

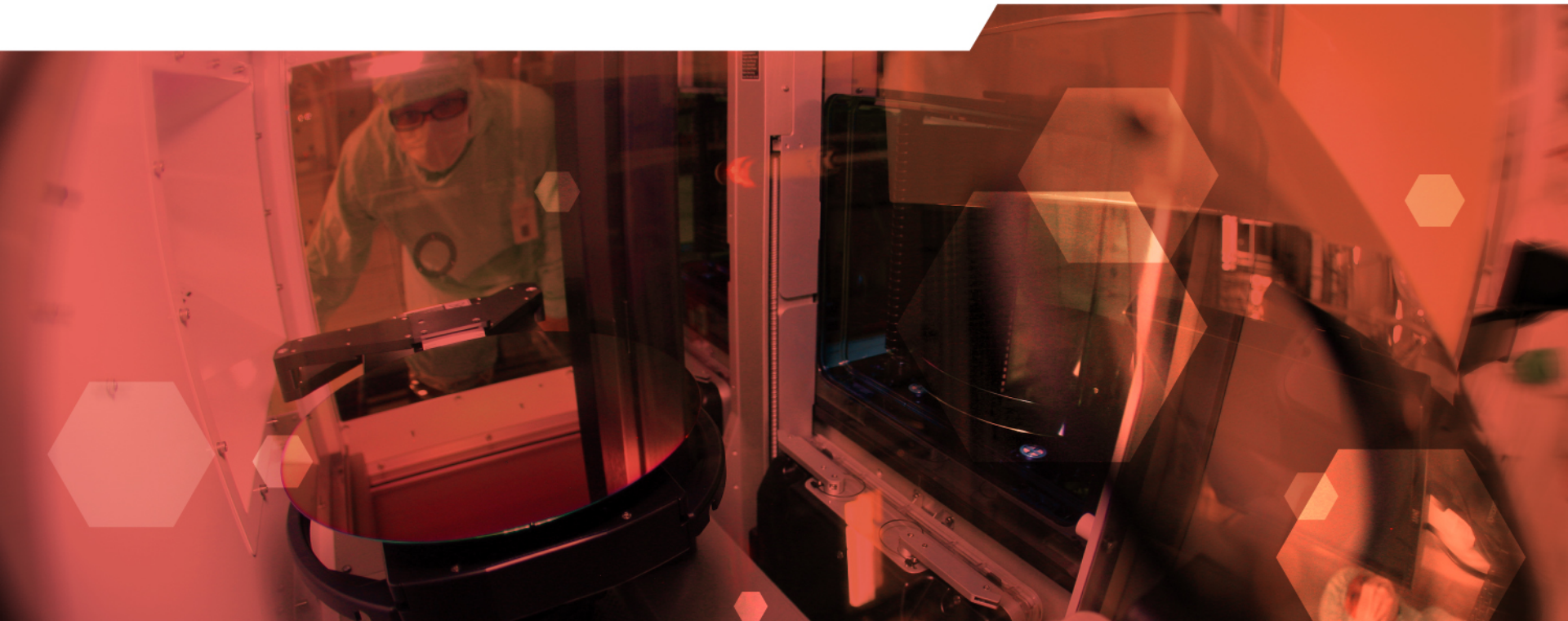
Electron Microscopy Workflow Taskforce

PIC TC update

February 8, 2021

Laurens Kwakman

Thermo Fisher Scientific



Agenda

- Taskforce activity update (November 2019 – January 2021)
- Taskforce activity outlook 2021
- SNARF change request
- Taskforce leadership change request
- Appendix
 - Detailed activities related to SEMI E177 (LC Standard)
 - Detailed activities related to doc. 6592 (LCC Standard)

Electron Microscopy Workflow Taskforce: activity update

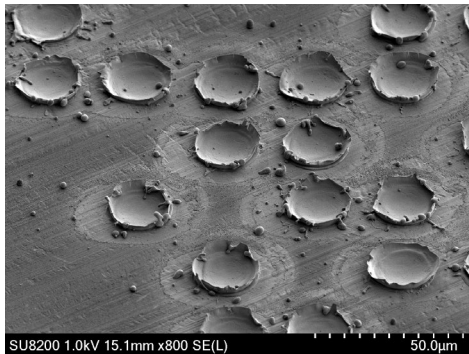
Since last PIC TC meeting in November 2019, the Taskforce members have not met face-to-face anymore (due to Corona pandemic) but have continued the Phase 2 activities through monthly telephone conference meetings (10 in total) and email/telephone exchanges when necessary.

- SEMI E177 (LC Standard) related activities:
 - One practical limitation has been identified with the 3mm grid LCs:
 - When a laser marked LC is coated with a thin carbon foil, the ID mark read-out quality is low due to optical disturbances induced by the presence of the foil
 - ID marks at the bottom side of the LC are judged non-practical (too complex!) and therefore, alternative solutions have been researched, proposed and tested
- Phase 2, Doc. 6592 (LCC Standard) related activities:
 - Taskforce members have started a [high-level review](#) of what characteristics are relevant for a LCC and what kind of specifications need to be included in the new SEMI Standard. *End-user's input is essential to define industry-aware concepts*
 - *Translation of high-level market requirements into low-level design and engineering specifications turns out less evident* as TEM automation is new and different engineering solutions can be considered, leading to different LCC specifications...

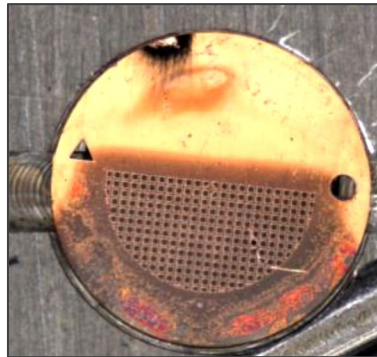
Electron Microscopy Workflow Taskforce: activity update

Activity summary

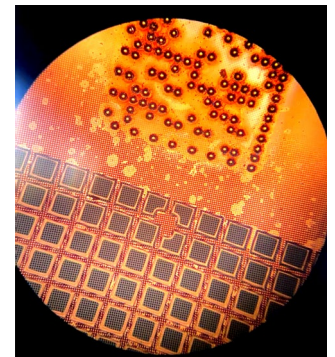
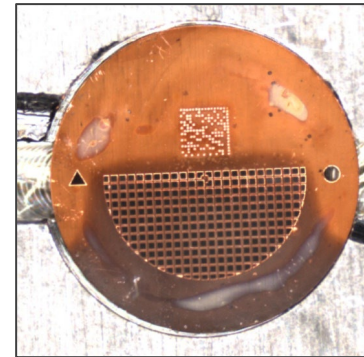
- Good work was done to address the remaining issues with the 3mm grid LCs as defined in SEMI Standard E177 related to laser ID marking:
 - Laser ID marking issues relate to **ID mark readout quality** (foil deposition after laser marking)
 - or to **particle contamination of the active area** (laser marking after foil deposition)
 - Japanese TF liaison (JEOL/Hitachi/KEYENCE) made good progress and did innovate methods together with Protochips in the USA.
 - Protochips has shown the feasibility of a **carbon foil deposition + area selective etch process**



Laser induced particles on LC



New LC process:

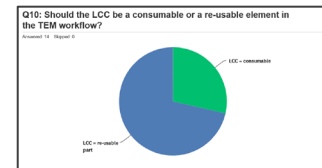
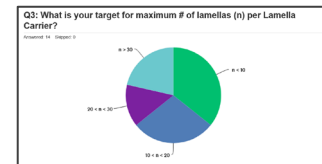
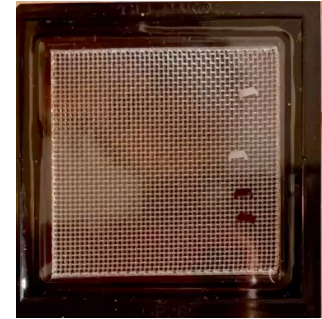


1. *Laser marking*
2. *C-foil deposition*
3. *Area selective C-foil removal (etch)*

Electron Microscopy Workflow Taskforce: activity update

Activity summary

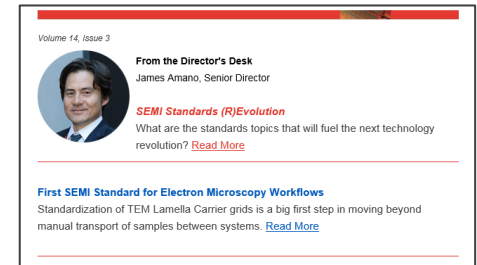
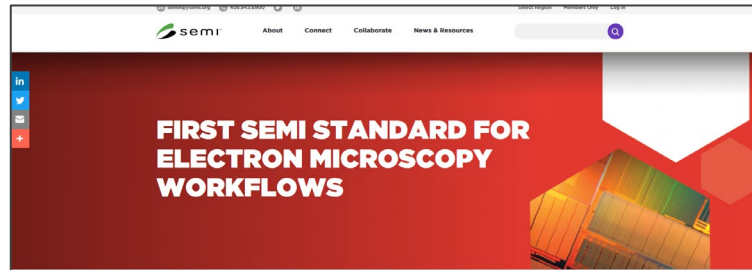
- The Phase 2 activities to prepare doc. 6592 (LCC Standard) did start off well end 2019 with high level market specifications and advanced with concrete activities in Q1 2020, but it was rapidly realized that the final choice between different technical options and solutions for the LCC is critically related to how the TEM microscopy end-users intend to use and operate such TEM workflows in their real, industrial context
 - ➔ needs the ‘**voice of the key customers**’: Q2 and Q3 2020 were essentially used to prepare a LCC customer Survey, that finally was executed in Q4 2020. To guarantee full confidentiality of the customer responses, **the survey was anonymized and conducted by SEMI HQ.**
- The specification of a (new) LCC requires a clear, detailed engineering study of the different technical and operational solutions for equipment automation:
 - ➔ End 2020, specific ‘focus teams’ were created in which marketing and engineering experts from (competing) microscope suppliers work together to translate the top-down market requirements into bottom-up engineering solutions and to **translate engineering ideas into generic LCC requirements/specifications**



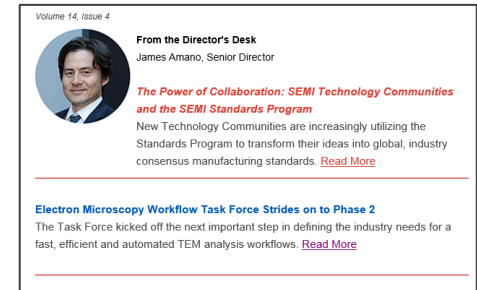
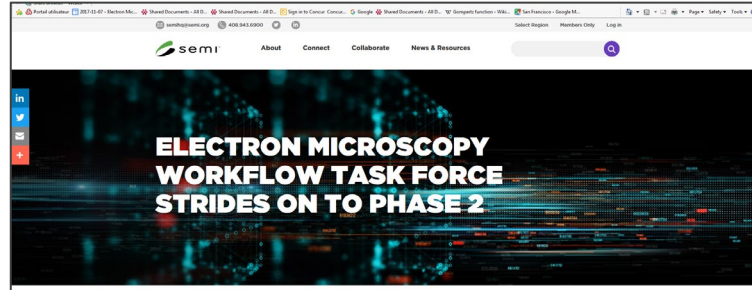
Electron Microscopy Workflow Taskforce: activity update

- EM Workflow TF also continued its advertising within SEMI

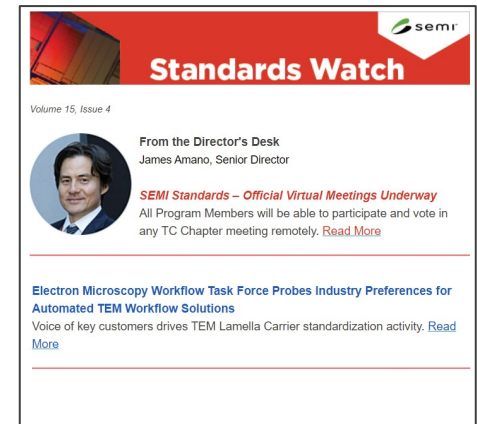
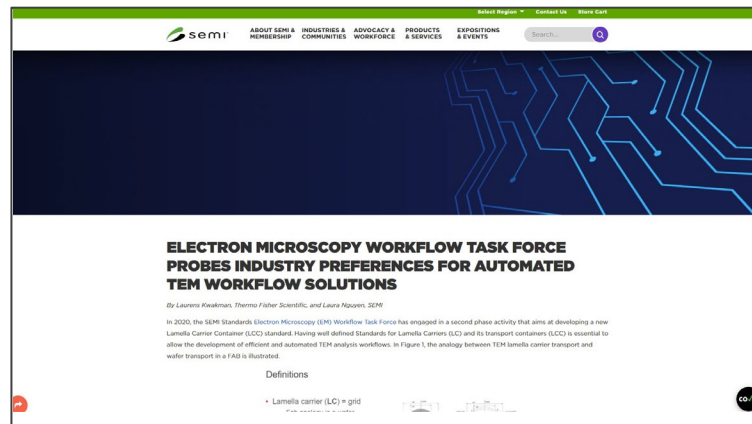
- September 2019



- December 2019



- December 2020



Electron Microscopy Workflow Taskforce: activity outlook

- Challenges for the LCC standardization:
 - Exchange between TEM end-users and TEM suppliers: SEMI hosted surveys are effective!
 - Exchange between competing TEM suppliers , JEOL, Hitachi, Thermo Fisher: building mutual trust over the last 3 years was key to get the technical discussions going in the focus teams!
 - Define standards for an automated TEM workflow that does not exist yet: the new focus teams will work on all relevant details and aspects of an automated TEM workflow (standardization will take at least one more year as originally planned..)
- These Taskforce activities will continue in 2021 with the aim of having a first draft Specification available in December 2021 and a 1st Letter Ballot by April 2022.
- This revised planning is needed as the original plan described in the SNARF was too optimistic and did not take into account the full complexity of the interdependencies of the physical LCC definitions and the functionalities of the LCC in the overall automated TEM workflow.
- However, given the good progress and new learnings in 2020, also based on the very useful customer survey, and with the creation of the new focus teams, the Taskforce is fully confident that 2021 can be a productive and successful year.

SNARF change request

- The TF phase 2 activity SNARF (doc. 6592) has been approved during the PIC TC meeting on November 6, 2019:
 - As reported before, the efforts to come to a new LCC SEMI Standard are significantly more important than originally estimated and milestone and deliverable dates in the SNARF need to be revised/updated
- Motion 1:

I move to approve updating of the Taskforce SNARF with new Milestone and Deliverable dates in the 'Projected Timetable for Completion' section as follows:

- | | |
|-------------------------------------------|-------------------------|
| • 1 st draft by: December 2021 | (was: July 22, 2020) |
| • Letter Ballot by: April 2022 | (was: November 4, 2020) |
| • TC Chapter approval by: September 2022 | (was: March 31, 2021) |

SEMI doc 6592 SNARF



STANDARDS NEW ACTIVITY REPORT FORM (SNARF)

Date Prepared: October 9, 2019 Revised (if Applicable): _____

SNARF for: New Standard: Specification for Container for Transport and Storage of Transmission Electron Microscope (TEM) Lamella Carriers within Electron Microscopy Workflows

Originating Global Technical Committee: Physical Interfaces & Carriers

Originating TC Chapter: North America

Task Force (TF) in which work is to be carried out: Electron Microscopy Workflow (EMW) TF

Submitted by: Laurens Kwakman Company: Thermo Fisher Scientific

Email: laurens.kwakman@thermofisher.com

Phone: +33 6 80 48 91 38

Fax: _____

Refer to Procedure Manual § 2.2.4 for more information on properly filling out the SNARF.

1. Rationale:

a: Describe the need or problem addressed by this activity.

(Indicate the customer, what benefits they will receive, and if possible, quantify the impact on the return on investment [ROI] if the Document is implemented.)

The PIC TC Chapter recently approved SEMI E177-0919 specifying the lamella carriers (LCs) used in Transmission Electron Microscopy (TEM) investigations. This was a first step for enabling automated workflows for TEM investigations in a fab environment. For a fully automated workflow standardization of other steps and components is required. One logical next step is the standardization of a container for the LCs. The LCs need to be transported between the different tools in a fab or lab that are part of the TEM workflow (FIB-SEM, plasma cleaner, TEM, storage). For this a well-defined, standardized container is required - similarly to FOUPs used for transporting silicon wafers - so that the interfaces of the various tools used can be designed and which complies with existing automated transport systems. This container is intended only for transporting the LCs within a fab/lab as well as for long term storage and not for shipping the LCs from the LC manufacturers to the LC customers/end-users.

b: Estimate effect on industry. Check one of the following:

☐ 1: Major effect on entire industry or on multiple important industry sectors

- identify the relevant sectors: _____

☒ 2: Major effect on an industry sector

- identify the relevant sector: Suppliers and users of FIB, SEM, TEM, lamella carriers, cleaning and storage equipment.

☐ 3: Major effect on a few companies

- identify the relevant companies: _____

☐ 4: Slight effect or effect not determinable

c: Estimate technical difficulty of the activity. Check one of the following:

☐ I: No Difficulty - Proven concepts and techniques exist or quick agreement is anticipated

☒ II: Some Difficulty - Disagreements on known requirements exist, but developing consensus is possible

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☐ III: Difficult - Limited expertise and resources exist and/or achieving consensus is difficult

☐ IV: Extremely Difficult - Expertise and resources are scarce and/or achieving consensus is very difficult

2. Scope:

a: Describe the technical areas to be covered or addressed by this Document development activity.

(For Subordinate Standards, list common concepts or criteria that the Subordinate Standard inherits from the Primary Standard, as well as differences from the Primary Standard.)

- The new standard will specify the form factor, parts and physical dimensions of the LC container.
- It will also specify the detailed design of the LC container such as the pockets/slots for the LCs and the fixture mechanism for the LCs.
- It will also specify physical features related to the storage, handling, transport and identification of the LC containers (e.g. fiducials for alignment, id location, etc.)
- In addition, the new standard will define new terms related to this activity.
- To arrive at the new standard it will also be required to consider the possible mechanism(s) by which the LCs will be transported in and out of the container and how LC identification within the container will be realized (LC face-up/down; LC horizontal/vertical; vacuum end-effectors from top or bottom, ID read-out from top or bottom, etc.)

b: Expected result of activity

☒ New Standard or Safety Guideline (including replacement of an existing Standard or Safety Guideline)

☐ New Subordinate Standard to an existing Standard or to a new Primary Standard to be developed concurrently with this new Subordinate Standard

☐ New Preliminary Standard

☐ Major revision to an existing Standard or Safety Guideline

☐ Line-item revision to an existing Standard or Safety Guideline

☐ Line-item revision to two or more existing Standards or Safety Guidelines

☐ Reapproval of a Standard or Safety Guideline

☐ Removal of a Standard or Safety Guideline

☐ Withdrawal of a Standard or Safety Guideline

☐ Reinstatement of a Standard or Safety Guideline

☐ Publication of an existing Standard or Safety Guideline as an American National Standard

☐ New Auxiliary Information

☐ Modification of existing Auxiliary Information

For a new Subordinate Standard, identify the Primary Standard here: _____

For revision of existing Standard(s) or Safety Guideline(s), identify the Standard(s) or Safety Guideline(s) that are to be revised here: _____, and identify which parts of the Standard(s) or Safety Guideline(s) that are to be revised. (Check all that apply.)

☐ Modification of an existing part of Standard(s) or Safety Guideline(s) including Appendices, Complementary Files, and Supplementary Materials

☐ Addition of one or more Appendices or Complementary Files to an existing Standard or Safety Guideline

☐ Addition of one or more Related Information sections or Various Materials to an existing Standard or Safety Guideline

☐ Revision or addition of one or more Subordinate Standards to an existing Primary Standard

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SEMI doc 6592 SNARF



For Standards, identify the Standard Subtype below:

- ☐ Classification
☐ Practice
☐ Test Method
☐ Miscellaneous (describe:)
- ☐ Guide
☒ Specification
☐ Terminology

3. Projected Timetable for Completion:

a: General Milestones

- a. Activity Start: November 6, 2019
b. 1st Draft by: July 22, 2020
c. (Optional) Informational Ballot by: _____
d. Letter Ballot by: November 4, 2020
e. TC Chapter Approval By: March 31, 2021

4. Liaisons with other Global Technical Committees/TC Chapters/Subcommittees/TFs:

- a: List Global Technical Committees, TC Chapters, Subcommittees, or Task Forces in your or other Regions/Locales that should be kept informed regarding the progress of this activity.
(Refer to SEMI Standards organization charts and global technical committee charters as needed.)

b: Intercommittee Ballots (check one):

- ☐ will be issued – identify the recipient global technical committee(s): _____
☒ will not be issued

5. Safety Considerations:

The resulting Document is expected (Check one):

- ☐ to be a Safety Guideline
☒ NOT to be a Safety Guideline

NOTE FOR 'to be a Safety Guideline': When all safety-related information is removed from the Document, the Document is NOT technically sound and complete – Refer to § 15.1 of the Regulations for special procedures to be followed.

NOTE FOR 'NOT to be a Safety Guideline': When all safety-related information is removed from the Document, the Document is still technically sound and complete.

6. Intellectual Property Considerations:

a: For a new Standard or Safety Guideline and for any part to be modified or added in a Revision of published Standards and Safety Guidelines (Check one):

- ☒ the use of patented technology is NOT required.
☐ patented technology is intended to be included in the proposed Standard(s) or Safety Guideline(s).
(If the second box is checked, check one):
☐ Letter of Intent received
☐ Letter of Intent not received



b: For Revision, Reapproval, Reinstatement, or Withdrawal of existing Standard(s) and Safety Guideline(s) (Check one):

- ☐ there is no known material patented technology necessary to use or implement the Standard(s) and Safety Guideline(s)
☐ there is previously known material patented technology necessary to use or implement the Standard(s) and Safety Guideline(s)

c: The body of the Document and any Appendices, Complementary Files, Related Information sections, or Various Materials that may or may not be a part of the Document by reference (Check one):

- ☐ will incorporate Copyrighted Item
☒ the incorporation of Copyrighted Item will NOT be required

NOTE FOR 'the use of patented technology or the incorporation of Copyrighted Item(s) is NOT required': If in the course of developing the Document, it is determined that the use of patented technology or Copyrighted Item(s) is necessary for the Document, the provisions of Regulations § 16 must be followed.

NOTE FOR 'will incorporate Copyrighted Item': A copyright release letter must be obtained from the copyright owner prior to publication.

7. Comments, Special Circumstances:

8. TC Member Review (Check one):

- ☒ took place between (put dates here: 10/09/2019 and 10/22/2019) before approval at the TC Chapter Meeting, or
☐ took place between (put dates here: MM/DD/YYYY and MM/DD/YYYY) before approval by the GCS, or
☐ is not required for this SNARF.

NOTE FOR 'TC Member Review': A TC Member Review is required by the Regulations for a period of at least two weeks before approval of a new, or a major revision of an existing, Standard or Safety Guideline. (See Regulations ¶ 8.2.1)

9. Approval Dates:

TC Chapter or GCS: November 6, 2019
Recorded in TC Chapter Minutes: Fall 2019

If you do not have email capability, you may fax this form to the nearest SEMI office:

SEMI HQ: 1.408.428.9800
China: 86.21.6027.8511
Europe: 49.30.8187.8879
Japan: 81.3.3222.5757
Korea: 82.2.551.3408
Taiwan: 886.3.560.1555

Taskforce leadership change request

- Due to the retirement of Loek Kwakman on November 1st, 2020, it is proposed to add Richard Young from Thermo Fisher as 2nd Taskforce leader. Loek and Richard will together ensure a smooth continuation of the Taskforce activities, Loek as a consultant to Thermo Fisher and Richard as a formal Thermo Fisher employee.
- Motion 2:

I move to appoint Richard Young as a second Taskforce leader



Name: Richard Young
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Email: Richard.young@ThermoFisher.com
Telephone: +1 971 570 4779



Name: Laurens Kwakman
Company: self-employed
Email: laurens.kwakman@wanadoo.fr
Telephone: +33 (0) 6 80 48 91 38

Appendix:

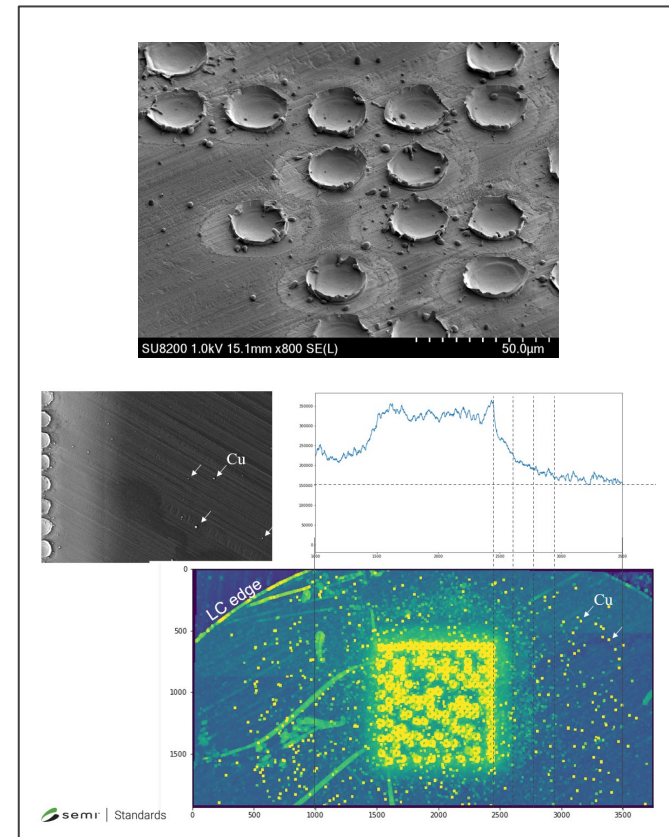
Details of the Taskforce activities in 2020

Electron Microscopy Workflow Taskforce: activity update

E177, LC Standard related activities

- January 2020:
 - Japanese TF liaison (JEOL/HITACHI/KEYENCE) reports contamination issues due to laser ID marking on 3mm grid LCs (after foil deposition).
 - Can laser ablation be improved, e.g. by using Femto-second lasers?
 - ID marking at the LC backside is not considered a practical solution
 - Is active area masking during laser marking a solution?
 - Any other solutions to this problem?
- March 2020:
 - Japanese TF liaison has quantified the reach of contamination: > 300 μm for foil flakes, > 1 mm for Copper particles

“Evaluation of laser marking induced contamination issues”

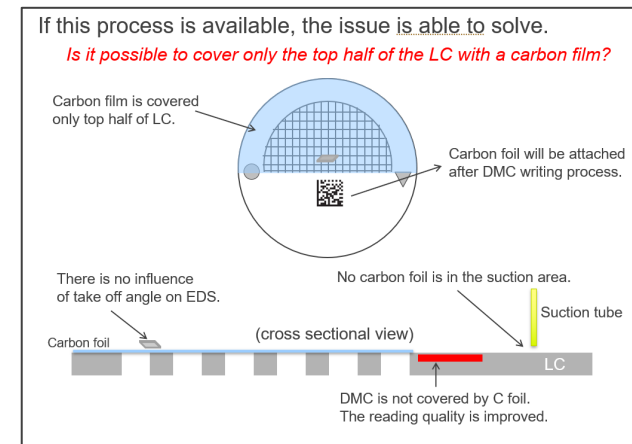


Electron Microscopy Workflow Taskforce: activity update

E177, LC Standard related activities

- May 2020:
 - Japanese TF liaison in view of the contamination issues and no evident solutions proposes a new idea, i.e. the selective area deposition of a thin carbon foil, only in the active area of the LC
 - Protochips (TEM LC supplier) sees a possible route by a deposition and selective area etch approach.
 - It is agreed to pursue this idea and to start targeted experiments
- August-September 2020:
 - Japanese TF liaison, Protochips and TF leader prepare and agree to test plan for proof of concept:
 - New LCs will be ordered from Pyser Optics , lasermarked in Japan and shipped to Protochips in USA for the carbon foil experiments and then inspected again in Japan

“an innovative solution to solve the contamination issues is proposed and will be tested”

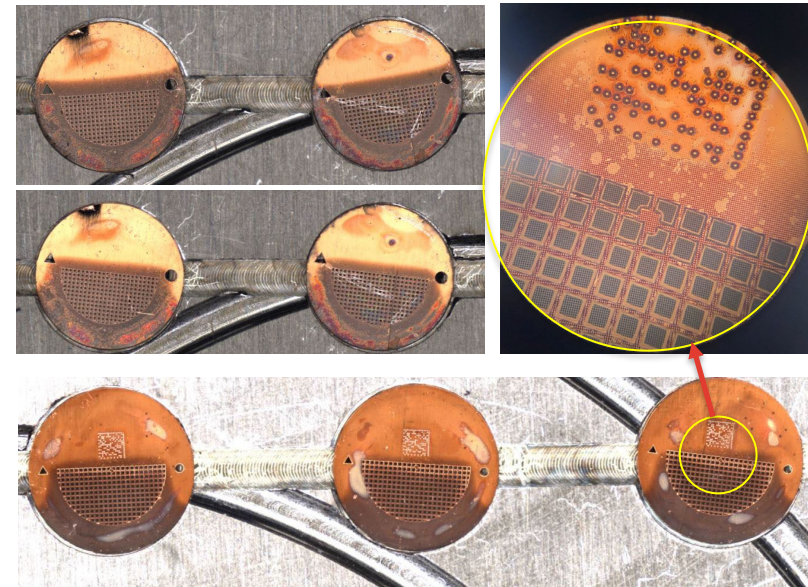


Electron Microscopy Workflow Taskforce: activity update

E177, LC Standard related activities

- October - December 2020:
 - Protochips demonstrates the feasibility of the carbon foil dep-etch process on Pyser Optics LCs that have not yet received the laser ID marking
 - Japanese TF liaison finishes LC laser marking and LCs are shipped to Protochips
 - Protochips starts carbon film dep-etch experiments
- January 2021:
 - Protochips finishes 1st phase experiments
 - Selective etch process works fine and in a controlled manner: selective area can be tuned to also free the fiducial marks
 - Control of etch distance from active area is in the ~ 200 μm range and may require a revision of the specification for the 'my' distance from 25 μm to 250 μm
 - LCs are returned to Japan for inspection

"The innovative solution to solve the contamination issues is shown to work and will be further tested"

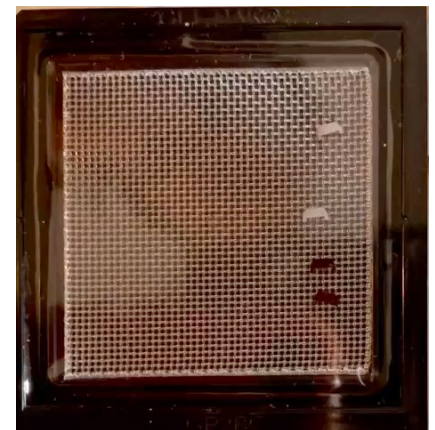


Electron Microscopy Workflow Taskforce: activity update

Doc 6592, LCC Standard related activities

- January 2020:
 - Japanese TF liaison presented ideas about LCC formfactors and # of LC slots.
 - A Customer survey was proposed for the first time by taskforce leader
- March 2020:
 - Hitachi reports availability of a first LC / LCC transfer station with circular LCC (prototype)
 - LC handling has some reliability issues, design needs adaptations (confirms earlier TFS findings)
 - Gel-Pak presents its 'sticky film' technology to the TF members and demonstrates first feasibility study results for TEM LCs.
 - Thermo Fisher presents a first draft version of a LCC focused Customer survey to the TF members

“First LCC specifications are proposed and discussed, different technical concepts are tested”

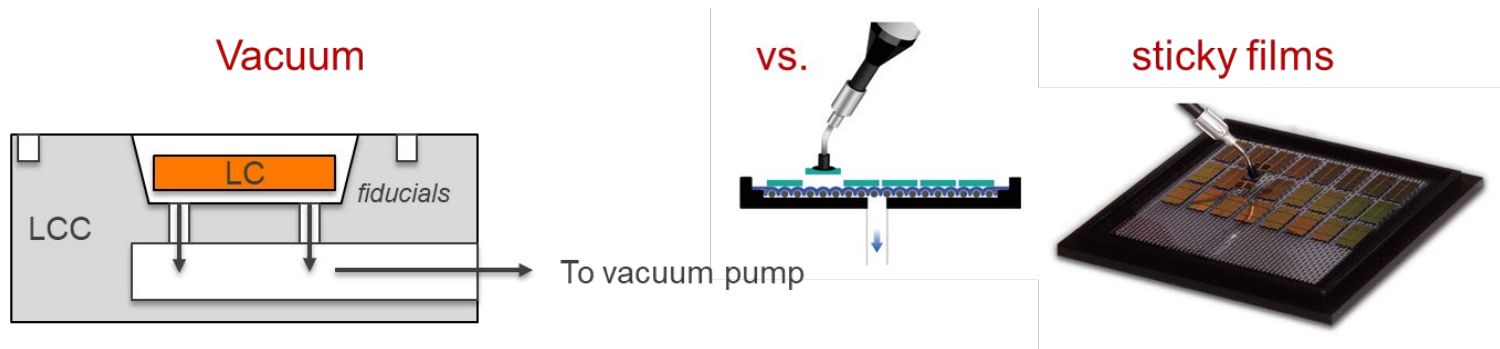


Electron Microscopy Workflow Taskforce: activity update

Doc 6592, LCC Standard related activities

“High level market requirements are defined for the LCC and potential technical solutions are envisaged”

- Nov 2019:
 - A first list of LCC considerations and relevant specifications was presented by Thermo Fisher to start high-level specification discussions.
- Dec 2019:
 - identification of “critical path” definitions for LCC
 - A take-over method in the LCC is required during LC transfer, different possible solutions were discussed:
 - Gel-film adhesion take-over was first mentioned, contacts with new companies were established : Gel-Pak and e-Pak



Electron Microscopy Workflow Taskforce: activity update

Doc 6592, LCC Standard related activities

“to fill the gaps an LCC focused customer survey is planned, prepared and to be executed through SEMI HQ”

- May 2020:
 - Thermo Fisher presents an updated version of the Customer survey
- July 2020:
 - It was agreed to run the survey via SEMI HQ, to ensure maximum confidentiality for participating customers and to guarantee an unbiased data analysis afterwards
 - *Would show a SEMI Standards initiative instead of an equipment supplier initiative*
 - Peter Wagner presented a first version of the new LCC SEMI document 6592, a framework document that still needs to be populated with all LCC specifications...
- August 2020:
 - The LCC Customer survey has been set up at SEMI HQ, microscopy suppliers provided all customer contact information, the LCC information package, LCC Questionnaire and customer communication suggestions
 - ➔ *SEMI (Laura!) converted all into a SEMI ‘SurveyMonkey’ format.*
 - In view of the difficulty to define LCC specifications at sufficiently detailed engineering/technical level, *the Taskforce leader proposes to create small ‘focus teams’* in which specific technical topics will be addressed more efficiently and in more details. (Aim is to speed-up the Phase 2 standardization activities).

Electron Microscopy Workflow Taskforce: activity update

Doc 6592, LCC Standard related activities

“the customer survey is executed and results are evaluated.”
“Focus teams are created to speed-up the LCC specification process”

- September 2020:
 - Thermo Fisher presents a more detailed plan for the focus teams
 - TedPella (TEM grid supplier) presents and formulates a request to consider how LC shipping containers can be linked to the automated TEM workflow and if LCC and shipping boxes can have commonality.
- October 2020:
 - The LCC Customer survey is launched, and customer responses are collected;
- December 2020:
 - The LCC customer survey results have been collected and analyzed and presented to the Taskforce members.
 - Customer feedback has been good (> 60% response rate, 14 customers –all key IC manufacturers included)
 - Customer inputs are very valuable to guide LCC specifications
- January 2021:
 - First focus team kick-off meeting between JEOL, Hitachi and Thermo Fisher