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Website: www.sintef.no/en/projects/mupia

Manufacturing process for ultimate performance inertial MEMS gyrometer (MUPIA)

Report on Communication, Dissemination, Exploitation actions and Business plan

VERSION
Version 1.0

DATE
15-06-2021

ABSTRACT

This is a report on the communication, dissemination and exploitation carried out in the MUPIA project. All in all, the communication and dissemination activities were not as active as planned. This was mainly due to the project focusing on the challenges that occurred during processing and packaging.

A short business plan is also included the summarises the SINTEF's and Micross' ability to meet the KPI's set in the proposal for delivery of MEMS gyroscopes in the future.

KEYWORDS: Communication, dissemination, exploitation, MEMS, gyrometer,

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NO	NO

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VERSION	DATE	VERSION DESCRIPTION
01	31-05-2021	Submitted version
02		

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List of Abbreviations

Table 1: List of abbreviations

Term	Explanation
SotA	State of the Art
TSV	Through silicon via
SME	Small medium enterprise
TRL	Technology readiness level
MRL	Market readiness level
MOD	MUPIA Open Design
COD	MUPIA Closed Design

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Executive Summary

This deliverable is a short report on the communication, dissemination, exploitation and business plan in the MUPIA project. The design and performance of the finished MUPIA gyro have not been disseminated. However, the project partners have disseminated some of the processing advances necessary in the project.

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1 Introduction

1.1 Purpose of the document

This report concludes the work on communication, dissemination, exploitation actions and the business plan for the MUPIA project.

1.2 Authorship and Intellectual Property Rights (IPR)

The stakeholders in the MUPIA project are two consortium partners, SINTEF and Micross, and the topic manager. The IPR of the final product of the MUPIA project belongs to the topic manager and is therefore not disseminated. However, some of the challenging specifications set forth in the project for the device to work properly have produced interesting challenges for the project consortium and have therefore produced results that can be interesting for the scientific community.

The table below lists some of the processing challenges that SINTEF and Micross identified as interesting for public dissemination at the start of the project.

Key Results	**Asset (IP)**	**IPR Principle**	**Primary Exploitation Partner**	**Secondary Exploitation Partner**
p-type TSV	Direct connection to sealed MEMS devices made of p-type Si	Processing parameters kept by SINTEF, key results disseminated	SINTEF	Customers
High resolution DRIE processing for MEMS	Accuracy in MEMS devices	Processing parameters kept by SINTEF	SINTEF	Customers
n-type TSV	Direct connection to sealed MEMS devices made of n-type Si	Processing parameters kept by SINTEF, key results disseminated	SINTEF	Customers
Topography measurement and statistical analysis	Automated analysis of a large sample of topography data to verify process specifications	Analysis principle disseminated, code kept by SINTEF	SINTEF	Scientific community
High vacuum package level sealing	Enabling open structure MEMS devices to operate in vacuum	Processing parameters kept by Micross	Micross	Customers

1.3 Intended readership

This report is publicly available and is intended for those who are interested in the development of MEMS processes and packaging.

1.4 Structure of this document

The main part of this document is in sections 2-5, with communication, dissemination, exploitation and business plan having their own sections. The content is mainly taken from the MUPIA proposal and altered to match the status of the project.

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1.5 Stakeholder involvement

The stakeholders involved in the preparation of this document is SINTEF and Micross. As the former has a larger stake in the project, the topics covered are primarily related to the development work at SINTEF.

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2 Report for communication of project results

For any communication, acknowledgment to the funding authorities was included.

A public website was set up for the project (https://www.sintef.no/mupia) and is maintained by SINTEF. The website contains a brief overview of the project on the main page, with contact information and partner logos. It lists the project's publications in the publication feed and the public deliverable D6.2 "Plan for Communication, Dissemination and Exploitation of project results" in the news feed.

Through the project the site has had in total about 85 unique visits and 105 visits in total. A frequency chart can be seen in Figure 1.

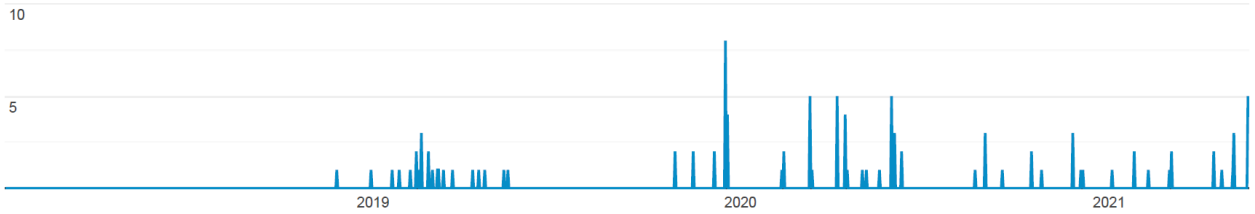

Figure 1: frequency chart for visits to the MUPIA wab page.

SINTEF chose not to communicate the project results to a broad audience using their Twitter feed (https://twitter.com/sintef) and blog posts (https://blog.sintef.com/). Such communication was reserved for definite improvement of MEMS gyros beyond state-of-the-art. However, the first round of gyros delivered in January 2020 had a wiring error that led to it being impossible to properly characterise the gyro performance. In addition, Covid19 lead to the test facilities at the Topic Manager's site being unavailable for extended periods of time.

The second round of gyros were delayed and not delivered to the Topic Manager before the very end of the project (May 2021). Hence, detailed analysis will not be available before the end of the project. However, if the results show an improved performance, the MUPIA consortium will communicate this in the abovementioned channels.

3 Dissemination of project results

The project partners have published three conference papers during the MUPIA project. These are:

1. Sordo et al. "Through Silicon Vias in MEMS packaging, a review", NordPac 2019, June 11-13, Lyngby, Denmark
2. Wright et al. "Development of mechanically compliant flip chip interconnect using single metal coated polymer spheres", EMPC 2019, September 16-19, Pisa, Italy
3. Sordo et al. "Wafer bonding process for zero level vacuum packaging of MEMS", ESTC2020, September 15-18, Online

All three articles are listed in the "Publications" section of the MUPIA website. Number 1 and 2 are published in the open access Zenodo repository, while number 3 is found at IEEExplore. Communication with IEEE has been initialised to see if paper 3 can be made open access in Zenodo.

The project has focused on solving the many challenges of the MUPIA gyro processing. This has unfortunately limited the efforts available for publication of our work.

Table 2: Channels initially considered as relevant for dissemination of results from MUPIA and the number of publications achieved.

Channel	Targeted#	Publications / Disseminations
Key journals (scientific)	1-2	None

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Key Conferences (scientific community, industry contact)	1-2	NordPac 2019, Lyngby, Denmark EMPC2019, Pisa, Italy ESTC2020, Vestfold, Norway
Key Magazines	1-2	None

4 Exploitation of project results

4.1 Exploitation for SINTEF

SINTEF already manufactures and delivers MEMS products (pressure sensors) to the aeronautics industry. Another product line with high-precision gyrometers for aeronautics will fit well to SINTEF's manufacturing strategy of small and medium scale production of high value MEMS products. Standardized process blocks, which have resulted from this project, will also be exploited in other research, innovation and manufacturing projects. This is an important strategy for SINTEF, to build a wide set of standard, well-controlled, advanced process steps, gaining steps for every new project that is being run. The control of the processes is built on a research-based innovation strategy where empirical work is performed in parallel with simulations and theoretical evaluations.

Based on the experience from MUPIA, SINTEF is currently developing a MEMS Strain Gauge. The idea is to use change in resonance frequency to measure the strain very accurately. The first round of gauges has been produced with an architecture which is open to the surrounding environment, which necessitated vacuum level sealing at package level. The next iteration will include vacuum sealing at wafer level, a process that was accomplished in MUPIA, albeit too late to be implemented in the final delivery.

4.2 Exploitation for MICROSS

Through MUPIA, Micross expects to increase its UK based capability and technical knowledge of this branch of semiconductor packaging and thus be in a position to introduce the increased capacity necessary to service an increasing market demand for such specialist packaging. The technology fits well alongside other high reliability components already sold into the same market place. Micross operates and sells its products and services to a global market place and will be seeking to gain new business from its existing OEM customer base within Europe but also new customers from the Asia Pacific region and the Americas, utilising its existing global sales channels.

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5 Business plan

In the MUPIA proposal there were four Key Performance Indexes (KPIs) listed in Table 3. These KPIs were based on not knowing the exact design and specifications that were later given in the project.

Table 3: Summary of KPIs and comments on experience

KPI		MOD	COD
An overall yield (including rework) > 85%,	SINTEF	Electrical characterisation at wafer level indicated that this KPI is met within the specifications given in the project.	Not proven. With the challenge of direct bonding solved, this KPI will mostly depend on the success of the TSVs' electrical connection to the device wafer. Pressure level is not validated.
	Micross	Assembly and wire bonding results fulfil this KPI. Vacuum sealing at package level is uncertain.	Assembly, wire bonding and lid sealing on mechanical test samples show good results to meet the KPI.
A batch processing time < 3 months	SINTEF	Assuming a 25 wafer batch (5000 units), this is feasible.	Assuming a 25 wafer batch (5000 units), this is not feasible. Process requires several more DRIE processing steps than MOD and these are done on single wafers. Polysilicon deposition of TSVs is also a time consuming process. The batch processing time for COD is closer to 5 months.
An assembly and test process time < 1 months	Micross	Assuming a 25 wafer batch (5000 units), this is not feasible.	Assuming a 25 wafer batch (5000 units), this is feasible.
A unit price in the range of 70€ for volumes ~10000 per year	SINTEF	Price per unit will be in the range €30 - €40	Price per unit will be in the range €50 – 60€.
	Micross	Approximately €125	Approximately €58
	Total	€155 – 165	€108 - 118

None of the variants meet all of the KPIs. However, if the COD variant is proven functional with an appropriate yield, it has the largest potential.

5.1 Business plan for SINTEF

SINTEF's main business is within research and development. However, small volume manufacturing of highly specialised silicon products is a benefit to SINTEF and the customer. SINTEF will therefore first and foremost use the experiences from MUPIA to extent the processing services it can provide to customers.

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5.1.1 Direct bonding of MEMS wafers

The MUPIA project finally accomplished vacuum sealing at wafer level for the MUPIA MEMS gyros. Unfortunately, this was not in time for the COD variant to constitute the final delivery of the MEMS gyros (which needed to be vacuum sealed at package level). This success has given SINTEF experience in which parameters need to be met in order to bond highly processed wafers together. This can be exploited in new business ideas that require high vacuum. The vacuum level available in SINTEF's bonding tool is currently $1x10^{-3}$ mbar. If a customer needs better vacuum, SINTEF will have to invest in better vacuum pumps. This investment will depend on the value of the order from the customer.

5.2 Business plan for Micross

As a result of the technical capabilities developed from this project, Micross has increased its UK based capability and technical knowledge of this branch of semiconductor packaging (i.e. MEMS packaging) and thus is considering the possibility to increase capacity necessary to service the increasing market demand for such specialist packaging specifically in the area of MEMS devices. The technology fits well alongside other high reliability components already sold into the same market place. Micross operates and sells its products and services to a global market place and will be seeking to gain new business from its existing OEM customer base within Europe but also new customers from the Asia Pacific region and the Americas, utilising its existing global sales channels.

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6 Conclusions

The deliverable has been the final report on the communication, dissemination and exploitation of the project results in MUPIA.

Communication was mainly done via the project web site.

The project did not meet the planned level of dissemination. This was mainly due to the focus on the challenging processing of the MEMS. Had the project managed to successfully fabricate and test the COD variant of the MEMS within the project time frame, the dissemination level would have been significantly increased.

Both partners will exploit the project results to expand and improve their services to their customers. This is also the main strategy behind the business plan.

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7 Appendix

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LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS AND TECHNICAL PAPERS

No.	Title	Main author	Title of the periodical or the series or the event	Number, date or frequency (N/A for events)	Publisher or organiser	Place of publication or event venue	Year of publication or event	Relevant pages or event session	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
1	*Through Silicon Vias in MEMS packaging, a review*	*Sordo*	*NordPac 2019*	*June 11-13, 2019*	*IMAPS Nordic / IEEE EPS*	*Copenhagen*	*2019*	*T1A: Ever Increasing Density*	10.5281/zenodo.3666348	yes
2	Development of mechanically compliant flip chip interconnect using single metal coated polymer spheres	Wright	22nd Microelectronics and Packaging Conference (EMPC) & Exhibition	September 16-19, 2019	IMAPs Europe	Pisa, Italy	2019	TuP3: Manufacturing Technologies 1	10.5281/zenodo.3605912	yes
3	Wafer bonding process for zero level vacuum packaging of MEMS	Sordo	European Systems-Integration Technology conference (ESTC)	September 15-18, 2022	IEEE EPS	Online. Vestfold, Norway	2020	MEMS/NEMS & Sensors		yes

[1] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).
[2] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

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Template A 1– List of Peer Reviewed Papers

	LIST OF DISSEMINATION ACTIVITIES								
No.	Type of activities[3]	Main leader	Title	Date/Period	Place	Type of audience[4]	Size of audience	Permanent identifiers ISBN	Countries addressed
1									
2									
3									

Template A 2 – List of Conferences and other dissemination activities (as specified in the CSMM)

[3] Choose the dissemination activity: Conference publications, workshops presentations, conference presentations, conference exhibitions, conference posters, Other.

[4] Choose the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

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LIST OF COMMUNICATION ACTIVITIES								
No.	Type of activities[5]	Main leader	Title/Subject	Date/Period	Place	Type of audience[6]	Size of audience	Countries addressed
1								
2								
3								

[5] Choose the dissemination activity: web, press releases, flyers, articles published in the popular press, videos, media briefings, exhibitions, interviews, films, TV clips, posters, Other.

[6] Choose the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

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Template A 3 - List of Communication activities

Section B (Confidential[7] or public: confidential information to be marked clearly)
Part B1

The applications for patents, trademarks, registered designs, etc. shall be listed according to the template B1 provided hereafter.

The list should, specify at least one unique identifier e.g. European Patent application reference. For patent applications, only if applicable, contributions to standards should be specified. This table is cumulative, which means that it should always show all applications from the beginning until after the end of the project.

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.						
No.	Type of IP Rights[8]:	Confidential YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
1						
2						
3						

[7] Note to be confused with the "EU CONFIDENTIAL" classification for some security research projects.

[8] Choose the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

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Part B2

Please complete the table hereafter:

No.	Type of Exploitable Foreground[9]	Nature of Exploitable Foreground[8a]	Description of exploitable foreground	Confidential YES/NO	Foreseen embargo date dd/mm/yyy	Exploitable product(s) or measure(s)	Sector(s) of application[10]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
1										
2										
3										

For each record in the above table is possible to further explain the exploitable foreground, in particular by addressing the following points:

Record No. 1:

a. Purpose of exploitable foreground
b. Achieved TRL at the end of period (where applicable)
c. How the foreground might be exploited, when and by whom
d. IPR exploitable measures taken so far or intended
e. Business case aspects considered (i.e. market study, opportunities, …)
f. Further research necessary, if any
g. Potential/expected impact (quantify where possible)
h. Role of ITD members towards potential commercialization of results
i. Relation to technical standards, EU/international regulations, directives

8 Choose type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

8a Choose nature of foreground: Product innovation, Process innovation, New method, Scientific breakthrough

[10] Choose the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

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Record No. x:

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