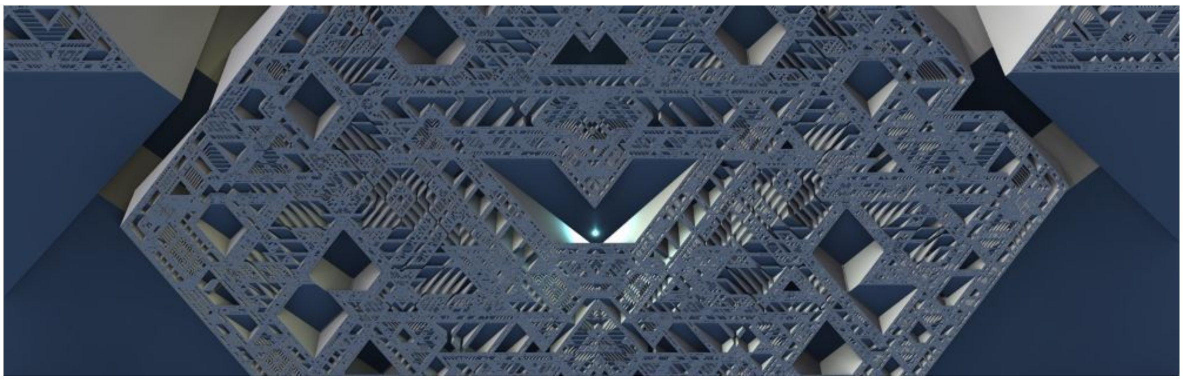
The National Academies of
SCIENCES • ENGINEERING • MEDICINE

Defense Materials Manufacturing and its Infrastructure (DMMI)

Workshop on:

Domestic manufacturing capabilities for Critical DoD Applications:

Emerging Needs in Quantum enabled systems



National Academy of Sciences building, March 19 - 20th 2019,
Room NAS120 at 2101 Constitution Avenue, NW.

The Academies will convene a workshop to discuss issues in defense materials and manufacturing. The topics to be discussed is Domestic manufacturing capabilities for Critical DoD Applications: Emerging Needs in Quantum - enabled systems

The following abstract will define the workshop:

The push towards quantum - enabled systems has shed light on the fact that there may be a number of emerging supply - chain issues. Quantum systems typically connect a core where quantum phenomena occur (e.g. a trapped atom/ion) with systems of detectors, signal sources, controlling elements, etc. Most demonstrations of quantum effects have been done on large optical tables, and are not yet miniaturized and integrated. It remains to be seen where world leading production systems will be developed. Much of the current expertise in critical materials and components, such as single photon detectors, is found offshore. The importance of quantum - enabled system to critical DoD applications argues for development of assured domestic sources of materials, manufacturing capabilities and expertise as this technology matures. Current technology trends and the collective needs and concerns of the DoD stakeholder materials and manufacturing community will be addressed during this workshop.

March 19, 2019

OPEN SESSION

8:00 Working Breakfast

8:30 Welcome, Meeting Objective, Introductions – CHAIR **Haydn Wadley**

8:45 **Keynote Speaker Christopher Monroe,** U. of Maryland
Presentation title: *The Quantum Landscape in the U.S.*

Topic 1: Quantum computing systems

Introductions by: Rudy Wojtecki Q&A lead by: Stephen Rossnagel

9:35 **Speaker Pat Gumann,** IBM research
Presentation title: *A System Overview of Quantum Computing*

10:05 Break

10:25 **Speaker Ravi Pillarisetty**, Intel
Presentation title: *Spin Qubits*

10:55 **Speaker Irfan Siddiqi,** Berkeley
Presentation title: *Superconducting Devices: Packing and Unpacking Quantum Information*

11:25 Lunch

12:25 **Panel Discussion on *Qubit Enabling Technologies and Manufacturing Issues***

Introductions by: Stephen Rossnagel Q&A lead by: Rudy Wojtecki

Panelists: William Oliver, MIT Lincoln Laboratory
Panelists: Joe Broz, SRI
Panelists: Jerry Chow, IBM

Topic 2: Quantum Communications and Networks

Introductions by: Elias Towe Q&A lead by: Alan Willner

01:45 **Speaker Prem Kumar**, Northwestern University (Via web link)
Presentation title: *A network and communication overview of Quantum efforts*

2:15 **Speaker Saikat Guha,** University of Arizona
Presentation title: *Quantum communications and networking*

2:45 Break

3:00 **Speaker Nitin Samarth,** Penn State
Presentation title: *Hybrid materials for quantum networks*

3:30 **Panel Discussion on *Technology Gaps***

Introductions by: Alan Willner Q&A lead by: Elias Towe

Panelist: Pat Gumann, IBM research
Panelist: Stuart Gray, Corning
Panelist: Paul Kwiat, University of Illinois at Urbana-Champaign
Panelist: Alexander Sergienko, Boston University

4:50 Wrap up and final comments

5:00 Adjourn meeting day 1

March 20, 2019

OPEN SESSION

8:00 Working Breakfast

8:30 Welcome, plans for today – **CHAIR Haydn Wadley**

8:45 **Keynote Speaker Jerry Chow,** IBM research
Presentation title: *Future quantum technologies*

Topic 3: Quantum Sensors

Introductions by: Susan Sinnott Q&A lead by: Robert Hull

9:35 **Speaker Philip Hemmer,** Texas A&M University
Presentation title: *Quantum Sensors, Imaging and Lithography*

10:05 Break

10:25 **Speaker Mohammad Soltani,** Raytheon Technologies
Presentation title: *Quantum Optical Hardware*

10:55 **Speaker David Awschalom,** Univ. of Chicago, (via web link)
Presentation title: *Driving quantum science and engineering with semiconductors*

11:25 Lunch

12:25 **Panel Discussion on *Science gaps, Implementation, challenges, and scalable manufacturing issues***

Introductions by: Robert Hull Q&A lead by: Susan Sinnott

Panelists: Michael Liehr, AIM Photonics
Panelists: Greg Boebinger, National High Magnetic Field Laboratory
Panelists: Juliet Gopinath University of Colorado at Boulder

1:45 **Wrap up discussion for the full workshop**

2:30 **Adjourn meeting**

3:00 (planning committee and Reliance only) **Call regarding future topic order**

4:00 (planning committee and Reliance only) **Adjourn fully**

For more information contact:

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Future Schedule

The future DMMI workshop schedule is as follows (Save the dates):

2019 March	19-20	D.C., NAS building, room 120
2019 July	16-17	D.C., NAS building, room 120
2019 November	19-20	D.C., NAS building, room 120
2020 March	17-18	tbd
2020 July	14-15	tbd
2020 November	17-18	tbd

Future Topics

The upcoming five topics are (not in order):

- **Domestic manufacturing capabilities: Emerging Needs in Quantum-enabled systems (March 19-20)**
- **What does quantum computing bring to new materials design? (order not set)**
- **Topology Optimization in Design: Exploiting Advanced Manufacturing Capabilities (order not set)**
- **Data analytics and what it means to the Materials Community (order not set)**
- **What's next after CMOS? (order not set)**

Expanded Future Topics

What does quantum computing bring to new materials design?

Fundamental transformations in the basic logic of computing are few and far between. However, today the materials research community is actively discussing the potential for quantum computing to apply such a transformation in materials and chemistry discovery. The ultimate goal in the materials research community is to synthesize new materials with desired properties in a controlled way via materials engineering modeling starting at the atomic scale, and extending to macro scales. These models are computationally limited even when implemented on the most capable supercomputers to date. It is believed that quantum computing can speed up the computation process, and, perhaps more importantly, support algorithmic approaches that uniquely fit the needs of multi-scale materials design. Quantum computers in the laboratory are built with an increasing number of qubits. At a few hundred qubits, materials research challenges will become possible to tackle. It is now time to better understand not only how algorithms are being developed for materials discovery, but also how materials science principles can be incorporated into the discovery and design tools that may emerge. This workshop will address the fundamental differences in quantum computing from today's algorithms, the principles that might be used to develop future algorithms suited to materials engineering, expected gains in computational speed and efficiency, and what topics might be attempted to be analyzed first.

Topology Optimization in Design: Exploiting Advanced Manufacturing Capabilities

Topological Optimization (TO), i.e. optimizing the layout of material in a design space, has become computationally practical, and offers new possibilities for integrating design of materials and design of products to take full advantage of advanced manufacturing (especially additive manufacturing). Success stories abound using TO to produce non-intuitive designs that minimize weight in structural components, and the technique has been used to optimize for unusual and often DoD specific needs and models, such as burn rate of propellants for rocket grain. Extending TO beyond shape optimization offers the possibility of designing and analyzing gradient material structures that can be built with additive manufacturing materials and methods. At the system level, TO offers a way to rapidly explore design trade spaces and generate designs that respond quickly to changes in needs. The combination of TO and additive manufacturing can bring production systems close to the vision of Agile Manufacturing, formulated in 1991 as “the ability to thrive on change”. This workshop will examine how TO can be effectively implemented and extended to meet next generation needs in defense manufacturing, and explore alternatives for unifying its use in materials and manufacturing communities..

Data analytics and what it means to the Materials Community

The 2013 NRC report on "Frontiers in Massive Data Analysis" makes the following statements about big data: "Experiments, observations, and numerical simulations in many areas of science and business are currently generating terabytes of data, and in some cases are on the verge of generating petabytes and beyond. Analyses of the information contained in these data sets have already led to major breakthroughs in fields ranging from genomics to astronomy and high-energy physics and to the development of new information-based industries.” Traditionally, in materials research a deterministic approach have been used to uncover mechanisms of observed behavior and to make predictions. A question that becomes obvious is: To what extent today, can one use informatics for materials research challenges and discover unexpected correlations by analyzing huge data sets to find relationships that were not anticipated? Another question is how could these insights help to guide experimentation in future materials research efforts? These, and related questions will be discussed in this workshop.

What's next after CMOS?

Both classical and quantum computing face significant challenges. On the classical side, silicon field effect transistors are reaching the fundamental limits of scaling and there is no replacement technology which has yet demonstrated even comparable performance to the current generation of commercially available silicon CMOS. On the quantum side, scaling the number of entangled superconducting or trapped ion qubits to that required to solve useful problems is an enormous challenge with current device technology. Both fields stand to benefit from transformational devices based on new physical phenomena, new materials, and new fabrication and manufacturing processes. While much attention has been given to these issues separately, the research must be both significant and coordinated among those with expertise in theoretical solid-state physics, quantum transport measurements, ultrafast optical spectroscopy, novel device engineering, electronic device processing, computational materials science, materials growth, materials fabrication, and advanced packaging. In this workshop, the issues at the convergence of these disciplines will be explored with the stakeholder communities involved.