Amendment Number 0002

Broad Agency Announcement 10-002

"Multidisciplinary University Research Initiative (MURI)"

The purpose of Amendment Number 0002 is to provide a general comment and answer questions received under BAA 10-002 entitled "Multidisciplinary University Research Initiative (MURI)" Topic Number 7 entitled, "Fundamental Study of High- and Low-K Dielectrics for III-V Electronic Devices" as follows:

General comment:

This is not a device MURI. The focus of the MURI is on the study and development of the basic materials properties of insulators. Devices should only enter as generic test vehicles to demonstrate the superior properties of the dielectrics.

Q#1: What is the relative emphasis on high-k (gate) dielectrics vs. low-k dielectrics? Do both need to be addressed?

A#1: Study of both high- and low- k dielectrics should be addressed as components in the program.

Q#2: Can you provide clarification regarding the high-k dielectrics for passives component of the MURI vis-à-vis as an active part of the device such as the gate dielectric, passivation etc.?

A#2: Capacitor size (due to limited capacitance per unit area) is an issue for a variety of high-voltage, high power amplifiers (HPA's). Insulators which can address this problem are of interest.

Q#3: From a low-k perspective, the mechanical interaction of low-k porous dielectric with a brittle III-V substrate is different from III-V epitaxial thin films on Silicon substrate. Are studies directly on III-V substrates (and not III-V on silicon (Si)) of primary interest in this program?

A#3: The two main guiding principles for the program are: 1) an experimental approach that lends itself to high-quality basic research (i.e. experiments should be such that they are well controlled and highly reproducible) and 2) the end results should be compatible with III-V manufacturing practices.

Although the end result should be compatible with III-V manufacturing practices it is understood that experiments directed at an understanding of the dielectric properties may not be.

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Q#4: Is it correct to assume that the III-V materials beyond Gallium Nitride (GaN) mentioned in the topic 7 text are also of interest? For example, higher mobility, lower bandgap III-Vs (such as phosphide and antimonide based devices) are suitable for high-speed, ultra low power mixed signal applications, In GaAs for low power, high performance complementary metal oxide semiconductor (CMOS), etc. – are such III-V materials of interest to Navy, or should GaN be the primary thrust?

A#4: III-V materials beyond GaN are of interest. One of the main objectives of this MURI is to find dielectrics appropriate for a broad base of III-V materials. Currently we are in a situation where silicon nitride (Si3N 4) is the default dielectric for virtually all III-V's. The goal is dielectrics that are optimized for a particular semiconductor.

GaN represents a special case in that the field dielectric needs to truly passivate (result in a very low number of interface traps) the surface. Ideally the dielectric would passivate the surface in all cases but the need for this is perhaps highest in the case of GaN. Partial passivation is clearly working for a number of commercial III-V's.

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Q#5: Is it correct that the study of basic circuit components (e.g., capacitors and field effect transistors) incorporating dielectrics are of interest in this program, without a requirement for submicron (or below) scaling? That is, studies correlating dielectric materials/interfaces with electrical characterization on large devices are suitable for this program.

A#5: Yes, large devices (capacitors and structures to investigate field insulator properties) are suitable for this program but current III-V device technology generally requires scaling to sub-micron dimensions.

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Q#6: In addition to atomic layer deposition (ALD) methods, are other approaches (e.g. Physical vapor deposition (PVD), Molecular beam epitaxy (MBE)) also of interest?

A#6: ALD is considered an enabling technology for this research. From a basic research perspective it allows for well controlled, reproducible experiments that can provide detailed insight into the materials properties of interest. Results established with ALD in one laboratory are comparatively easy to reproduce in another, and the growth techniques are compatible with industrial practices.

PVD, although clearly compatible with industrial practices, is judged problematic as a research tool for this program. MBE is clearly an excellent research tool but it's usefulness in an industrial setting is limited. Other techniques not mentioned will be similarly evaluated for both experimental control and industrial applicability.

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Q#7: Are the dielectric mechanical properties (e.g. thermal stability, piezoelectric effects, etc) intended to have a power device focus with a strong reliability context?

A#7: The work is to be directed to radio frequency (RF) and mixed signal (as opposed to power switching) devices. Correctly executed it is expected that the results will have the most effect on HPA's and digital devices. Attention should be paid to reliability issues but this program is not expected to demonstrate the reliability of devices and circuits fabricated with the resulting insulators.

An example of how reliability might enter the program is the following. It is well known that one the major failure mechanisms in III-V devices is energetic electron damage of the insulators and the insulator semiconductor interface. Demonstrations of insulators that are more robust in this context would be useful.

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Q#8: Are the mechanical properties to be considered at the surface or around the passives (e.g. airbridges)?

A#8: While the control of the dielectric semiconductor interface is considered to be of primary interest to III-V device functionality, consideration of the impact of the dielectric choice on the passive elements is of interest. The desirability of conformal films on three dimensional structures such as airbridges also highlights why ALD is considered an enabling technology for this work.

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