INTEL REQUEST FOR PROPOSALS (RFP)

SUBJECT

Intel's University Research & Collaboration Office (URC) requests proposals for "Center of Ferro-Electrics for Energy Efficiency (COFEEE)" to address novel methods of fabrication of ferroelectric structures that can be switched with low energy.

KEY DATES

Information session for proposers: **JAN 26 to FEB 18, 2022**

Intel's research staff will be available for a conference call on **JAN 26 10-11 am PST** (conference call details to be shared upon request) to answer questions and provide additional clarifying information regarding the RFP**.** Additional information sessions (up to two more, dates TBD) will be scheduled based on requests.

Proposal Submission Deadline (PIs): **MAR 4, 2022 at 5:00pm PST.**

Proposal Responses from Intel: **APR 4, 2022**

Planned Research Start: **Jun 1, 2022**

OVERVIEW

Intel's University Research & Collaboration Office (URC) invites proposals to explore material/structure solutions and methods of fabrication towards realization of <0.2V switching, energy efficient (EE) ferroelectric FET (FEFET). Low voltage switching FEFET enable low-voltage logic which is necessary for EE and not achieved in existing FEFET technology, which switch at >1.8V. Recent results indicate crystalline perovskite ferroelectrics (FE) can achieve switching <0.2V. These new materials in transistors come with problems of low mobility, depolarization, imprint, & gate leakage. Methods of material deposition, patterning, & etch require fundamental material science research. We expect the center to address and resolve the multiple problems in this field.

PROGRAM SCOPE AND FUNDING

Intel intends to fund a new collaborative, multi-university research center addressing the **3 Research Vectors (RVs)** described in detail below. We suggest that each submitting organization focus their proposal on one research vector (in line with their primary expertise) and identify key contributions that are expected. We envision that PIs might form teams collaborating on related

topics across different research vectors. (This is entirely optional). In this case please still submit separate proposals and indicate that it is a part of a team.

The Center will pursue research towards an extremely-low-voltage FEFET (based on ferroelectric gate oxide and semiconducting oxide channel) switching at <0.2V. Such transistors will enable low voltage swing interconnects to overcome the dominant source of power dissipation and reliability issues in the future as Moore's law continues to scale.

RV1. Deposition of ferroelectrics.

Single crystal perovskite ferroelectrics are needed for low voltage operation. Methods of deposition of crystalline FE (including on vertical surfaces/sidewalls) need to be developed and made amenable to high volume manufacturing (HVM) with lattice matching to the substrate and low defects. Novel metrology to characterize the FE material and its switching dynamics. Learnings from this research are transferable to a variety of magneto-electric devices.

RV2. Interfaces with ferroelectrics.

The interfaces between layers are crucial for the specifications of a transistor. Creation of the oxide channel lattice matched to the FE and having higher carrier mobility. Decrease of interface charge traps and oxygen vacancies is required to eliminate deleterious slow-switching processes and degraded endurance. Removing depolarization by eliminating the FE-semiconductor interface dead layer is crucial for retention. Lattice matched materials for contacts are needed for lowering contact resistance.

RV3. Integration of a complete FEFET.

Methods of patterning and etching perovskite FE materials. Study of the influence of strain and lattice distortion on FE switching. Engineering the metal work function to tune the threshold voltage such that the device operates within low supply voltage, e. g. ~0.2V. Improvement of endurance. Nano-second or faster scale switching speed. Understanding single domain FE vs. multi-domain behavior and its scaling dependence.

Related to all research vectors.

In recent years, most of the ferroelectric research was focused on hafnium oxide related ferroelectrics. In this center we are aiming to explore different materials which inherently have a lower coercive field. Perovskite ferroelectrics are the primary candidates. If you propose a different class of ferroelectrics, a convincing value proposition needs to be provided.

Ferroelectric materials will not be considered in isolation. They need to be compatible and preferably lattice matched with the rest of layers comprising a FEFET. There needs to be a viable process flow including all these layers. Lead containing materials are strongly discouraged.

PROPOSAL FORMAT

Please note that Intel is unable to receive proposals under an obligation of confidentiality. All proposals submitted should therefore include only public information.

Proposals should be 3-6 pages, not including citations or cost volume. Slight preference will be given to proposals that aim at defining a project for one Principal Investigator (PI) for up to three years. Researchers can be part of only one proposal. Each proposal should comprise the following sections:

- **Proposal cover page (max 1 page)**
  - **Organization**
  - **List of PIs and the main contact person**
  - **List one or at most two targeted research vectors**
  - **Executive summary** including intended outcomes. Summarize the key elements of the proposal.
- **High-level motivation, preliminary results, approach, and proposed goals for the research questions (<= 3 pages)**. Briefly describe the motivation for the proposed project, preliminary results, techniques (especially novel ones) that underpin the approach, and the plan of tackling the proposed research questions. Summarize what will have been accomplished after 3 years if all goes according to plan. Be sure to detail the current state-of-the-art for the proposed technology (or nearest related technologies). This section must also include an explicit statement of the Intellectual Property (IP) status for all background IP related to this technology (i.e., are the property rights to this technology protected, and if so, who owns those rights).
- **Statement of work, schedule, milestones, success criteria and deliverables (<=3/4 page).** For each of the goals addressed, outline the 3-year scope of the effort including tasks to be performed, schedule, milestones, deliverables, and success criteria. It is understood that aspects of this research effort may be exploratory in nature and schedules/deliverables reflect intentions rather than a firm commitment.
- **Personnel plan and expertise statement (max. 1/4 page per Researcher).** Include a list of key personnel (at most 6) plus a statement on each person's role and time commitment. For each person, please add a brief bio or web page link and list their 6 most relevant prior publications (within the last 8 years) for the selected research questions.
- **Student plan (<1 page).** In light of Intel's strong commitment to diversity and creating an inclusive environment, please address: (a) your organization's commitment to diversity and inclusion with respect to race, national origin, gender, veterans, individuals with diverse abilities and LGBTQ, (b) a summary of your performance in this area and any initiatives you are pursuing, and (c) the diverse team you propose for this project, and information about the PhD students and postdocs you envision to assign to this project (if known). Outline the approach and plan whereby PhD students will be recruited and incorporated into the team, and any plans for encouraging/supporting those students in collaborations with Intel (e.g., availability for Internships should a mutually interesting opportunity arise). If the PIs have

a pre-existing relationship and history of student hiring by Intel please discuss issues/plans/ideas to continue or strengthen that connection.

- **Diversity and Inclusion (<1 page).** In light of Intel's strong commitment to diversity and creating an inclusive environment, please address: (a) your organization's commitment to diversity and inclusion with respect to race, national origin, gender, veterans, individuals with diverse abilities and LGBTQ, and (b) a summary of your performance in this area and any initiatives you are pursuing.
- **Prior Intel Collaborations (max 1/3 page per project).** If you collaborated with Intel in the past, please list the project/institute, the year, and the main contact(s) at Intel. Furthermore, add a short abstract outlining the scope.
- **Past Successful Technology Transfers (<=1 page).** Evidence of past successful industry collaborations and technology transfers. Examples include startups, products, and other evidence of tangible business impact of the involved academics.
- **Budget and Financials (1/3 page).** Typical grants are USD $150K per year for three years. We plan to work under an Open Intellectual Property model (results are published, code is open sourced). Our goal is to maximize the available research ideas for our fixed amount of total funding. Universities may propose how to achieve this. Please also indicate how many researchers (FTE) can contribute their research for the proposed funding.
- **IP-compatible funds amplification (no limit).** If the team can obtain funding for related work from other sources (including the University) and the sponsor commits to follow a public dedication approach for that project or provide Intel with non-exclusive, royalty-free **research and commercial** licenses to any IP, the team may list funding that would be considered to amplify the proposed project.
- **Citations (unlimited).**
- **Cost volume (unlimited)**. Cost proposal in Excel or another format as appropriate.

EVALUATION CRITERIA

In order of importance, the evaluation criteria for this solicitation are as follows:

1. **Potential contribution and relevance to Intel and the broader industry**: The proposed research should directly support a technology solution that addresses the RVs outlined above, leading to technological advances with the potential for ongoing technology transfer in collaboration with Intel and the broader industry.

2. **Technical innovation**: Proposed solutions of interest should clearly push the boundaries of technical innovation and advancement. Research that is not of interest in this program include incremental advancements to state-of-the-art and current design practices. Feasibility of new algorithms/techniques should be demonstrated through SW/HW implementations.

3. **Clarity of overall objectives, intermediate milestones, and success criteria**: The proposed Research Plan should clearly convey that the PIs have the knowledge and capability to achieve the stated research goals. It is understood that any research program will have

uncertainties and unanswered questions at the proposal stage, but a clear path forward in key challenge areas must be identified and justified. Teams are expected to demonstrate progress toward project goals at quarterly milestones and monthly project status updates. As detailed in "Program Scope and Funding" section, the proposal should explicitly point out which RV is being addressed, the synergy among them if more than one RV, the plan and milestones towards building research prototypes, plan for ongoing technology transfers, and the anticipated proof of concept outcome. Strength of project management will also be considered.

4. **Qualification of participating researchers:** The extent to which expertise and prior experience bear on the problem at hand. Please elaborate on track records of building research prototypes (e.g., open-source research code/collaterals on GitHub) and resulting publications from past relevant projects.

5. **Cost effectiveness and cost realism**: The extent to which the proposed work is both feasible and impactful within the proposed resource levels will be examined.

6. **Potential for co-funding:** Opportunity for closely synergistic matching grants and co-funding with other funding entities, such as SRC, NSF, DARPA, NSERC, etc. will be given significant consideration.

7. **Potential for broader impact:** As an industry leader, Intel pushes the boundaries of technology to make amazing experiences possible for every person on earth. From powering the latest devices and the cloud you depend on to driving policy, diversity, sustainability, and education, we create value for our stockholders, customers, and society. Intel expects the academic community to be strong partners in making Intel successful through support of Intel's goals and commitments to diversity, sustainability, and education. Intel supports the advancement of computing education and diverse participation in STEM. Significant consideration will be given to proposals in which the outcome of the research can influence the development of new curriculum initiatives impacting undergraduate or graduate education at the respective universities (e.g., exposure to latest industry technologies/tools in classroom setting). Proposals are encouraged to elaborate on how the proposed work is anticipated to impact student education on campus and/or the broader academic community.

PI MEETINGS AND COLLABORATION STRUCTURE

Intel will be deeply engaged with the center and will assign partner technologists/collaborators across RVs to interact with the academic community to produce a stream of innovation proof-points, publications, demonstrations, and technology transfers into Intel and the broader industry throughout the duration of the program. We aim for the interaction to be bi-directional where Intel collaborators are part of the research team. Not only will they provide research feedback, but they

will also actively contribute and co-develop the research to amplify the center outcome and enable continuous technology transfers into Intel and the broader industry.

It is expected the PI and student researchers will collaborate on a daily or weekly basis. Monthly PI, student and Intel collaborator meetings will be used to review research results, present significant updates, and provide feedback.

Semi-annual face-to-face or virtual meetings will be held to facilitate center-wide information exchange, review, and discussion of research. Researchers should anticipate one annual face-to-face meeting to be held at an Intel site in the US or Europe and one annual face-to-face meeting to be held at a university associated with this center. Associated travel costs for two annual meetings should be considered and included in the proposed budget. In the event unexpected travel restrictions prohibit a face-to-face meeting, a virtual meeting will be held.

To aid in collaboration across projects within the center and communication of research findings to the public, it is anticipated that a center website will be established, hosted, and maintained and Intel request the right to host the associated website link on their respective university program websites.

Intel will offer free access to Intel's Academic Compute Environment, a resource for academia researchers in the center to exercise their workloads on Intel's latest hardware.

For those researchers who are already funded and seek collaboration opportunities with Intel and other researchers in the area of this RFP, please let us know. One option is to participate in center activities (e.g., seminars, workshops, and hardware access) without Intel funding.

ELIGIBILITY

This RFP is open only to academic researchers and institutions that have been specifically invited to participate in the proposal process. However, invitees may freely select additional academic collaborators. Any questions regarding eligibility should be directed to Sowmya Venkataramani (contact info below).

INTELLECTUAL PROPERTY

This solicitation affords proposers the choice of submitting complete program proposals for the award of a grant, a Sponsored Research Agreement, or other agreement as appropriate. Intel reserves the right to negotiate the final choice of agreement.

INTEL TEAM CONTACT INFO

The following individuals from Intel are actively involved with the creation of this center:
Sowmya Venkataramani Sowmya.venkataramani@intel.com

Dmitri Nikonov Dmitri.e.nikonov@intel.com
Please send proposal submissions and related inquiries to the above contacts; and please include “RFP COFEEE” in the Subject of your email.

FAQ

1. What is the typical grant and proposal team size?
   Proposals generally request grants of approximately $150K per year. This would typically support 1 or 2 graduate students advised by 1 or 2 PIs. We expect to receive roughly 20 proposals and award 3-4 grants.

2. What is the envisaged project duration?
   Three years (there is a renewal process each year, but proposals should outline all 3 years).

3. Do you consider proposals primarily concentrating on theory/simulations?
   Proposals with theory or simulation parts are encouraged, but the main focus of the proposal should be on fabrication and characterization of ferroelectric structures.

4. Can you specify which researchers have been invited to this RFP?
   We don’t release the names of invited researchers. Keep in mind that if you are seeking to partner with a specific academic PI, your partners do not have to be invited; you can choose to partner with any PI and share the RFP with them.

5. Are we encouraged to seek co-funding opportunities?
   While co-funding is not required, a proposal with co-funding or matching funding would be a strong plus.