

3eFERRO

Energy efficient Embedded Non-volatile Memory Logic based on Ferroelectric Hf(Zr)O₂

Document Title	Dissemination and Exploitation Plan (update 1)		
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Project	3eFERRO	Grant number	780302
Coordinator	CEA	Project coordinator	Dr Nicholas Barrett
Call identifier	H2020-ICT-2016-2017		
Work Package	WP6: Dissemination, Communication, Exploitation, Training Activities		
WP lead beneficiary	ECL	Task lead beneficiary	NCSR D
Project Start date	01/01/2018		
Project Duration	42 month		

Partners list

Partner n°	Organisation name (short name)	Country
	European Commission (EU) – Project Officer	Belgium
1	Commissariat à l’Energie Atomique (CEA)	France
2	STMicroelectronics Crolles2 SAS (ST)	France
3	NaMLab gGmbH (NaMLab)	Germany
4	Institutul National de Cercetare Dezvoltare Pentru Fizica Materialelor (NIMP)	Romania
5	Ecole Polytechnique Fédérale de Lausanne (EPFL)	Switzerland
6	Ecole Centrale De Lyon (ECL)	France
7	National Center For Scientific Research Demokritos (NCSR D)	Greece
8	Forschungszentrum Jülich GmbH (FZJ)	Germany

1. DISSEMINATION PLAN IN 2019

The planning in the initial Plan for the Exploitation and Dissemination Results (PEDR) (see Table 2.2b in 3εFERRO-DoA) and the updated PEDR (see below) are made for the whole project duration. Therefore, some of the plans which appear to be, at the end of the 1st project year, in a status of “non-implementation”, they could be implemented in subsequent years until project end. To give an overview of what was implemented during the first year, a list of 3εFERRO dissemination activities in 2018 has been included in the annex.

3εFERRO dissemination activities cover broad area of Scientific & Engineering Communities. More specifically, its target groups include:

- Electrical & electronic engineers
- -Materials Scientists and Engineers
- -Physicists,
- -Electrochemical scientists

Table 2.2b- Updated PEDR after the first project year

This table is retrieved from the project proposal (page 38 – Description of Action part B).

Activities and minimum targets	Initial planning	Up-dates
<u>Conference & Workshop participations</u> Initial plan: 24	Publications in international “top notch” conferences IEDM, VLSI Technology, ECS: 10 joint presentations; 10 invited/plenary expected	Initial plan still valid.
	International Meeting on Ferroelectricity (IMF) and International symposium on Application of Ferroelectrics (ISAF) - 3 oral presentations expected	ISAF 2019 partly sponsored by EPFL features U. Schroeder (NaMLab) as plenary speaker and I. Stolichnov (EPFL) as invited speaker.
	International workshop on oxide electronics (IWOE) in 2018	No contribution at IWOE 2018.
	Romanian Conference on Advanced Materials (ROCAM)	Participation expected in 2020. The date has moved to 2020 due to overlaps with other similar conferences in 2019.
	Participation to the annual meeting of the French CNRS “Groupe De Recherche”(research group) OXYFUN on oxide electronics.	French partners will participate in the CNRS GDR OXYFUN meeting in 2020.
		<u>Conference/workshop participations in 2019</u> <ul style="list-style-type: none"> - INFOS 2019: NCSR - EMA Orlando (American Ceramic Soc.) in Florida: NaMLab - FMA 2019 in Kyoto: NaMLab (invited talk) - ISAF Lausanne Switzerland: EPFL, NaMLab (invited talk), NCSR - DPG Frühjahrstagung in Regensburg (Spring Conference of the German Physical Society): FJZ

		<ul style="list-style-type: none"> - SISC 2019: NCSR - High K workshop is organised by NaMLab, and most project partners will participate: CEA, FZI, EPFL - E-MRS Spring Meeting in Nice: ECL, NIMP, CEA, NaMLab - E-MRS Fall in Warsaw: NIMP, CEA - INFOS in Cambridge: ECL, NaMLab (invited talk) - IEEE ELNANO at Kiev: ECL - HAXPES 2019 in Paris: FZI - ISOE2019 summer school: CEA PhD fellow funded by 3eFERRO will attend it <p>In addition, INL-ECL research team in System design is considering participating to the following events:</p> <ul style="list-style-type: none"> - DATE - IEEE/EDAA/ACM/ECSI Design Automation and Test in Europe - DAC - ACM/ESDA/IEEE Design Automation Conference - ICCAD - ACM/IEEE International Conference on Computer-Aided Design - ISSCC - IEEE International Solid State Circuits Conference - VLSI-SoC - IFIP/IEEE International Conference on Very Large Scale - Integration - NEWCAS - IEEE New Circuits and Systems Conference - ISCAS - IEEE International Symposium on Circuits and Systems - ICECS - IEEE International Conference on Electronics Circuits and Systems - IMW - IEEE International Memory Workshop - ICRC - IEEE International Conference on Rebooting Computing <p>Depending on the project progress CEA will also submit to: SSDM, ALC'19 in Kyoto, and IEDM.</p>
<p><u>Conference / Workshop organization</u></p> <p>Initial plan: 12</p>	<p>Organization (E)-MRS symposia</p>	<p>E-MRS 2019, symposium Q Polar oxides: synthesis, science and applications is organized by B. Vilquin (ECL) and A. Dimoulas (NCSR). NIMP and CEA are among the contributing partners</p>
	<p>International conference on Hard X-ray photoelectron spectroscopy and the International LEEM-PEEM workshop ; 2 invited and 1 oral presentations expected</p>	<p>Initial plans for LEEM-PEEM workshop organization in France were not realized. Proposal was not accepted the year 2020 workshop will be held in Spain. Plans for conference presentations are still valid.</p>
	<p>Organization/ participation in annual Hellenic Forum/Summer school, Athens</p>	<p>A workshop will be organized in July 2020 by NCSR</p>

	A special edition of the International Workshop on Materials Physics (IWMP) organized by NIMP	IWMP 2020 will focus on ferroelectric HfO ₂ .
		- SSDM 2019: Laurent Grenouillet (CEA) is part of the program committee in Area 2 "Advanced / Emerging memories and new applications.
<u>Publications in Journals</u> Initial plan 10	Publications in international journals, high impact factor Nature series: Nanotech, Materials, Communications; - Advanced Materials series (Wiley); IEEE journals (EDL, TED); 10 joint publications, "Gold" Open Access (OA).	Articles published by ECL - "Characterization of ferroelectric hafnium/zirconium oxide solid solutions deposited by reactive magnetron sputtering" in Journal of Vacuum Science and Technology - "Prospects for energy-efficient edge computing with integrated HfO ₂ -based ferroelectric devices" at the IFIP/IEEE International Conference on Very Large Scale Integration (VLSI-SoC) (conference proceeding)
		Unlike what has been stated in the proposal, and because no budget has been allocated to article processing charges (APCs), articles will be published first and foremost in Green OA journals. They will then be shared via online scientific repositories like arXiv and HAL (https://hal-cea.archives-ouvertes.fr/HAL-3εFERRO/).
<u>Plans after project end</u>	First year after project end: Edit a scientific brochure, tentative title "e-NVM" to disseminate project results among industry and academia	This plan still remains valid as initially foreseen.

2. INDIVIDUAL PARTNER EXPLOITATION PLANS

The use of results in further research activities other than those covered by the action is the individual exploitation plans which are described in detail in the 3εFERRO DoA. Due to the early stage of the proposal, no implementation action has been taken up to now. Most of the plans remain unchanged. Here we present them again with small updates wherever applicable. This section also include the additional information requested in the review report concerning ST exploitation strategy.

CEA

Expected exploitable results, exploitation strategy and benefits are not up-dated. Benefits have been up-dated to include the following item:

The knowledge produced in during and alongside the 3εFERRO project, will also serve as a leverage for CEA's request for national funding (e.g ANR project). Therefore, it will contribute to create a momentum on Ferroelectrics research at CEA.

ST

Expected exploitable results, Benefit and Time scale have not been changed, however **the exploitation strategy has been up-dated considering the review report. ("Recommendations concerning the period covered by the report")**.





The successful implementation of a thin ferroelectric hafnia based film in a FeRAM capacitance structure will require the following actions in the post-project road map for the period 2022-2025 in order to fully qualify and characterize future products

- (1) Generate structures and elementary devices to characterize these new devices
- (2) Start the reliability test
- (3) regarding the first characterization results, a first set of discussion with ST's design and marketing Team to identify an eventual market/ Application.
- (3) Generate a macrocell with major functionalities to help statistical memory cell data collection.
- (4) Evaluation of process costs and benefits
- (5) With the characterization of the macrocell, a new set of discussion with ST's design and marketing Team will allow to confirm /Infirm the first application targeted and to define more precisely the first product to use Ferroelectric memories within ST, if it appears competitive with other solutions.
- (6) Implementation on first product.
 - Design of a first product
 - Validation of the product functionality (and performance) / Eventual adjustment (New Loop)
 - Start of prototyping and Put in place of the production process.

NaMLab

No up-date of the exploitation plan.

NIMP

No up-date of the exploitation plan.

EPFL

No up-date of the exploitation plan.

ECL

Minor change in the expected exploitable results: ECL expects to achieve results beyond state of the art in ALD **and PVD** growth of ZrHfO₂ ferroelectric based capacitor for back-end of line applications

Exploitation strategy, benefits and time scale have not been up-dated.

NCSR

Initial expected exploitable results:

(1) Ge dopants may stabilize MBE HfO₂ and ZrHfO₂ orthorhombic ferroelectric phase at lower temperatures, below 450°C facilitating BEOL integration with CMOS for 16 kbit array demonstrator. Involved partners: NCSR, NaMLab, CEA.

(2) Ferroelectric HfO₂ and ZrHfO₂ on Ge channels grown by MBE may result in sharp, interface layer-free interfaces minimizing or completely eliminating charge trapping during cycling of 1T FeFET memory cell.

Involved partners: NCSR, NaMLab





Update: Item (1) above is no longer considered as exploitable result since the Ge-doped HfO2 does not produce good ferroelectric material as reported in D2.1. Therefore, we focus on item (2) since our work on HfZrO on Ge substrates is successful and, given that area of Ge MFS and Ge GeFET is a rather unexplored area, we believe that item (1) remains a very good exploitable result.

Initial exploitation strategy:

For both expected exploitable results, the exploitation strategy involves three main steps.

Step 1: the foreground IP will be protected by jointly owned patents from all involved partners respecting the IP rules to be set in the Consortium Agreement.

Step 2: the technology will be transferred from MBE (NCSR D) to industrially relevant ALD or CVD methodologies (NaMLab, CEA)

Step 3: Validation of the results at industrially relevant environment to enhance TRL to 6-7 with participation of interested European industries (potentially ST for result 1 and GF for result 2)

Update: We believe that we need to fabricate Ge FeFETs and demonstrate 1T memory operation or Ge NC FET functionality before we proceed to Step 1 targeting a patent by the end of 2019. This is because FeFETs on Ge have not been demonstrated yet facilitating patenting of our research.

Benefits & Time scale have not been up-dated

FZJ

No up-date

3. COMMUNICATION PLAN-IMPLEMENTATION STATUS AND UPDATES

The communication draft plan in the 3εFERRO DoA is designed to prepare, as broadly as possible, the concerned communities (Industry, researchers, academia, EU and national technical bodies) to assess, accept, adopt and facilitate turning the 3εFERRO new knowledge into a socio-economic viable and sustainable innovation.

In brief, here we describe again the communication activities providing also the status of the implementation for each action as well as an action plan how to improve and maximize the impact along with the associated time scale for the completion of the action. Finally, we update our list of communication actions with an additional item (9) regarding a press release to an electronics/electronic engineering Magazine.

Initial Planning	Up-dates
(1) Planned Public workshops and events. To facilitate communication of our results to the public, consortium members will participate in public workshops in their home states.	Table 2.2b (see above) has been up-dated with a list of conferences, workshops that 3εFERRO partners are planning to attend and to organize in 2019/2020.
(2) Video production. Two videos, one in the first 2 months will advertise the project goals through electronic media. A second near the end of the project will advertise achievements.	This activity has been delayed. The issue was discussed in the Management meeting in Athens on the 15 th January 2019. The video production will be organized by the 3εFERRO coordinator. Expected time of completion: End of 2019
(3) Newsletter and project facts sheet. A first issue will be released in the first 2 months describing the	The first issue of the Newsletter was produced by NCSR D in November 2018. In Athens, consortium



<p>Vision/scope, the objectives and the main project components and core tasks. Subsequently, 6-monthly newsletter will be issued to advertise the results and interim achievements.</p>	<p>members agreed on the content and layout of the final version.</p>
<p>(4) Electronic social media. We will make use of official EU-H2020 services and “instruments” of publicity to announce main achievements. We plan “top stories” publication in CORDIS /projects and results, interviews at EU Horizon Magazine (horizon-magazine.eu), blogposts in Digital agenda for Europe (ec.europa.eu/digital-agenda) with a simultaneous posting in the beneficiaries organization social media to maximize impact. This action has no cost.</p>	<p>In the review report, it was suggested that the newsletters can be distributed through the “nano-electronics newsletters” of the European Commission. The 1st issue of the newsletter will be sent to the PO.</p>
<p>(5) Management meetings - invitation of local communities. During the 6-monthly management meetings in beneficiaries states we plan to invite representatives from relevant communities and associations to the public parts of the project meetings.</p>	<p>The time constraints combined with the large number of important issues to be discussed at the consortium meeting in Athens on 14-15 January, did not allow us to organize a satellite event with the participation of other interested research and technology communities in Greece. Such a meeting would require a 3-day event.</p>
<p>(6) Public website: General public awareness about the project activities will be increased with a public web site in English which will be monitored through detailed analytics such as the possible impacts of the participation to a major event or the contact of the persons that have been interested in downloading a technical deliverable. All communication documents will be made available (posters, scientific papers and “public” deliverables). The 3εFERRO website will be maintained 3 years after the project end for supporting the project impacts. In addition, each consortium member will have a dedicated section to the project in their own organization website. Minimum target values until project end: Number of single visits: 500</p>	<p>The public website was constructed by NCSR D and delivered within the first 3 months of the project. NCSR D is also responsible for the maintenance of the website and the continuous update with new data. In the next two months NCSR D will take measures to improve the website partly in response to the reviewers’ comments:</p> <ul style="list-style-type: none"> (a) counter of website visits in order to make some statistics about the appeal of the site content to the public (b) regular updates with the upcoming workshops and events as already described in table 2.2b above (c) keywords (e.g. IoT, edge computing, NVM, etc) so website is prominent in the list of web search machines. These improvements are expected to be completed by June 2019.
<p>(7) Social media: Professional Social Networks (such as LinkedIn and Twitter etc.) will be set-up in order to maximize the visibility of the published results and partners organization/participation of international events, and also to monitor the feedback (number and type of followers, comments regarding the project activities). Minimum target value until project end: At least 300 followers (Twitter); 36 updates – 1 per month - (Linkedin).</p>	<p>A Twitter account was set-up in January 2019 (@3εFerro). No target was clearly defined but in practice it is used as way to boost the project visibility in a broad sense (academics, general audience, industry). At one point, we will refine our “Hashtag”¹ strategy that to match our channel and audience. News worthy information like article, conference attendance or organization, etc... will be promoted via social media.</p>

¹ Keyword to help other social users find your tweets and or your social media account



<p>(8) Visual identity: Branding of the project. It will be built as soon as the project starts with the design of an original visual identity, i.e. a logo.</p>	<p>Completed</p>
<p>(9) New action: Press release: The Coordinator will inquire about the possibility of an interview with a journalist or for an illustration in a relevant magazine. One option is the magazine <i>ee News Europe</i> (http://www.eenewseurope.com/) (former eeTimes Europe).</p>	<p>The coordinator will make first contact in December 2019.</p>



Annex

Activities in 2018:

IT: Invited Talk

OP: Oral presentation

		Partner	Lead person	Type	Conference	Presentation	Venue	Date
Participation to conference or workshop	WP3	NIMP	Lucian Pinitilie	IT	E-MRS Fall meeting, syposium P	Recent developments in the field of ferroelectrics for electronic applications	Warsaw, Poland	18-20 September, 2018
	WP2	ECL	Jordan Bouaziz	OP	GDR OXYFUN Annual Meeting	Deposition of hafnium/zirconium oxides solid solution by reactive magnetron sputtering for fast and low power ferroelectric devices	Piriac sur mer, France	21-23 March, 2018
	WP2	ECL	Bertrand Vilquin	Poster	WODIM 2018	Annealing effect on hafnium/zirconium oxides solid solution deposited by reactive magnetron sputtering on silicon	Berlin, Germany	10-14 June, 2018
	WP4	ECL	Ian O'Connor	OP	VLSO-SOC 2018	Prospects for energy-efficient edge computing with integrated HfO ₂ -based ferroelectric devices	Verona, Italia	8-10 October, 2018
	WP2	ECL	Jordan Bouaziz	OP	Journées de la matière condensée JMC 2018	Deposition of hafnium/zirconium oxides solid solution by reactive magnetron sputtering for fast and low power ferroelectric devices.	Grenoble, France	27-31 August, 2018
	WP4	EPFL	Igor Ionescu	IT	IEEE S3S	Negative Capacitance: next technology booster for digital computation and sensing near 100milliVolts?	San Francisco	15 October, 2018
	WP5*	CEA	Jean Coignus	OP	<i>International Conference on Solid State Devices and Materials</i>	<i>Evaluation of Ferroelectricity in Si-implanted HfO₂ along Cycling</i>	Tokyo, Japan	9-13 September, 2018
Conference organization	WP5	CEA	Laurent Grenouillet		International Conference on Solid State Devices and Materials	Committee member of the memory area	Tokyo, Japan	9-13 September, 2018

*Not funded by 3eFERRO but subject close to 3eFERRO and serves the interests of the project.