semi | Standards

# TEM grid standardization Survey Results

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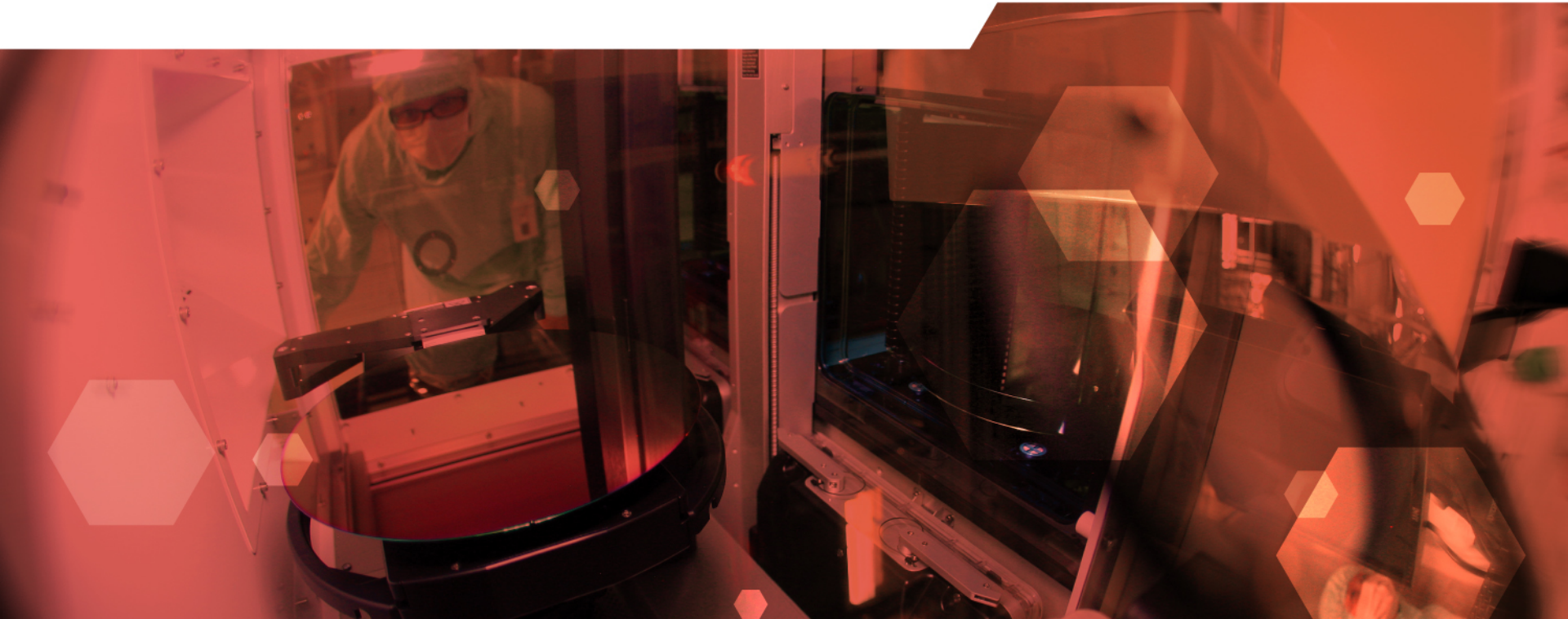


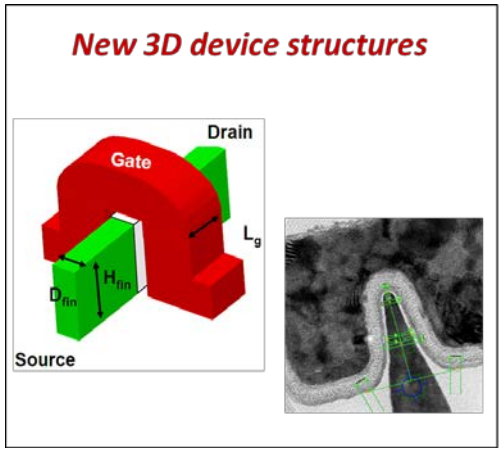
# Outline

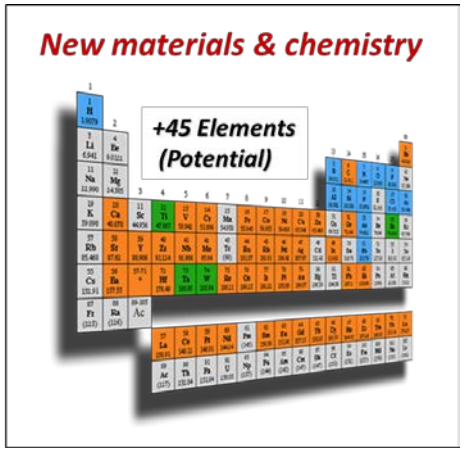
- Rationale for TEM grid Standardization
- Scope of TEM-grid Standardization Survey
- Results of TEM-grid Standardization Survey
- Conclusions
- Proposed next steps

# Rationale for TEM-grid Standardization

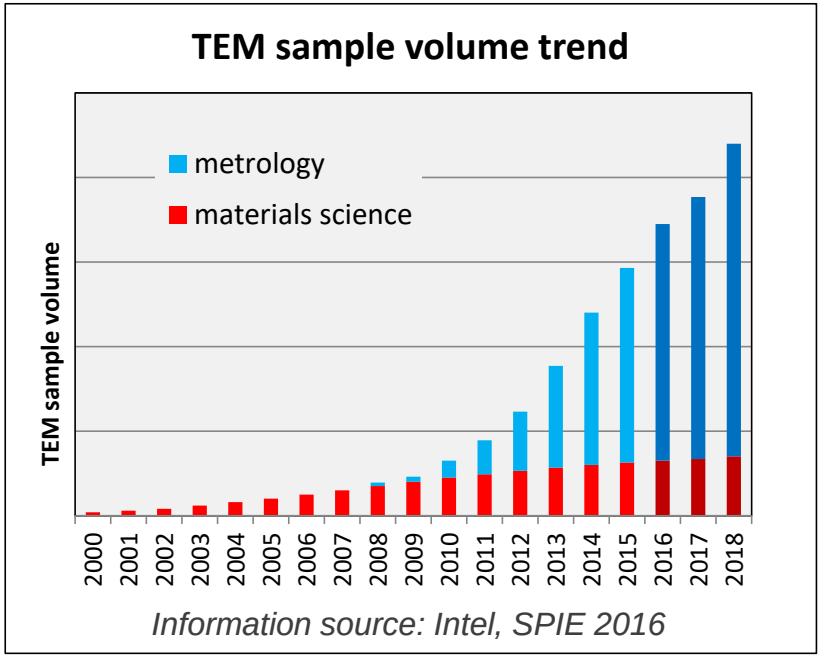
# Rationale: TEM metrology and analysis, from LAB to FAB

- Semiconductor Industry metrology needs: TEM demand explodes to meet 3D transistor and multiple patterning challenges



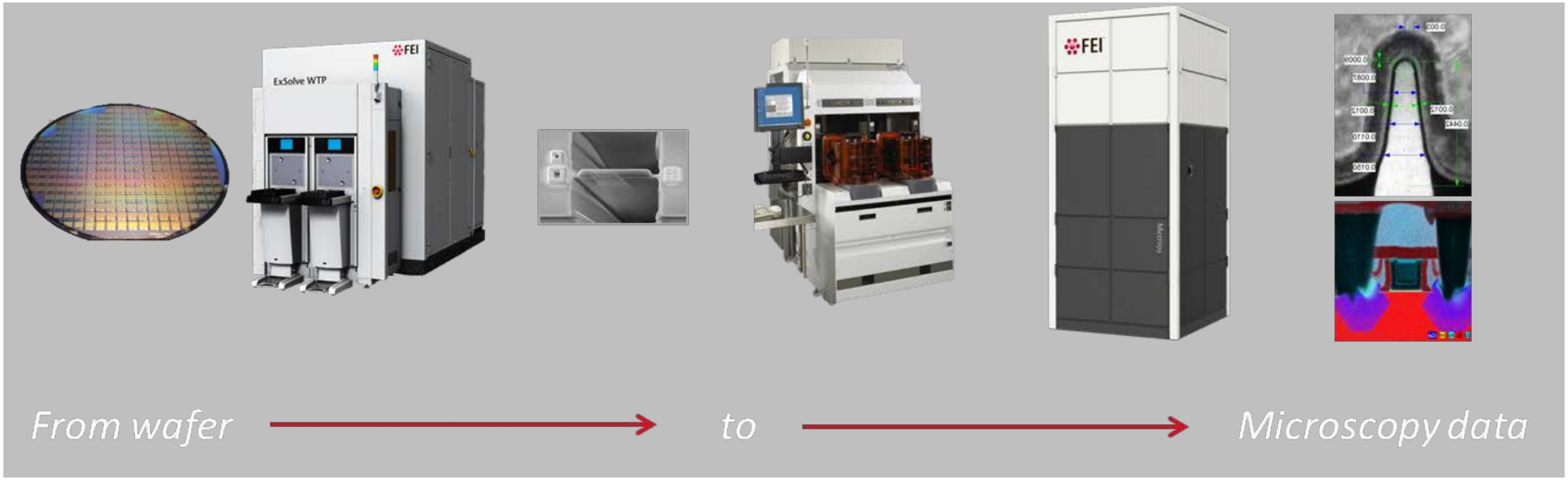




*Complex, marginal processes …*
*Critical dimensions in 3D, < 10 nm*



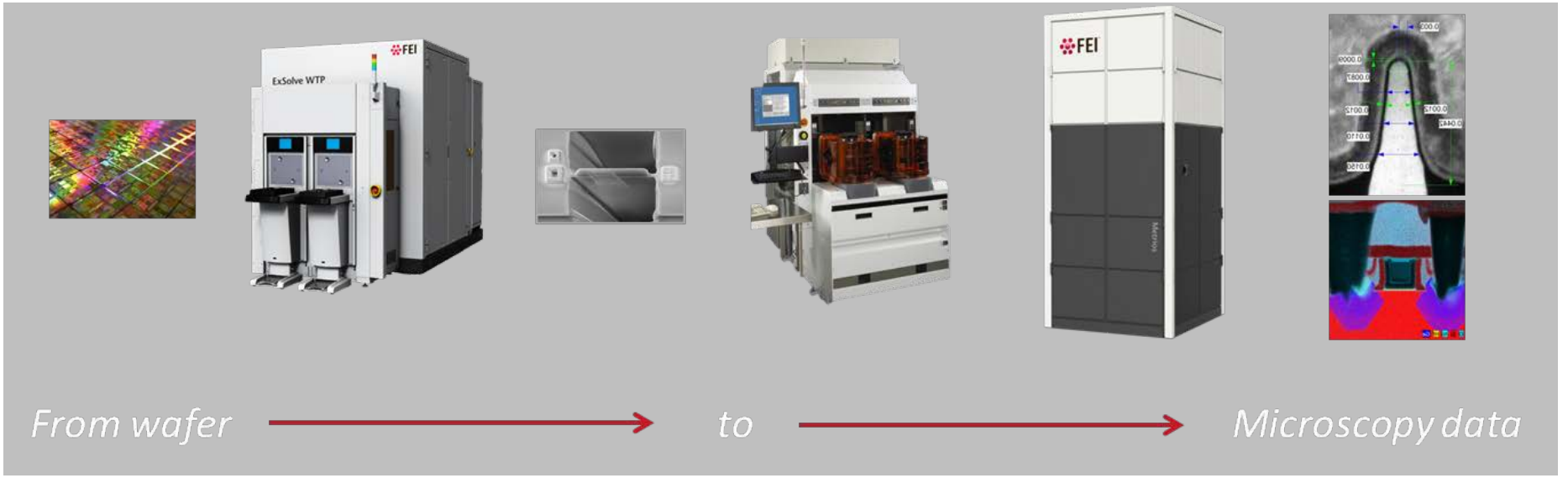

- Faster TEM data and more TEM data: TEM transition from Lab to Fab
- ➔TEM microscopy needs to be fast, automated and easy to use

# Rationale: TEM metrology and analysis, from LAB to FAB




- TEM microscopy requires a workflow with different tools to
  - Prepare thin TEM lamellas from full wafers
  - Extract TEM lamellas from wafer, return wafers in manufacturing line
  - Measure TEM lamellas in TEM microscope
- TEM lamellas are mounted on TEM “grids” and transported on these grids between the different tools: 300 mm FIB/SEM tool, TEM microscope and if needed, plasma cleaner, storage units,…

# Today's state-of-the-art in TEM metrology

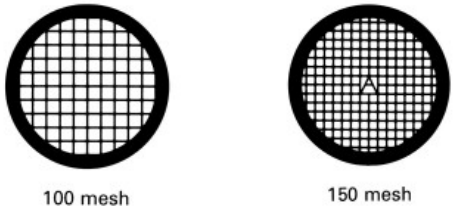



- Lamella preparation and extraction from full wafers is automated ✓ ☺
- Data acquisition (TEM imaging) and TEM metrology is automated ✓ ☺
- But TEM grid transport between tools is manual, using tweezers ✘ ☹
  - Requires operator interventions, and has a non-zero failure rate…
  - Is slow and not really compatible with FAB operation…
- A fully automated workflow requires automatic TEM grid handling
  - Like wafer handling, but unlike wafers, grids have different form-factors ☹

# Why is standardization of TEM grids important?

FIB lift-out grids


Standard 3 mm grids




*Thicknesses vary between 25-50 um, Diameter is 3.00 – 3.05 mm, Form factors are different, Materials can be different (Co, Si, Mo,..).*

- Today the industry uses “3 mm grids” that have different form factors and do not respect a ‘standard’ for critical dimensions.
- There are several TEM grid suppliers (Ted Pella,Omniprobe, Agar,…)
- There are several TEM microscope suppliers (JEOL, Hitachi, FEI,..)
- Our customers need to be able to buy FIB/SEM and TEM systems from different suppliers (mix and match, best-in-class)
- ➔ compatibility between tools needs to be guaranteed
- ➔ a TEM grid should be compatible with all FIB/SEM/TEM systems

# How to standardize TEM grids?

- A standard for diameter and thickness: to allow robotics for grid handling
  - Edge grippers (end effectors) of handling robots
  - Receptors of grids in TEM systems
- A standard for the grid form factor: to ensure that all kind of receptors are compatible
  - A “cassette” for grid transport and grid storage
  - Mechanical positioning and alignment of grids in cassettes, or in TEM systems, plasma cleaners,…
- A standard for grid material options: to control mechanical strength (deformation) and TEM performance (e.g. EDX spurious peaks)
- A SEMI Standards task force in which IC manufacturers, TEM equipment and TEM grid suppliers define new standards together, enabling future developments of more automated TEM workflow solutions that are open rather than proprietary and industry-wide compatible/acceptable!

# Scope of TEM-grid Survey

# TEM grid survey: the SEMI Standards Questionnaire

- To find answers about how relevant TEM grid standardization is for the Semiconductor industry, direct stakeholders were invited to complete a simple questionnaire.
- The Survey was prepared by Thermo Fisher Scientific and launched through the SEMI Standards organization.
- The Survey and questionnaire was launched on June 1, 2017 and feedback was collected for one month
- The questionnaire was sent to various stakeholders:
  - IC manufacturers
  - SEMI Standard Program Members
    - PIC
    - Silicon Wafer
    - 3DS-IC)

# Customer feedback
# Survey results

# Executive Summary

- A good response was obtained with all major IC manufacturers responding to the survey (n = 64)
- 90% of current TEM sample handling is done manually and 75% of respondents would like to have it automated.
- > 80% of respondents are in favor of having standard grids for:
  - Further automation (80%), TEM workflow efficiency (75%)
  - Compatibility between tools used in workflow (70%)
- < 20% of respondents see drawbacks related to costs/compatibility

- *> 80% of respondents are in favor of a SEMI standardization effort and 60% of respondents are willing to actively contribute to this effort*

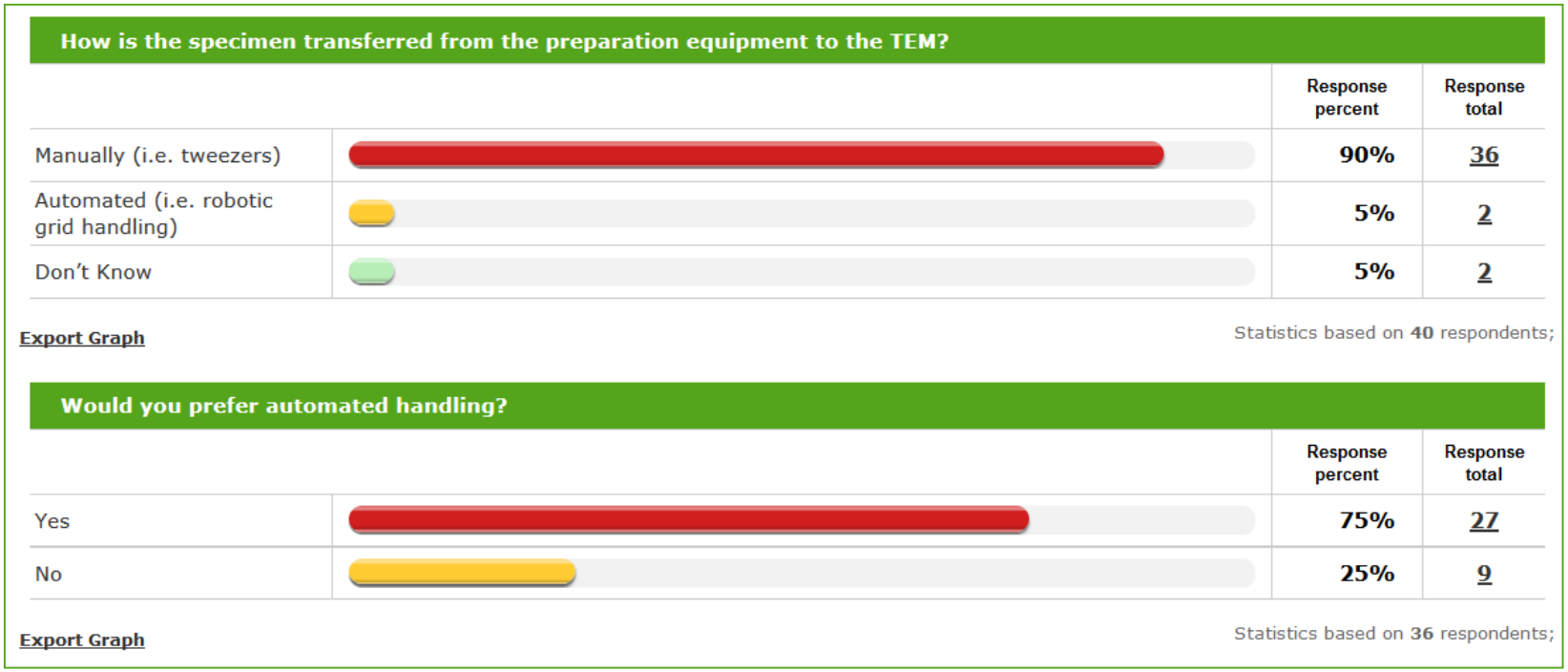
# Profile of respondents (64)

- IC manufacturers, R&D centers, Equipment suppliers,  adjacent industry (hard disks, solar, bio)
  - All major IC manufacturers responded to the survey!
- Mix of (senior) managers in various fields and experts in the field of (TEM) Analytics

- ***Fair mix of relevant Disciplines and Industry players***

# How do respondents handle their TEM samples? (1/2)

- Current sample transport between tools
- The preference for sample transport automation



**How is the specimen transferred from the preparation equipment to the TEM?**

| | Response percent | Response total |
|---|---|---|
| Manually (i.e. tweezers) | 90% | 36 |
| Automated (i.e. robotic grid handling) | 5% | 2 |
| Don't Know | 5% | 2 |

Export Graph

Statistics based on 40 respondents;

**Would you prefer automated handling?**

| | Response percent | Response total |
|---|---|---|
| Yes | 75% | 27 |
| No | 25% | 9 |

Export Graph

Statistics based on 36 respondents;

- ***>90% of current sample handling is done manually***
- ***75%  of respondents would like to have it automated***

# How do respondents prepare their TEM samples? (2/2)

- The kind of TEM Grids currently used
- The preference for a standardized TEM grid

**What kind TEM grid carriers do you currently use? (select all that apply)**

| | Response percent | Response total |
|---|---|---|
| 3mm mesh TEM grids | 48.72% | 19 |
| 3mm half moon TEM grids | 61.54% | 24 |
| Don't Know | 15.39% | 6 |
| Other, please mention | 10.26% | 4 |

Export Graph

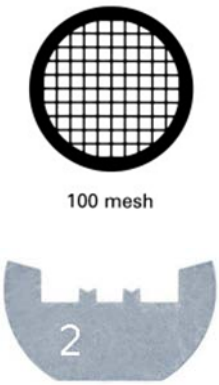
Statistics based on 39 respondents;

**Do you see any potential benefits in creating a standard for specimen carriers?**

| | Response percent | Response total |
|---|---|---|
| Yes | 81.4% | 35 |
| No | 18.61% | 8 |

Export Graph

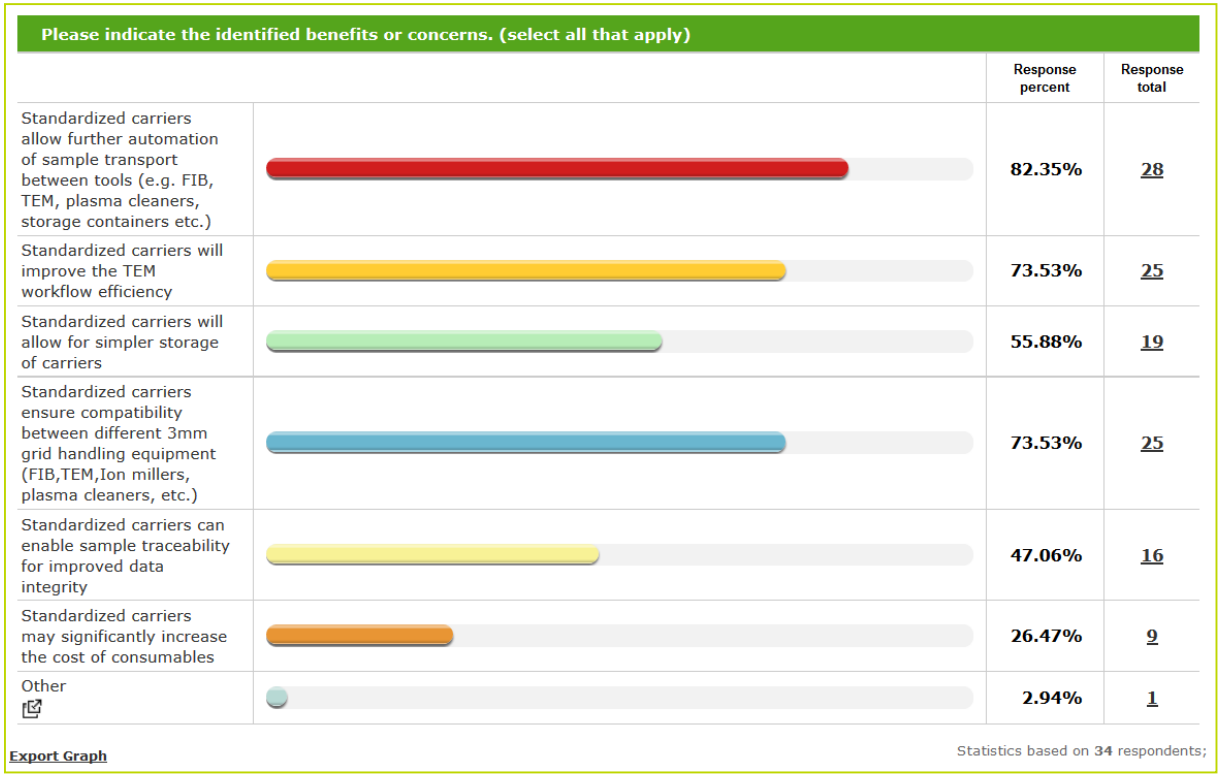
Statistics based on 43 respondents;




- ***Predominant use of 3mm mesh and 3mm half-moon grids***
- ***Most respondents (>80%) welcome a standardized grid***

# The interest of respondents in TEM carrier standardization

- Respondents see following standardization benefits and concerns



**Please indicate the identified benefits or concerns. (select all that apply)**

| | Response percent | Response total |
|---|---|---|
| Standardized carriers allow further automation of sample transport between tools (e.g. FIB, TEM, plasma cleaners, storage containers etc.) | 82.35% | 28 |
| Standardized carriers will improve the TEM workflow efficiency | 73.53% | 25 |
| Standardized carriers will allow for simpler storage of carriers | 55.88% | 19 |
| Standardized carriers ensure compatibility between different 3mm grid handling equipment (FIB,TEM,Ion millers, plasma cleaners, etc.) | 73.53% | 25 |
| Standardized carriers can enable sample traceability for improved data integrity | 47.06% | 16 |
| Standardized carriers may significantly increase the cost of consumables | 26.47% | 9 |
| Other | 2.94% | 1 |

Export Graph

Statistics based on 34 respondents;

**Benefits:**
1. >80% automation and
2. >70% efficiency
2. > 70% compatibility

**Concern:**
< 30% cost

- ***Multiple benefits (>70%) outweigh the limited concern (30%) of potential extra consumable costs***

# The interest of respondents in a SEMI standard

- Respondents support of the idea of a SEMI standardized TEM grid
- Respondents willingness to actively contribute to establishing standard

**Would you support the idea of standardized specimen carriers?**

| | Response percent | Response total |
|---|---|---|
| Yes | 83.33% | 35 |
| No | 16.67% | 7 |

Export Graph

Statistics based on 42 respondents;

**Would you be willing to contribute to the SEMI Standards activity to help establish a standard?**

| | Response percent | Response total |
|---|---|---|
| Yes | 64.29% | 27 |
| No | 35.71% | 15 |

Export Graph

Statistics based on 42 respondents;

- ***More than 80% support TEM grid standardization effort***
- ***More than 60% willing to actively help***

# Conclusion

- A fair response was obtained with all major IC manufacturers responding to the survey (n = 64)
- 90% of current sample handling is done manually and 75% of respondents would like to have it automated.
- > 80% of respondents are in favor of having standard grids for:
  - Further automation (80%), TEM workflow efficiency (75%)
  - Compatibility between tools used in workflow (70%)
- < 30% of respondents see drawbacks related to costs/compatibility
  - Weigh cost benefit of additional standards
    - i.e. Keep standardized grid costs < 1% value of a grid with lamella

- *> 80% of respondents are in favor of a SEMI standardization effort and 60% of respondents are willing to actively contribute to this effort*

# Proposed next steps

# Proposed next steps and suggested time lines

- Recommend initiation of a new task force for lab standards with initial focus on a 3mm TEM grid
  - TFOF has already been prepared and is ready for review
    - PIC July 12
  - SNARF has already been prepared for submission to selected TC
- Tentative Time schedule:
  - TFOF approval July 2017
  - SNARF submission July 2017, Approval August 2017
  - 1st 3mm Grid Std TF mtg September 2017
  - Face to face TF mtg at SEMI NA November 2017
  - Creation of a first TEM Grid standard document (draft v.1): Dec 2017
  - Ballot authorization via GCS Jan 2018
  - Ballot cycle 2 for adjudication at NA spring mtg April 2018
- *TFOF = Task Force Organization Form, SNARF = Standards New Activity Report Form*
- *TF = Task Force, TC = Technical Committee*