



Broad Agency Announcement

Material Synthesis Technologies for Universal and Diverse
Integration Opportunities (M-STUDIO) Program

Microsystems Technology Office

HR001124S0019

March 7, 2024

This publication constitutes a Broad Agency Announcement (BAA) as contemplated in Federal Acquisition Regulation (FAR) 6.102(d)(2) and 35.016 and 2 CFR § 200.203. Any resultant award negotiations will follow all pertinent law and regulation, and any negotiations and/or awards for procurement contracts will use procedures under FAR 15.4, Contract Pricing, as specified in the BAA.

Overview Information:

- **Federal Agency Name:** Defense Advanced Research Projects Agency (DARPA),
Microsystems Technology Office
- **Funding Opportunity Title:** Material Synthesis Technologies for Universal and Diverse
Integration Opportunities (M-STUDIO)
 - This BAA solicits research proposals which address both Phase 1 and Phase 2 of
the M-STUDIO program.
- **Announcement type:**
 - Initial announcement
- **Funding Opportunity Number:** HR001124S0019
- **NAICS Code:** 541713
- **Assistance Listing Number:** 12.910 Research and Technology Development
- **Important Dates (All times listed herein are Eastern Time):**
 - Posting Date: **March 07, 2024**
 - Proposers Day: **March 08, 2024, 10:00 AM** Eastern Time
 - Abstract Due Date and Time: **March 21, 2024, 01:00 PM** Eastern Time
 - Question Submittal Closed: **April 26, 2024, 01:00 PM** Eastern Time
 - Proposal Due Date and Time: **May 06, 2024, 01:00 PM** Eastern Time
- **Anticipated Individual Awards:** Multiple awards are anticipated. The level of funding
for individual awards made under this solicitation has not been predetermined and will
depend on the scope and quality of the proposals received, as well as the availability of
funds.
- **Types of instruments that may be awarded:**
 - Procurement contract, cooperative agreement, or Other Transaction agreements.
- **Agency Points of Contact:**
 - Technical Point of Contact: Dr. Jason Woo, Program Manager
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Section I: Funding Opportunity Description

The Defense Advanced Research Projects Agency (DARPA) is soliciting innovative proposals in the following technical areas: development of nano-scale heterogeneous material synthesis on lattice mismatched substrates to realize defect-free, multi-layer heterogeneous junctions with atomically sharp surface/interface and atomically abrupt compositional transition. Proposed research should investigate innovative approaches that enable revolutionary advances in science, devices, or systems. Specifically excluded is research that primarily results in evolutionary improvements to the existing state of practice.

A. Background

Heterogeneous integration (HI) has been actively pursued for the Department of Defense (DoD) and commercial applications in the past few years. Previous DARPA HI programs at the dielet, circuit, and component levels using 3D layer stacking and monolithic heterogeneous material synthesis have demonstrated revolutionary circuits and systems capabilities. However, state-of-the-art (SOA) heterogeneous material synthesis and layer transfer have reached a size/thickness limit of 1 μm , preventing heterogeneous integration, especially monolithically, at nanometer scales.

M-STUDIO will realize a universal heterogeneous integration technology, compatible with leading edge and future advanced-node semiconductor manufacturing processes, via atomic-precision nano-scale multi-layer material synthesis. Specifically, the program goals are:

- Material synthesis techniques with one heterogeneous interface: compound semiconductor layer on lattice mismatched substrate with a thickness ≤ 10 nm and with $< 10^3$ / cm^2 defect density
- Growth scalability with multiple heterogeneous interfaces: multiple ≤ 10 nm heterogeneous semiconductor layers on a lattice mismatched substrate with atomically sharp transitions and with $< 10^3$ / cm^2 defect density

B. Program Description

State-of-the-art heterogeneous integration at the highest integration level is done by realizing components fabricated in micron-scale heterogeneous materials that are synthesized monolithically on a lattice mismatched substrate, mainly silicon. To realize such materials in nanometer dimensions, two key technical challenges (TCs) must be overcome:

- TC1: Achieving nanometer-scale, defect-free semiconductor materials synthesized on lattice mismatched substrates.

The SOA heterogeneous integration research has realized low defect compound semiconductors grown on silicon substrate with thick (i.e., greater than 1.0 μm) defect mitigation buffer layers. Alternatively, precision material transfer techniques have been demonstrated, which require a base layer thicker than a few microns to provide adequate mechanical support. Due to their size and thickness, such techniques are not compatible with nano-dimension device level monolithic integration.

- TC2: Realizing multiple heterogeneous nanometer-scale thick material layers with atomic precision.

Due to the atom diffusive movement during the high temperature growth, current multilayer compound semiconductor synthesis has a heterogenous interface sharpness on the order of one decade of atomic composition transition per 5 nm thickness, which is not sufficient for nano-devices requiring 10 nm heterogeneous semiconductor multi-layer junctions with atomic precision.

To overcome the above-mentioned technical challenges, M-STUDIO seeks to develop a universal defect-free heterogeneous integration methodology, informed by emerging nano-scale material growth with surface free-energy driven defect termination and non-thermal-equilibrium synthesis, to achieve defect-free multi-layer heterogeneous materials with nanometer dimensions and atomically sharp interfaces. Potential approaches include nanometer scale synthesis with aspect defect trapping and energetic assisted selective material growth. All novel material synthesis techniques compatible with leading edge and future advanced node semiconductor manufacturing processes that can result in achieving M-STUDIO goals will be considered.

C. Program Structure

The M-STUDIO program will consist of two 18-month program phases. It is expected that fewer performers will be selected to participate in Phase 2 option of the program. Options may be exercised, at the Government’s sole discretion, based on technical progress measured against the metrics and milestones defined in the BAA and funding availability. The main objectives of the two phases are:

- Phase 1: Demonstrate defect free single sub-10 nm compound semiconductor material synthesized on lattice mismatched substrates.
- Phase 2: Realize multiple heterogeneous sub-10 nm thick material layers with atomic precision on lattice mismatched substrates.

The program metrics for both phases are shown below:

Program Metrics:

TC	Metrics ¹	Phase 1 (18 months) ² <i>Defect free sub-10 nm total thickness heterogeneous material synthesis demonstration</i>	Phase 2 (18 months) ³ <i>Multiple heterogeneous sub-10 nm thick layer material with atomic precision on lattice mismatched substrates realization</i>
TC1	Growth film thickness	10 nm	10 nm
	Growth film flatness	1 nm (RMS)	1 nm (RMS)
	Defect density	10 ³ /cm ²	10 ³ /cm ²
	Electrical carrier mobility	≥ 95% of SOA ⁴	≥ 95% of SOA ⁴
TC2	Superlattice layer thickness	N/A	10 nm per layers
	Superlattice layer number	N/A	10 layers
	Atomic composition sharpness	N/A	1 decade per 2 nm
	Electrical carrier mobility	≥ 95% of SOA ⁴	≥ 95% of SOA ⁴

1. *Proposer defines heterogeneous materials on silicon for technology development*
2. *Proposer defines two-terminal device measurement to assess the electrical quality of the heterogenous interface*
3. *Proposer defines three-terminal device measurement to assess the electrical quality of the heterogenous interface*

4. *SOA carrier mobilities = channel carrier mobilities in the same material measured in SOA transistors such as high mobility channel transistors (HEMT), Insulated Gate Field-effect Transistor (IGFET), or metal semiconductor transistor (MESFET)*

An M-STUDIO proposal is expected to define the proposed heterogeneous materials to be grown on lattice mismatched silicon substrate, compatible with leading and future advanced node complementary metal-oxide-semiconductor (CMOS). The proposal should also provide in-depth technical discussion and rationale about how the proposed technical approaches will overcome both M-STUDIO technical challenges and explain how each program metric will be achieved. In addition, performers should describe and appropriately document in the proposal the procedures/plans to comply with the CUI requirements outlined in Attachment F (please see “10. Statement of Work” in Attachment B).

D. Schedule/Milestones

M-STUDIO will be a 36-month, two-phase program with a period of performance estimated to start in October 2024. A post-award program kickoff meeting will be held for performers to present the technical approaches, discuss technical and programmatic items of concern, and interact with the Government team and other program performers. The end of Phase 1 represents a major technical milestone in the program. End-of-phase review meetings will be scheduled approximately six weeks before the end of Phase 1 and approximately six weeks before the end of Phase 2. These meetings will be used to assess technical progress toward the metrics during the entire program phase. Technical progress towards the metrics of the program is a significant deciding factor for continuation into the subsequent phase and will be monitored through monthly teleconference calls and occasional site visits by the DARPA program manager and other members of the Government team.

E. Deliverables

1. Program Review Meetings

Technical review meetings with the M-STUDIO Program Manager are anticipated to be held every month as a teleconference and every three months in person. The review meeting deliverable will be a technical slide presentation. Additional program reviews with all performers are anticipated to be held in person at the beginning of each program phase and may replace the technical review meetings. An end-of-phase in person meeting with each individual performer approximately six weeks before the end of each phase is also anticipated. Prior to each end-of-phase meeting, performers will provide to the Government a written report covering, a) technical results and b) charts with explanations of how well the component(s)/system(s) meets, exceeds, or falls short of specified program metrics (as described in this BAA). Templates may be provided for the technical review teleconferences, and reports will include technical updates with simulated and measured results to demonstrate progress toward the program metrics, as well as an up-to-date financial spend plan.

2. Monthly Financial Reports

The financial report shall describe resources expended, resources available, any deviation from planned expenditures, and any potential issues requiring the attention of the Government team. This report should be provided within 10 days after the end of each month.

3. Final Report

After the end of each phase, a final report shall summarize the effort in a comprehensive text document.

F. Government Furnished Equipment/Property/Information

No Government furnished equipment, property, or information is anticipated to be provided in this program.

G. Intellectual Property

It is expected that the data/software developed under M-STUDIO will have the following minimum data rights:

- Government Purpose Rights.

Section II: Evaluation Criteria

Proposals will be evaluated using the following criteria listed in *descending order of importance*: Overall Scientific and Technical Merit, Potential Contribution and Relevance to the DARPA Mission, and Cost Realism.

- **Overall Scientific and Technical Merit:** The proposed technical approach is innovative, feasible, achievable, and complete. The proposed technical team has the expertise and experience to accomplish the proposed tasks. Task descriptions and associated technical elements provided are complete and in a logical sequence with all proposed deliverables clearly defined such that a final outcome that achieves the goal can be expected as a result of award. The proposal identifies major technical risks and planned mitigation efforts are clearly defined and feasible.
- **Potential Contribution and Relevance to the DARPA Mission:**
The potential contributions of the proposed effort bolster the national security technology base and support DARPA's mission to make pivotal early technology investments that create or prevent technological surprise. The proposed intellectual property restrictions (if any) will not significantly impact the Government's ability to transition the technology.
- **Cost Realism:** The proposed costs are realistic for the technical and management approach and accurately reflect the technical goals and objectives of the solicitation. The proposed costs are consistent with the proposer's Statement of Work (or Technical Milestones) and reflect a sufficient understanding of the costs and level of effort needed to successfully accomplish the proposed technical approach. The costs for the prime proposer and proposed subawardees are substantiated by the details provided in the proposal (e.g., the type and number of labor hours proposed per task, the types and quantities of materials, equipment and fabrication costs, travel and any other applicable costs and the basis for the estimates). It is expected that the effort will leverage all available relevant prior research in order to obtain the maximum benefit from the available funding. DARPA recognizes that undue emphasis on cost may motivate proposers to offer low-risk ideas with minimum uncertainty and to staff the effort with junior personnel in order to be in a more competitive posture. DARPA discourages such cost strategies.

Unless otherwise specified in this announcement, for additional information on how DARPA reviews and evaluates proposals through the Scientific Review Process, please visit: [Proposer Instructions and General Terms and Conditions](#)

Section III: Submission Information

- This announcement allows for multiple award instrument types to include Procurement Contracts, Cooperative Agreements, and Other Transactions for Prototypes. Some award instrument types have specific cost-sharing requirements. The following websites are incorporated by reference and contain additional information regarding overall proposer instructions, general terms and conditions, and each specific award instrument type.
 - **Proposer Instructions and General Terms and Conditions:** [Proposer Instructions and General Terms and Conditions](#)
 - **Procurement Contracts:** [Proposer Instructions: Procurement Contracts](#)
 - **Assistance (Cooperative Agreements):** [Proposer Instructions: Grants/Cooperative Agreements](#)
 - **Other Transaction agreements:** [Proposer Instructions: Other Transactions](#)
- This announcement contains an abstract phase. Abstracts are due on March 21, 2024, at 1:00 PM Eastern Time as stated in the Overview section. Abstracts are strongly encouraged but not required. Instructions for abstract submission are contained within **Attachments A**.
- Full proposals are due on May 6, 2024, at 1:00 PM Eastern Time as stated in the Overview section. **Attachments B, C, D, and E** constitute a full proposal submission. Please visit [Proposer Instructions and General Terms and Conditions](#) for information regarding all approved submission methods.
- **BAA Attachments:**
 - **Attachment A:** Abstract Instructions and Template
 - **Attachment B:** Proposal Instructions and Volume I Template - Technical and Management
 - **Attachment C:** Proposal Instructions and Volume II Template - Cost
 - **Attachment D:** Proposal Summary Slide Template
 - **Attachment E:** DARPA Standard Cost Proposal Spreadsheet
 - **Attachment F:** General MTO Controlled Unclassified Information Guide (CUIG)
 - **Attachment G:** Other Transaction Certification Form Template

Section IV: Special Considerations

- This announcement, stated attachments, and websites incorporated by reference constitutes the entire solicitation. If there is any discrepancy, the Broad Agency Announcement would take precedence.
- All responsible sources capable of satisfying the Government's needs, including both U.S. and non-U.S. sources, may submit a proposal that shall be considered by DARPA. Historically Black Colleges and Universities, Small Businesses, Small Disadvantaged Businesses and Minority Institutions are encouraged to submit proposals and join others in submitting proposals; however, no portion of this announcement will be set aside for these organizations' participation due to the impracticality of reserving discrete or severable areas of this research for exclusive competition among these entities. Non-U.S. organizations and/or individuals may participate to the extent that such participants comply with any necessary nondisclosure agreements, security regulations, export control laws, and other governing statutes applicable under the circumstances.
- As of the time of publication of this solicitation, all proposal submissions are anticipated to be unclassified.
- Federally Funded Research and Development Corporations (FFRDCs) and Government entities interested in participating in the M-STUDIO program or proposing to this BAA should first contact the Technical Point of Contact (POC) and Contracting Officer listed in Part I prior to the Abstract due date listed in Part I to discuss eligibility. Complete information regarding eligibility can be found at [Proposer Instructions and General Terms and Conditions](#).
- As of the date of publication of this solicitation, the Government expects that program goals as described herein may be met by proposed efforts for fundamental research and non-fundamental research. Some proposed research may present a high likelihood of disclosing performance characteristics of military systems or manufacturing technologies that are unique and critical to defense. Based on the anticipated type of proposer (e.g., university or industry) and the nature of the solicited work, the Government expects that some awards will include restrictions on the resultant research that will require the awardee to seek DARPA permission before publishing any information or results relative to the program. For additional information on fundamental research, please visit [Proposer Instructions and General Terms and Conditions](#).

Proposers should indicate in their proposal whether they believe the scope of the research included in their proposal is fundamental or not. While proposers should clearly explain the intended results of their research, the Government shall have sole discretion to determine whether the proposed research shall be considered fundamental and to select the award instrument type. Appropriate language will be included in resultant awards for non-fundamental research to prescribe publication requirements and other restrictions, as appropriate. This language can be found at [Proposer Instructions and General Terms and Conditions](#).

For certain research projects, it may be possible that although the research to be performed by a potential awardee is non-fundamental research, its proposed subawardee's effort may be fundamental research. It is also possible that the research performed by a potential awardee is fundamental research while its proposed subawardee's effort may be non-fundamental research. In all cases, it is the potential awardee's responsibility to explain in its proposal which proposed efforts are fundamental research and why the proposed efforts should be considered fundamental research.

- DARPA's Fundamental Research Risk-Based Security Review Process (formerly CFIP) is an adaptive risk management security program designed to help protect the critical technology and performer intellectual property associated with DARPA's research projects by identifying the possible vectors of undue foreign influence. The DARPA SID team will create risk assessments of all proposed Senior/Key Personnel selected for negotiation of a fundamental research grant or cooperative agreement award. The SID risk assessment process will be conducted separately from the DARPA scientific review process and adjudicated prior to final award. For additional information on this process, please visit [Proposer Instructions: Grants/Cooperative Agreements](#).
- This program is subject to Attachment F: General MTO Controlled Unclassified Information Guide (CUIG). All individuals accessing CUI agree to protect CUI in accordance with *DoD Instruction 5200.48 CONTROLLED UNCLASSIFIED INFORMATION (CUI) and NIST Special Publication 800-171 Protecting Controlled Unclassified Information in Nonfederal Systems and Organizations*.
- DARPAConnect offers free resources to potential performers to help them navigate DARPA, including "Understanding DARPA Award Vehicles and Solicitations," "Making the Most of Proposers Days," and "Tips for DARPA Proposal Success." Join DARPAConnect at www.DARPAConnect.us to leverage on-demand learning and networking resources.
- DARPA has streamlined our Broad Agency Announcements and is interested in your feedback on this new format. Please send any comments to DARPA solicitations@darpa.mil.