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Halo Industries - EPIC5 Research Concept - Light-based SiC wafer manufacture

Additional submitted attachment is included below.

Electric Program Investment Charge 2026–2030 (EPIC 5) Research Concept Proposal Form

The California Energy Commission (CEC) is currently soliciting research concept ideas and other input for the Electric Program Investment Charge 2026–2030 (EPIC 5) Investment Plan. For those who would like to submit an idea for consideration, please complete this form and submit it to the CEC by **August 8, 2025**. More information about EPIC 5 is available below.

To submit the form, please visit the e-commenting link: https://efiling.energy.ca.gov/EComment/ECommentSelectProceeding.aspx and select the Docket **25-EPIC-01**. Enter your contact information and then use the "choose file" button at the bottom of the page to upload and submit the completed form. Thank you in advance for your input.

1. Please provide the name, email, and phone number of the best person to contact should the CEC have additional questions regarding the research concept:

   J Provine
   Head of Technology Partnerships and Government Programs
   jprovine@halo-industries.com
   650-644-9403

2. Please provide the name of the contact person's organization or affiliation:

   Halo Industries

3. Please provide a brief description of the proposed concept that you would like the CEC to consider as part of the EPIC 5 Investment Plan. What is the purpose of the concept, and what would it seek to do? Why are EPIC funds needed to support the concept?

   Advanced power electronics plays a crucial role in multiple facets of the clean energy ecosystem, from efficient electric vehicles (EVs) to better renewable-to-grid conversion to modern IT infrastructure including data centers. Silicon carbide (SiC) is a semiconducting material at the heart of the highest performance power electronics. The manufacture of SiC substrates on which SiC power devices such as transistors can be fabricated, requires significant scaling to meet demand.

We propose a project to accelerate the manufacture of SiC substrates within CA at Halo Industries based on our laser manufacturing core capabilities, which further will provide economic and environmental improvements over today's state of the art material manufacturing.

The manufacture of SiC substrates is a multi-step process that begins with separating individual wafers (or substrates) from a crystalline block of SiC material (or ingot). These separated wafers must be further processed to be a ready for chip manufacture substrate based on post-separation grind, polish, and edge bevel of the wafers. In the past all of these steps were performed mechanically, generated enormous waste, consumed copious amounts of process water and mechanical abrasive material, and consumed significant power. With the support of past EPIC funding Halo has developed and brought to market a laser-based wafer separation process which is gaining rapid adoption in industry due to improved material performance, reduced cost, and reduced environmental impact. The company is turning an R&D focus toward edge bevel, wafer grind, and wafer polish by all light-based manufacture as well to continue to modernize the SiC substrate manufacture.

Developmental work to bring Halo's promising early stage results in grind and bevel to market. Additionally, exploratory research on SiC wafer polish will follow directly from the work on grinding to meet the demanding specifications of the microelectronic industry.

More generally, while the earliest use case market has been found in laser-based manufacture of SiC substrates, Halo is building platform technology understanding to bring light-based manufacture to a much wider set of essential emerging materials in the semiconductor industry.

4. In accordance with Senate Bill 96[i], please describe how the proposed concept will "lead to technological advancement and breakthroughs to overcome barriers that prevent the achievement of the state's statutory energy goals." For example, what technical and/or market barriers or customer pain points would the proposed concept address that would lead to increased adoption of clean energy technology or innovation? Where possible, please provide specific cost and performance targets that need to be met for increased industry and consumer acceptance. For scientific analysis and tools, provide more information on what data and information gaps the proposed concept would help fill, and which specific parties or end users would benefit from the results, and for what purpose(s)?

SiC is utilized in traction converters with battery EVs and provides greater efficiency (which translates to greater range) compared to power electronics based on Si or even GaN. This has been a great enabler in EV performance improvement and adoption. For a completed SiC microelectronic device (such as a power transistor) over 50% of the final device cost is derived from the expense of the SiC starting substrate. A great deal of that cost comes from the expense of wasted material and low yield associated with mechanical processing of the material, which can be significantly reduced through laser-based processing. The success of this project will help to drive costs of power electronics in EVs down and thus allow more affordable, high efficiency vehicles to the enter the market.

Similar knock on effects will be felt in other areas of the clean economy that benefit from improved high voltage electronics. In particular better converters for renewable-to-grid transformers and power handling for data centers. New data center construction is looking at both SiC-based electronics for the power conversion from grid to building and within individual server racks, which will be able to operate at higher speed and efficiency by a move to higher voltage SiC power electronics.

All of these markets are contributing to CA's vision for a cleaner economy without loss of viability and performance, and they will drive an increased demand for SiC wafer manufacture. Thus making SiC wafer manufacture as environmentally responsible as possible is necessary for the most beneficial full life cycle consideration of power electronics possible.

5. Please describe the anticipated outcomes if this research concept is successful, either fully or partially. For example, to what extent would the research reduce technology or ratepayer costs and/or increase performance to improve the overall value proposition of the technology? What is the potential of the innovation at scale? How will the innovation lead to ratepayer benefits in alignment with EPIC's guiding principles to improve safety,[ii] reliability,[iii] affordability,[iv] environmental sustainability,[v] and equity?[vi]

   The proposed project brings value to CA's citizens in a number of interconnected ways:
   - Enabling higher efficiency (longer range) EVs for wider adoption
   - Lowering the cost of EV for wider adoption
   - Improving efficiency for renewable-to-grid conversion
   - Improving efficiency for data center grid-to-center power handling
   - Improving efficiency and speed of data processing within data centers through high voltage server rack power

- Reducing environmental impact of SiC substrate manufacture by reducing power consumption, drastically reducing water usage and mechanical consumables, and improved yield of final wafer material
- Developing a strong domestic and within CA supply of these critical semiconductor materials

6. Describe what quantitative or qualitative metrics or indicators would be used to evaluate the impacts of the proposed research concept.

   Halo's laser-based approach to SiC wafer separation has already shown >90% reduction in material loss compared to the wire-saw based separation technology it is preplacing. Similar benefits will be seen in replacing mechanical grinding of the wafers to achieve smooth, uniform material needed for device fabrication. The grinding process consumes massive amounts of process water (10s of L per wafer) which can be completely eliminated with laser-based ablative removal. Additionally, the extreme hardness of SiC material causes the solid abrasive grinding pads to be consumed rapidly, generating significant expensive solid waste. A 100% solid consumable waste target is the goal along with 0 L/wafer waste water and 90% reduction in cooling water requirements compared to mechanical processing.

   Similar mechanical wear makes the wafer edge beveling process (which reduces cracking failure in SiC wafers) inconsistent and highly consumptive of solid material abrasives, which can be completely eliminated through laser processing.

   Finally, if light-based polishing of SiC material can be achieved, it will remove one of the most environmentally damaging processes in wafer manufacture because of the extensive mechanical and caustic chemical waste streams that are generated in polishing. Most of this material is currently landfilled. Further, polish is again a source of significant water use with limited to no opportunity for recycling.

7. Please provide references to any information provided in the form that supports the research concept's merits. This can include references to cost targets, technical potential, market barriers, equity benefits, etc.

   The following scientific publications describe early technology explorations of light-based SiC grind techniques that Halo will expand upon and make market ready:

   - https://www.sciencedirect.com/science/article/pii/S2238785424011657

- https://www.mdpi.com/2072-666X/16/1/62

The following websites make clear the significant improvements necessary in the environmental impact of integrated circuits and semiconductor wafer manufacturing:

- https://www.imec-int.com/en/semiconductor-education-and-workforce-development/microchips/how-are-microchips-made/environmental
- https://www.semiconductorreview.com/news/environmental-sustainability-in-silicon-wafer-production-nwid-743.html

8. The EPIC 5 Investment Plan must support at least one of five Strategic Goals:[vii]
    a. Transportation Electrification
    b. Distributed Energy Resource Integration
    c. Building Decarbonization
    d. Achieving 100 Percent Net-Zero Carbon Emissions and the Coordinated Role of Gas
    e. Climate Adaptation

   Please describe in as much detail as possible how your proposed concept would support these goals.

   The role in SiC power electronics in extending range and improving efficiency in EVs has been well established. There are more gains to come in this area, particularly through the gains Halo Industries will be able to bring through this project. This directly addresses Strategic Goal a) Transportation Electrication for both within vehicle power electronics and charging infrastructure electronics.

   Further Strategic Goal b) Distributed Energy Resource Integration will benefit from widely available SiC power electronics. This will come from the unique capabilities of SiC transistors to handle high-voltage electronics needs for renewable-to-grid power conversion. SiC enabled electronics can be significantly smaller and more efficient than other materials when operating at high voltages.

About EPIC

The CEC is one of four EPIC administrators, funding research, development, and demonstrations of clean energy technologies and approaches that will benefit electricity ratepayers of California's three largest investor-owned electric utilities.

EPIC is funded by California utility customers under the auspices of the California Public Utilities Commission.

To learn more about EPIC, visit: https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program

EPIC 5 documents and event notices will be posted to: https://www.energy.ca.gov/proceeding/electric-program-investment-charge-2026-2030-investment-plan-epic-5

Subscribe to the EPIC mailing list to stay informed about future opportunities to inform the development of EPIC 5: https://public.govdelivery.com/accounts/CNRA/signup/31897

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i See section (a) (1) of Public Resources Code 25711.5 at: https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=PRC&sectionNum=25711.5.

ii EPIC innovations should improve the safety of operation of California's electric system in the face of climate change, wildfire, and emerging challenges.

iii EPIC innovations should increase the reliability of California's electric system while continuing to decarbonize California's electric power supply.

iv EPIC innovations should fund electric sector technologies and approaches that lower California electric rates and ratepayer costs and help enable the equitable adoption of clean energy technologies.

v EPIC innovations should continue to reduce greenhouse house gas emissions, criteria pollutant emissions, and the overall environmental impacts of California's electric system, including land and water use.

vi EPIC innovations should increasingly support, benefit, and engage disadvantaged vulnerable California communities (DVC). (D.20-08-046, Ordering Paragraph 1.) DVCs consist of communities in the 25 percent highest scoring census tracts according to the most recent version of the California Communities Environmental Health Screening Tool (CalEnviroScreen), as well as all California tribal lands, census tracts with median household incomes less than 60 percent of state median income, and census tracts that score in the highest 5 percent of Pollution Burden within CalEnviroScreen, but do not receive an overall CalEnviroScreen score due to unreliable public health and socioeconomic data.

vii In 2024 the CPUC adopted five Strategic Goals to guide development of the EPIC 5 Investment Plan. A description of the goals can be seen in Appendix A of CPUC Decision 24-03-007 available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M527/K228/527228647.PDF