REPORT DOCUMENTATION PAGE

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a. REPORT	b. ABSTRACT	c. THIS PAGE			Timothy Grotjohn
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RPPR Final Report
as of 26-Apr-2022

Agency Code: 21XD

Proposal Number: 75497ELCF **Agreement Number: W911NF-20-1-0005**
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Report Date: 02-Jul-2021 Date Received: 15-Apr-2022
Final Report for Period Beginning 03-Oct-2019 and Ending 02-Apr-2021
Title: Second Workshop on Diamond Electronics: Status, Challenges, and Opportunities
Begin Performance Period: 03-Oct-2019 **End Performance Period:** 02-Apr-2021
Report Term: 0-Other

Submitted By: Timothy Grotjohn Email: grotjohn@msu.edu
Phone: (517) 353-8906

Distribution Statement: 1-Approved for public release; distribution is unlimited.

STEM Degrees: **STEM Participants:**

Major Goals: The goal was to organize and run and Second Workshop on Diamond Electronics.
The objective of this second workshop is to communicate to interested U.S. scientific, engineering, and government communities the current, world–wide, state–of–the–art diamond technologies and highlight a number of diamond based applications.

In particular, the objective of this workshop will be to provide a summary of the state–of–the–art current, and potential world–wide diamond electronics developments, diamond-based quantum sensor, communications and computing developments, and electrochemical and interfaces developments. Topics include diamond material supply, applications, and characterization techniques specific to the current and future applications.

Accomplishments: The workshop was initially scheduled for April 2020. However, it was postponed due to the COVID 19 pandemic. The workshop was subsequently offered in a virtual format Oct. 19-22, 2020. The statistics of the conference included:
224 registered attendees
7 International Invited Presentations
13 Regular Presentations
9 posters (work in progress)
3 panel sessions

Training Opportunities: Nothing to Report

Results Dissemination: Nothing to Report

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: PD/PI

RPPR Final Report
as of 26-Apr-2022

Participant: Timothy Grotjohn
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
National Academy Member: N

Partners

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I certify that the information in the report is complete and accurate:
Signature: Timothy Grotjohn
Signature Date: 4/15/22 9:29AM

Welcome to the Second Workshop on Diamond Electronics

October 19-22, 2020

9am-noon East Coast Time USA

Repeat: 9pm-midnight East Coast Time USA

Location: Virtual

Leaves changing color in Michigan

Second Workshop on Diamond Electronics: Status, Challenges, and Opportunities

Introduction
Diamond is a unique material with a wide and unusual constellation of highly attractive material properties that are crucial to modern science and technology. Its properties give it promising applications in a wide range of applications including high-power, high voltage electronics, high power, high frequency electronics, high temperature electronics, high radiation hardness detectors, quantum sensors, communications and computing using color sensors, and electrochemical based sensors and water purification.

The first workshop was held in February, 2018 at the Army Research Laboratory in Adelphi, Maryland. The number of attendees was approximately 80 including five invited international speakers. This second workshop is being offered in a virtual format.

Workshop Objective
The objective of this second workshop is to communicate to interested U.S. scientific, engineering, and government communities the current, world–wide, state–of–the–art diamond technologies and highlight a number of diamond based applications.

In particular, the objective of this workshop will be to provide a summary of the state–of–the–art current, and potential world–wide diamond electronics developments, diamond-based quantum sensor, communications and computing developments, and electrochemical and interfaces developments. Topics include diamond material supply, applications, and characterization techniques specific to the current and future applications.

Organizers

- Timothy Grotjohn, Michigan State University, Co-chair
- Robert Nemanich, Arizona State University, Co-chair

- Elias Garratt, Michigan State University, Local (virtual) Organizer

- Additional members of the organizing committee
  - Pankaj Shah, Army Research Laboratory
  - Tony Ivanov, Army Research Laboratory
  - Glen Birdwell, Army Research Laboratory

- Financial sponsorship: Army Research Office, Joe Qiu

Workshop Statistics

- 224 registered attendees
- 7 International Invited Presentations
- 13 Regular Presentations
- 9 posters (work in progress)
- 3 panel sessions

Virtual Housekeeping Details

- We will be using ZOOM meetings. (Contact Tim Grotjohn- grotjohn@msu.edu or Elias Garratt- garratte@msu.edu with virtual meeting problems)
- Talks are prerecorded so they will run without interruption to the end.
- When a talk ends we will have open discussion for the remaining time. We want to have good discussions to maintain a workshop flavor to the meeting. So please think of good questions and discussion points.
- The presenter will be online to answer questions and participate in discussion after their talk plays. (A few presenters may not be present due to time zone differences.)
- To ask a questions either raise your “virtual” hand, send a chat note that you have a question, or if there is a pause in discussion ask your question.
- To raise your “virtual” hand, click on participants and a new panel appears on the right side of your screen. On this screen is a “Raise Hand” button.
- Please keep your microphone on “MUTE” unless you are talking. This reduces background noise. (In advance I apologize if my dog barks- even after 7 months she still does not understand “quiet” while I am talking on ZOOM calls). The hosts may occasionally mute you if you forget to “mute”, please do not be offended. With a large number of attendees sometimes folks forget to mute. You can later unmute yourself.
- We hope glitches will be minimal during our virtual meeting. If glitches happen, please be patience.

Monday Schedule

Day One: Monday Oct. 19, 2020

Session Chairs: Robert Nemanich and Pankaj Shah

- 9:00 – 9:10 am -- Opening remarks
- 9:10-9:25 Welcome Address, Dr. Patrick Baker, Director of the US Army Combat Capabilities Development Command -- Army Research Laboratory
- 9:25-9:45 Regular talk: “Single Crystal Diamond Electronics Applications”, by T. Ivanov from Army Research Laboratory (ARL).

Devices: Session 1 (Mostly RF Devices)

- **9:45-10:25 Invited Talk**: “Inversion Layer MOSFET” N. Tokuda, Kanazawa University
- 10:25-10:35 Break
- 10:35-10:55 Regular talk: Diamond FinFET, B. Huang, HRL
- 10:55-11:15 Regular talk: “Diamond HBT”, Jack Ma, U. of Wisconsin-Madison
- **11:15-11:55 Invited Talk**: “H-terminated diamond FETs”, M. Kasu, Saga University
- 11:55-12:15 Regular talk: “Nanolaminates on Diamond,” Orlando Auciello, U. Texas-Dallas

Tuesday Schedule

Day Two: Tuesday Oct. 20, 2020

Session Chair: Shannon Nicley

Mostly Quantum Applications of Diamond

- 9:00-9:40 **Invited Talk**: “Diamond Growth for Power Electronics and Quantum Applications” T. Teraji, NIMS Japan
- 9:40—10:00 Regular talk: “Diamond Processing for Nanophotonics for Quantum Applications”, M. Loncar, Harvard Univ.
- 10:00-10:20 Regular talk: “Influences of Surfaces on Color Centers in Diamond”, R. Hamers, Univ. Wisconsin-Madison
- 10:20-10:30 Break
- 10:30-10:50 Regular talk: “Understanding Photo-generation, Diffusion, and Trapping of Carriers in Diamond” Carlos Meriles, City College of New York
- 10:50-11:10 Regular talk: “Diamond Quantum Gyroscopes” Andrey Jarmola, University of California-Berkeley
- 11:10-11:30 Poster Session 1 (3 minute overview of each poster)
- 11:30-12:00 Panel on Quantum Applications of Diamond

Wednesday Schedule

Day Three: Wednesday Oct. 21, 2020

Session Chairs: Elias Garratt and David Moran

Mostly RF H-Terminated FETs

- **9:00-9:40 Invited talk** "Diamond – Dielectric Interfaces for Electronics", David Moran, U. Glasgow
- 9:40-10:00 Regular talk "Diamond for RF Electronics: Research and Applications", Mike Geis, MIT Lincoln Labs.
- 10:00-10:20 Regular talk "Oxide Transfer Doped Diamond RF FET Performance and Compact Model Extraction for RF System Design", P. Shah, Army Research Lab (ARL).
- 10:20-10:30 Break
- **10:30-11:10 Invited Talk**: "Transfer Doped Diamond FETs using V_2O_5" C. Verona, Universita di Roma Tor Vergata.
- 11:10-11:30 Regular talk: "Quantum Chemistry-based Predictive Modeling of Novel Acceptor Layer Technology for Diamond Electronics" M. Neupane, Army Research Lab-West
- 11:30-12:00 Panel on Diamond Electronics Session (RF)

Thursday Schedule

Day Four : Thursday Oct. 22, 2020

Session Chairs: Tim Grotjohn and Julien Pernot

Devices Session II (Mostly Power Electronic Devices, High Temperature and Detectors)

- **9:00-9:40 Invited talk**, “Diamond deep depletion MOSFET” J. Pernot, U. Grenoble Alpes, France
- **9:40-10:20 Invited Talk**: “Diamond Devices for High Power, High Temperature and High Radiation Environments” H. Umezawa, AIST, Japan
- 10:20-10:30 Break
- 10:30-10:50 Regular talk: “Diamond for High Temperature Applications”, R. Nemanich, Arizona State University
- 10:50-11:10 – Regular talk: “Diamond Synthesis- paths to larger substrates and higher quality” by T. Grotjohn from Michigan State University.
- 11:10- 11:35 Poster Session 2:
- 11:35-12:00 Panel on Diamond Substrates & Power Electronics (Including a Short Description of EFRC- Ultra Materials by R. Nemanich and EU Green Diamond project achievements and perspectives by Etienne Gheeraert)

Poster Session 1: Tuesday

- Poster #1: Sergey Dushenko, University of Maryland “Order of Magnitude Speed up of NV- Center Magnetometry using Sequential Bayesian Experiment Design” Breakout Room #1
- Poster #2: Bo Hsu, University of Illinois at Chicago, High Performance Ionic-Liquid-Gated Air-Doped Diamond Field-Effect Transistors” Breakout Room #2
- Poster #3: Saha Niloy, Saga University, “Observation of Nitrogen Species at Al2O3/NO2/H-diamond Interfaces by Synchrotron Radiation X-ray Photoemission Spectroscopy” Breakout Room #3
- Poster #4: Sidra Farid, University of Illinois at Chicago, “Role of Remote Interface Polar Phonon Modes on the Electronic Transport Properties of Diamond” Breakout Room #4

Poster Session 2: Thursday

- A. Vardi, Massachusetts Institute of Technology, Diamond Electronics Based on Transition-Metal Oxides, Breakout Room #1
- Matthias Muehle, Fraunhofer USA Center for Coatings and Diamond Technologies, Designing Artificial Intelligence Algorithms for In-situ Predictive Crystal Synthesis, Breakout Room #2
- Trevor Thornton, Arizona State University, SPICE Models for Diamond PIN Diodes, Breakout Room #3
- Summayya Kouser, Rice University, Dual Role of Adsorbent and Non-monotonic Transfer p-doping of Diamond, Breakout Room #4
- J. Canas, Univ. Grenoble Alpes, CNRS, Grenoble INP*, Institut Néel, France, Normally-Off Reverse Blocking MESFET, Breakout Room #5