

## Cooperative Research and Development Agreement (CRADA) Final Report

**Report Date:**

8/31/21

*In accordance with Requirements set forth in the terms of the CRADA, this document is the CRADA Final Report, including a list of Subject Inventions. It is to be forwarded to the DOE Office of Scientific and Technical Information upon completion or termination of the CRADA, as part of the commitment to the public to demonstrate results of federally funded research.*

**Parties to the Agreement: ActiveMEMS LLC and Lawrence Berkeley National Lab**

**CRADA number: FP00007506**

**CRADA Title: High-Performance Piezoelectric MEMS Manufacturing & Application on Micro Power Generators**

**Responsible Technical Contact at Berkeley Lab: Thomas Kirchstetter**

**Name and Email Address of POC at Partner Company(ies):**

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**Sponsoring DOE Program Office(s):**

*EERE AMO (funded via DARPA)*

**LBNL Report Number:**

*[PI to complete]*

**OSTI Number:**

*[SPO to complete]*

**Joint Work Statement Funding Table showing DOE funding commitment:**

DOE Funding to LBNL	\$100,000
Participant Funding to LBNL	\$0
Participant In-Kind Contribution Value	\$100,000
Total of all Contributions	\$200,000

**Provide a list of publications, conference papers, or other public releases of results, developed under this CRADA:**

*(Publications must include journal name, volume, issue, Digital Object Identifier)*

*None*

**Provide a detailed list of all subject inventions, to include patent applications, copyrights, and trademarks:**

*(Patents and patent applications are to include the title and inventor(s) names. When copyright is asserted, the Government license should be included on the cover page of the Final Report)*

None

**Executive Summary of CRADA Work:**

This project aimed to develop and characterize a micro-fabrication technology for wafer-scale heterogeneous integration of bulk piezoelectric materials on silicon substrates that could enable manufacturing of high-performance micro transducers. Typical technical challenges for piezoelectric microfabrication technologies are high-temperature processing, non-uniform film quality, and low process repeatability, which will be addressed during this project. Progress was made on preliminary research towards development of a technology platform that will enable a new micro-fabrication process to provide the highest electromechanical coupling among any other thin/thick-film deposition methods available today. This work has tested and characterized samples that we hope will further our goal of refining and enabling existing micro transducers to achieve unprecedentedly high performance. This project focused solely on the characterization of the proposed microfabrication process technology, and it did not consist of design or manufacturing of new transducers, such as sensors, actuators or energy harvesters based on this fabrication process. Future work will be aimed at the research and development of process steps specifically to enable integration of on-chip electronics with piezoelectric materials.

**Summary of Research Results:**

The project established benchmark requirements to standardize and compare the fabrication technology and its key differentiators against commercially available microfabrication technologies.

Work was conducted to identify target market, customer value proposition, and technical performance goals for the fabrication process.

Experiments explored the technical limits to reliably integrate high-quality piezoelectric thin films on silicon from bulk materials.

We characterized piezoelectric, mechanical, and electrical material properties of the fabricated thin films integrated on silicon.

We tested laboratory samples and compared the obtained results to the initially determined technical performance goals.

## APPENDIX A (Reference Only)

*This appendix has been developed by DOE to assist DOE Labs in drafting the **Executive Summary** and **Summary of Research Results** sections of the CRADA Final Report.*

### **Executive Summary of CRADA Work:**

*Include a discussion of 1) how the research adds to the understanding of the area investigated; 2) the technical -effectiveness of the materials, methods or techniques investigated or demonstrated, and their economic feasibility, if known; and 3) how the project is otherwise of benefit to the public. The discussion should be a minimum of one paragraph and written in terms understandable by an educated layman.*

### **Summary of Research Results:**

- *INCLUDE, IF APPLICABLE: "This product contains Protected CRADA Information, which was produced on [DATE] under CRADA No. [##-####] and is not to be further disclosed for a period of [ up to and not to exceed] five (5) years from the date it was produced except as expressly provided for in the CRADA."*
- *Summarize project activities for the entire period of performance, including original hypotheses, approaches used, problems encountered, any departure from planned methodology, and an assessment of their impact on the project results. Incorporate technical data, e.g. facts, figures, analyses, and assumptions used during the life of the project to support the technical conclusions of the work. It is acceptable to incorporate the technical data by reference to other publicly available sources, such as a publications or other reports, but not websites. Provide a comparison of the actual accomplishments with the goals and objectives of the project. Where possible, the summary should cover each task listed in the Statement of Work (SOW) and should note any deviations from the project plan, or lack of technical data.*
- *Identify products, potential applications, and technology transfer activities developed under the CRADA, including those completed and anticipated at the time of the report. These include, but are not limited to: 1) networks or collaborations fostered; 2) technologies/techniques/methodologies; 3) other products that reflect the results of the project, such as commercial products, internet sites, data or databases, physical collections, audio or video, software, models, educational aid or curricula, and instruments or equipment.*

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