# Automated Sample Preparation

Application Note

Author: Dr. Heiko Stegmann
Date: June 2008

## Introduction

In semi-conductor or storage media industry analysis labs, samples for TEM and SEM investigation are prepared to a large extent by focused ion beam (FIB) technology. Often, more than ten high quality TEM samples and dozens of SEM samples have to be prepared per day. Academic materials researchers and analysis service providers are beginning to demand the same sample throughput and precision. Sample preparation by FIB is often performed by an operator who defines and controls each individual preparation step for every sample while remaining at the tool during the whole preparation procedure. This labour and cost-intensive repetitive task can be largely automated using the Automated Sample Preparation (ASP) software available on NEON® and NVision 40 workstations.

## Solution

The ASP system for NEON® and NVision 40 work-stations allows automated FIB preparation of TEM samples and SEM cross-sections. All settings that define a particular sample type, such as the dimensions of a TEM lamella or the milling currents to be used etc. are stored in a reference sample file. When creating a sample using ASP, these reference recipes are reused to produce samples of the same type at other locations on the specimen as often as required. Thus, a series of samples can be defined in a short time, while the actual preparation of the samples will run unsupervised.

ASP offers two user interfaces, Quick ASP and the ASP Wizard (Fig. 1). After selecting a sample recipe using Quick ASP the settings are recalled and the operator may specify the location, length and depth of the lamella or cross-section and define alignment marks. This procedure takes only one to five minutes. The next sample can be defined in the same way. For most purposes, Quick ASP will be the primary interface for creating and executing a new sample definition with a few mouse clicks only. A set of reference recipes for typical tasks (e.g., TEM lamellas for lift-out or H-bar TEM lamellas) is supplied with the ASP distribution.

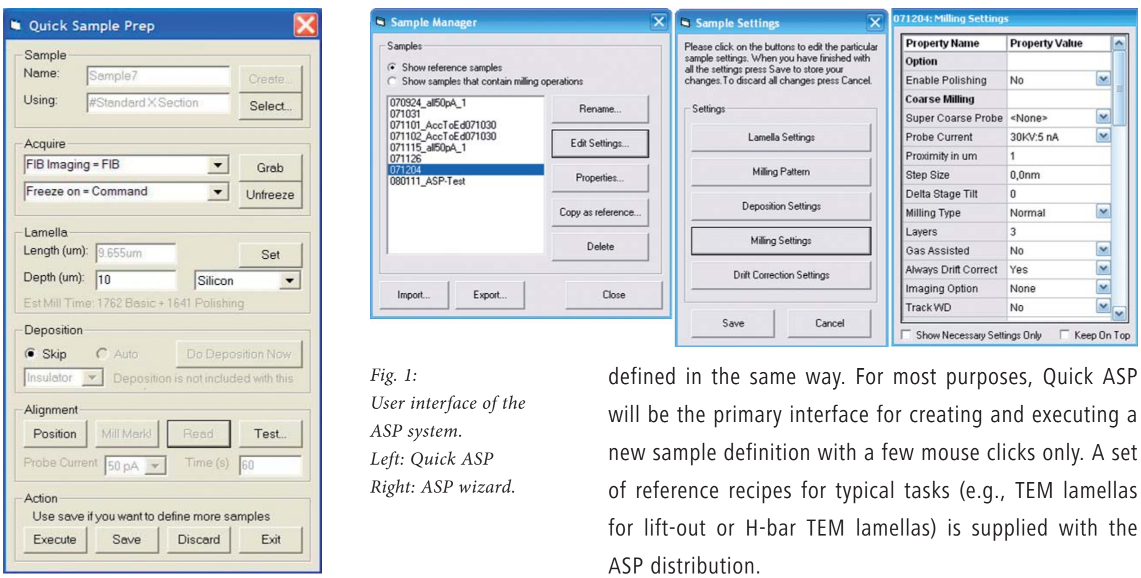
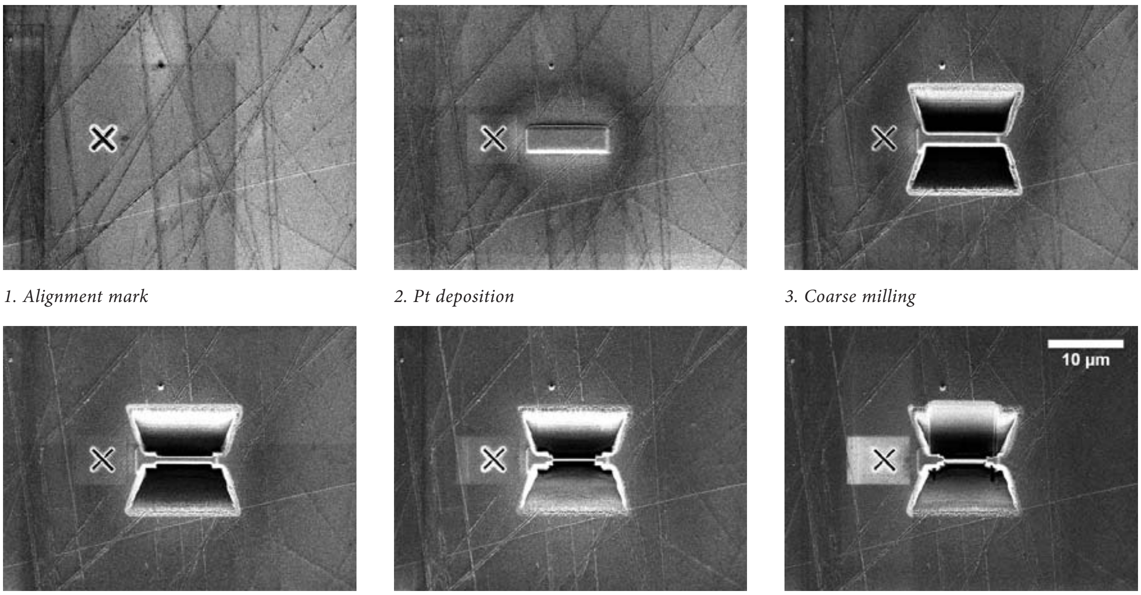



*Fig. 1: User interface of the ASP system. Left: Quick ASP Right: ASP wizard.*

They provide a baseline which will be useful for most applications.
The ASP Wizard is used for designing new sample recipes for specific requirements or for tweaking existing ones. Here, all parameters involved in milling a sample can be adjusted. The sample definition is broken up into a series of steps, with awizard guiding through the set-up procedure.
When all required samples are defined, the automatic milling of the whole sample batch may be started immediately or at a later point in time. The milling process is subdivided into several steps (Fig. 2). The process starts with an optional metal deposition for sample protection. A coarse milling step using a high ion current then removes the bulk of the material around system determines any offset relative to the reference within a selectable time interval. It then shifts the beam accordingly to ensure an accurate milling result corrected for sample movement. The ASP accuracy can be further improved using the fine correction option. Fine correction takes an additional reference image at a higher, user-defined magnification and uses this image for drift correction with increased precision.
The ASP routine also allows to incorporate additional processing steps such as super coarse milling, automated cut-out of lamellasor an additional polishing step for H-bar TEM samples. The ion currents used for each step may be chosen without restriction from the ion beam current table which in particular allows to employ low-kV FIB for polishing.




*1. Alignment mark* *2. Pt deposition* *3. Coarse milling*

*4. Medium milling* *5. Fine milling* *6. Cutout*

*Fig. 2: ASP procedure for a TEM lift-out lamella.* *By courtesy of AMD*

the required location of the cross-section or lamella. After a milling step at medium beam current, the final cross-section or final lamella thickness is achieved in a fine milling step at low beam current.

To correct for sample drift or stage movement, an image of the alignment mark, or another clearly distinguishable feature of the sample is used as a reference. Using an image registration algorithm, the

Requirements for throughput and precision of FIB sample preparation are different for different applications. The preparation of TEM lamellas is the most demanding application and sets the benchmark. Using ASP on a well aligned system and employing the fine correction feature TEM lamellas with a thickness down to about 70 nm can be safely prepared fully unattended. The preparation time depends on parameters such as sample size, the ion currents used and the frequency of drift correction. It is typically 15 to 60 minutes per sample.

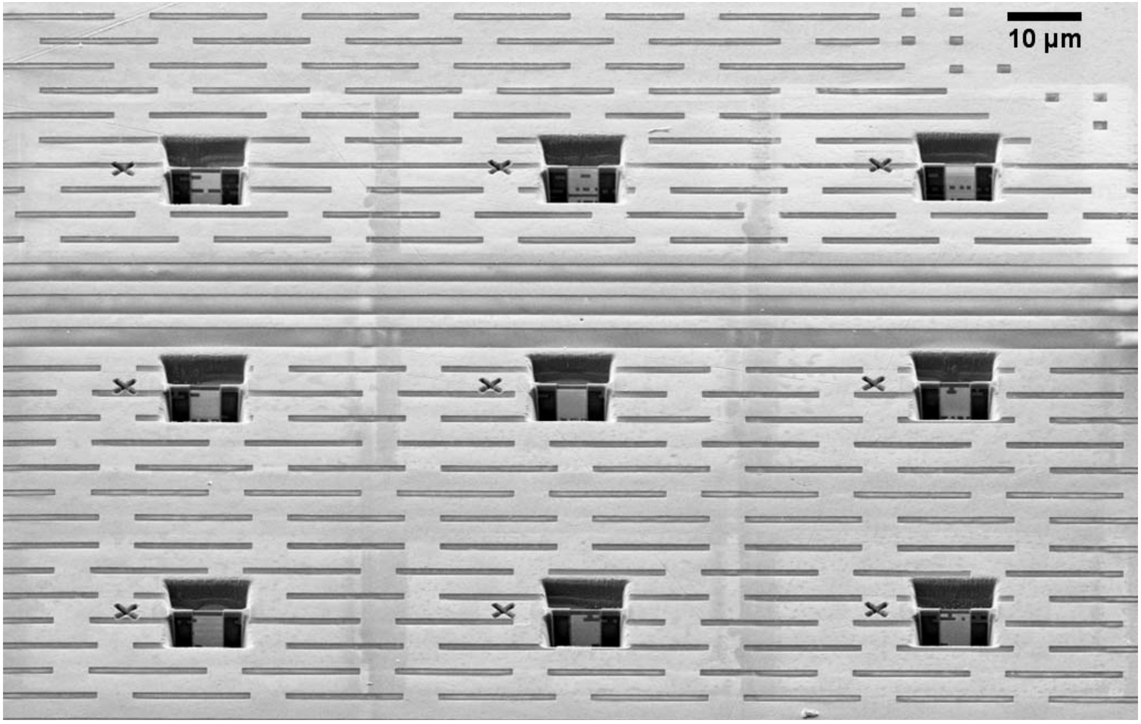



*Fig. 3: Nine 200 nm thick TEM lamellas for lift-out automatically prepared from a microprocessor specimen.* *By courtesy of AMD*

## Examples

Fig. 3 shows an SEM overview of the result of a batch of nine TEM lamellas for liftout. The overall length of the lamellas was set to 10 µm and their depth to 5 µm. The width of the central, electron-transparent area of each lamella was set to 4 µm, its target thickness to 200 nm. The time required to set up the samples was 30 minutes, total milling time was 6 hours. No fine correction was used in this case. The bottom right lamella of this series can be seen in Fig. 4 at higher magnifications. Using a slight tilt of the sample relative to the ion beam during fine milling, practically coplanar lamella surfaces were achieved.

Top views of a 70 nm lamella from a batch of TEM liftout lamellas prepared using fine correction are shown in Fig. 5. Note that these were made for demonstration. Because of re-deposition issues, a liftout lamella will usually be thinned to the final thickness only after it has been lifted out and attached at the TEM grid. However, this example demonstrates ASPs capability of reproducibly producing very thin TEM lamellas.

this

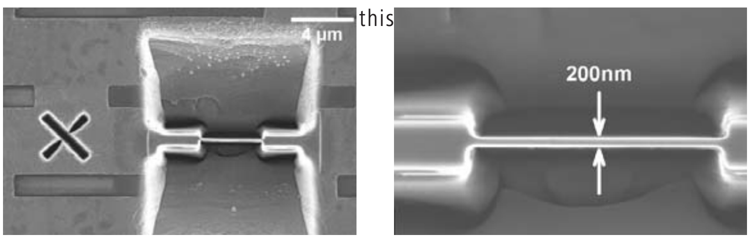



*Fig. 4: Top views of the bottom right lamella from the example shown in Fig. 3.* *By courtesy of AMD*

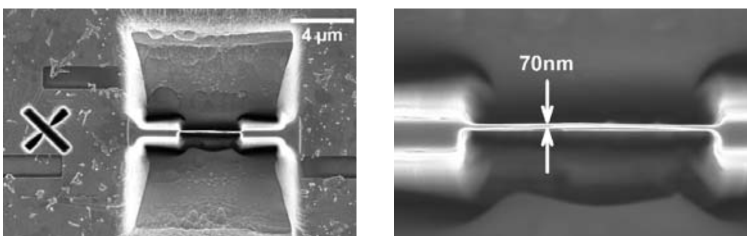



*Fig. 5: Top view of another TEM lamella with 70 nm thickness.* *By courtesy of AMD*

The result of the automated cutout of a lamella can be seen in Fig. 6. H-bar samples automatically milled to the final thickness and ready for TEM observation are shown in Fig. 7.

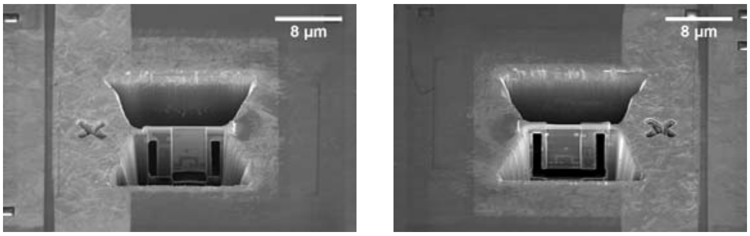



*Fig. 6: Front and rear side of a TEM lamella automatically cut out for subsequent lift-out.* *By courtesy of AMD*

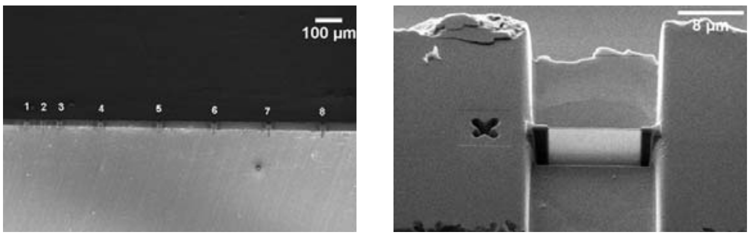



*Fig. 7: Left: nine 200 nm thick H-bar sample TEM lamellas automatically cut into a silicon strip. right: Detail of one of the samples.* *By courtesy of AMD*

## System benefit

The use of ASP on a NEON® or NVision 40 CrossBeam® workstation allows samples to be prepared without operator supervision providing a means for optimally employing tool and operator ressources. This not only increases sample throughput but also allows a better standarization of sample preparation for decreasing variation of analysis and metrology results. The ease-of-use of the routine will also help users with little experience to achieve excellent results.

In summary, ASP will increase both tool and operator efficiency.

**Global Solution Provider**

The Nano Technology Systems Division of Carl Zeiss SMT provides its customers with complete solutions featuring the latest leading-edge EM technology. The company's extensive know-how, meticulously acquired over 60 years in the field of e-beam technology, has brought many pioneering innovations to the market. Our global applications and service network ensure fast, reliable and high quality support sharply focused on customer requirements. Combined with dedicated upgrade strategies, this will protect your investment for its entire lifetime. The core technology embedded in our innovative products enables us to provide solutions which add value to our customers' businesses.

Customer feedback is always welcomed and gathered by collecting valuable information at trade shows, in workshops, in user meetings and upon instrument installation. The Division's business services also include outstanding support from sales consultancy to technical service options even when the warranty has expired.


**Carl Zeiss NTS GmbH**
A Carl Zeiss SMT AG Company
Carl-Zeiss-Str. 56
73447 Oberkochen, Germany
Tel. +49 73 64 / 20 44 88
Fax +49 73 64 / 20 43 43
info-nts@smt.zeiss.com

**Carl Zeiss SMT Inc.**
One Corporation Way
Peabody, MA 01960, USA
Tel. +1 978 / 826 7909
Fax +1 978 / 532 5696
info-usa@smt.zeiss.com

**Carl Zeiss SMT Pte Ltd.**
Jean Yip Building
50 Kaki Bukit Place #04-01
Singapore 415926, Singapore
Tel. +65 65 67 / 30 11
Fax +65 65 67 / 51 31
info.sea@smt.zeiss.com

**Carl Zeiss SMT Ltd.**
511 Coldhams Lane
Cambridge CB1 3JS, UK
Tel. +44 12 23 41 41 66
Fax +44 12 23 41 27 76
info-uk@smt.zeiss.com

**Carl Zeiss SMT S.a.s.**
Zone d'Activité des Peupliers
27, rue des Peupliers -
Bâtiment A
92000 Nanterre, France
Tel. +33 1 41 39 92 10
Fax +33 1 41 39 92 29
info-fr@smt.zeiss.com


Plus a worldwide network of authorised distributors

**www.smt.zeiss.com/nts**



We make it visible.