehieli
Director of Image-Processing SW Engineering
Applied Materials Israel, Image procesing,
Rehovot, Israel

**Abstract**
Coming soon

**Biography**
Director of Image-Processing SW Engineering & Computing architecture : Distinguished Member of Technical Staff.
In his 20 years at Applied Materials he has held leadership roles in the field of system architecture and implementation of
SW-Electronics-Computing combined solutions as well as defining the Computing and Electronic boards solutions and the SW BSP to support it for
high end Optical Wafer inspection tools.
Before joining Applied Materials , Mr. Yehieli worked at Lucent , where he held various R&D for both HW boards and SW Low level drivers for Embedded CPU/FPGA/ASIC devices.
positions in process integration and yield enhancement.
Mr. Yehieli is currently leading the R&D of advanced AI Deep-Learning based architecture.
Mr. Yehieli earned his bachelor of Science (BSc)in Electrical and Electronics Engineering from Tel Aviv University
and Master of Science (MSc) in Computer Science from Open University in Israel