

REPORT DOCUMENTATION PAGE			Form Approved OMB NO. 0704-0188		
<p>The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA, 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.</p>					
1. REPORT DATE (DD-MM-YYYY) 05-05-2017		2. REPORT TYPE Final Report		3. DATES COVERED (From - To) 5-Jul-2016 - 4-Jan-2017	
4. TITLE AND SUBTITLE Final Report: International Conference on Metalorganic Vapor Phase Epitaxy (ICMOVPE)			5a. CONTRACT NUMBER W911NF-16-1-0380		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER 611102		
6. AUTHORS Russell D. Dupuis, PhD			5d. PROJECT NUMBER		
			5e. TASK NUMBER		
			5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAMES AND ADDRESSES Materials Research Society 506 Keystone Dr.  Warrendale, PA 15086 -7573			8. PERFORMING ORGANIZATION REPORT NUMBER		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS (ES) U.S. Army Research Office P.O. Box 12211 Research Triangle Park, NC 27709-2211			10. SPONSOR/MONITOR'S ACRONYM(S) ARO		
			11. SPONSOR/MONITOR'S REPORT NUMBER(S) 69466-EL-CF.1		
12. DISTRIBUTION AVAILABILITY STATEMENT Approved for Public Release; Distribution Unlimited					
13. SUPPLEMENTARY NOTES The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.					
14. ABSTRACT The ICMOVPE-XVIII conference created meaningful opportunities for intellectual challenge, networking opportunities, and intellectual stimulation for graduate students, Post-Doctoral Fellows and all attendees. This technical and social program further provided many opportunities for communication, brainstorming, and transfer of information as well as the development of collaborations across many institutions and companies. We had a significant number of members of underrepresented groups in STEM attending this conference. We also are publishing the proceedings of this conference with the Journal of Crystal Growth, a journal which receives wide					
15. SUBJECT TERMS metalorganic vapor phase epitaxy					
16. SECURITY CLASSIFICATION OF:		17. LIMITATION OF ABSTRACT UU	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Russell Dupuis	
a. REPORT UU	b. ABSTRACT UU			c. THIS PAGE UU	19b. TELEPHONE NUMBER 404-385-6094

## Report Title

Final Report: International Conference on Metalorganic Vapor Phase Epitaxy (ICMOVPE)

### ABSTRACT

The ICMOVPE-XVIII conference created meaningful opportunities for intellectual challenge, networking opportunities, and intellectual stimulation for graduate students, Post-Doctoral Fellows and all attendees. This technical and social program further provided many opportunities for communication, brainstorming, and transfer of information as well as the development of collaborations across many institutions and companies. We had a significant number of members of underrepresented groups in STEM attending this conference. We also are publishing the proceedings of this conference with the Journal of Crystal Growth, a journal which receives wide electronic distribution in many academic institutions world-wide, making the technical information presented at ICMOVPE-XVIII have a much broader impact than would otherwise be possible.

---

**Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:**

**(a) Papers published in peer-reviewed journals (N/A for none)**

<u>Received</u>	<u>Paper</u>
-----------------	--------------

**TOTAL:**

**Number of Papers published in peer-reviewed journals:**

---

**(b) Papers published in non-peer-reviewed journals (N/A for none)**

<u>Received</u>	<u>Paper</u>
-----------------	--------------

**TOTAL:**

**Number of Papers published in non peer-reviewed journals:**

---

**(c) Presentations**

Number of Presentations: 216.00

---

**Non Peer-Reviewed Conference Proceeding publications (other than abstracts):**

Received      Paper

**TOTAL:**

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

---

**Peer-Reviewed Conference Proceeding publications (other than abstracts):**

Received      Paper

**TOTAL:**

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

---

**(d) Manuscripts**

Received      Paper

**TOTAL:**

Number of Manuscripts:

---

**Books**

Received      Book

**TOTAL:**

Received

Book Chapter

**TOTAL:**

---

**Patents Submitted**

---

**Patents Awarded**

---

**Awards**

---

**Graduate Students**

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
<b>FTE Equivalent:</b>	
<b>Total Number:</b>	

---

**Names of Post Doctorates**

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
<b>FTE Equivalent:</b>	
<b>Total Number:</b>	

---

**Names of Faculty Supported**

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
<b>FTE Equivalent:</b>	
<b>Total Number:</b>	

---

**Names of Under Graduate students supported**

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
<b>FTE Equivalent:</b>	
<b>Total Number:</b>	

**Student Metrics**

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: ..... 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense ..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:..... 0.00

**Names of Personnel receiving masters degrees**

NAME  
**Total Number:**

**Names of personnel receiving PHDs**

NAME  
**Total Number:**

**Names of other research staff**

NAME                      PERCENT SUPPORTED  
**FTE Equivalent:**  
**Total Number:**

**Sub Contractors (DD882)**

**Inventions (DD882)**

**Scientific Progress**

SEE ATTACHMENT

**Technology Transfer**

18<sup>th</sup> International Conference on Metalorganic Vapor Phase Epitaxy (ICMOVPE XVIII)  
July 10-15, 2016

**ICMOVPE XVIII Organization**

CONFERENCE CHAIR

Robert Biefeld, Sandia National Laboratories

PROGRAM CO-CHAIRS

Andrew Allerman, Sandia National Laboratories

Christine Wang, MIT Lincoln Laboratory

PUBLICATION

Thomas Kuech, University of Wisconsin-Madison

SPONSORSHIP

Russell Dupuis, Georgia Institute of Technology

EXHIBITS

Raj Bhat, Corning, USA

LOCAL ARRANGEMENTS

David Bour, Avogy, Inc.

**ICMOVPE XVIII Objectives and Scope**

This conference is eighteenth in a biennial conference series that, since 1981, has become the premier international conference devoted to advancing the knowledge of the MOVPE growth materials and the corresponding improvement in MOVPE-grown devices. The first ICMOVPE conference was held in 1981 in Ajaccio, Corsica, France. Beginning in 1983, the conference has been held every two years at a site that rotates between Europe, Asia, and North America. Recent past conferences have been in Lake Tahoe CA, USA (2010), Busan, Korea (2012) and Lausanne, Switzerland (2014).

The ICMOVPE-XVIII Program Committee has arranged for many excellent invited speakers who agreed to present their latest work at this conference. The excellent leadoff Plenary Talk was given by Dr. Drew Nelson, the founder and CEO of IQE Inc., a world-leader in commercial production of custom epitaxial wafers grown by MOVPE. The other Invited speakers covered a wide range of important topics related to the growth of advanced MOVPE materials growth and device structures. These materials play a significant role in the current a future electronic, optoelectronic, and energy saving systems to be developed in the USA and the world.

<b>Plenary speaker</b>	<b>Affiliation</b>	<b>Title</b>
Shuji Nakamura	University of CA Santa Barbara	Invention of the Blue LED and Future of Solid State Lighting
Drew Nelson	IQE PLC	The Impact of MOVPE on the World
Ignacio Rey-Stolle	Technical University of Madrid	MOVPE and III-V Photovoltaics: Perspectives, Challenges and Potential for the Electricity Market
Joshua Robinson	Pennsylvania State University	Epitaxy in the World of 2D
Wolfgang Stolz	Philipps-Universität Marburg	Material Challenges in the MOVPE of III/V-Semiconductors Integrated on (001) Si-Substrate

The ICMOVPE-XVIII conference created meaningful opportunities for intellectual challenge, networking opportunities, and intellectual stimulation for graduate students, Post-Doctoral Fellows and all attendees. This technical and social program further provided many opportunities for communication, brainstorming, and transfer of information as well as the development of collaborations across many institutions and companies. We had a significant number of members of underrepresented groups in STEM attending this conference. We also are publishing the proceedings of this conference with the Journal of Crystal Growth, a journal which receives wide electronic distribution in many academic institutions world-wide, making the technical information presented at ICMOVPE-XVIII have a much broader impact than would otherwise be possible. We actively solicited papers describing the latest work in the technical areas shown below.

### **ICMOVPE XVIII Symposium Topics**

- Fundamental Studies and Modeling of Epitaxial Processes
- Wide-Bandgap Group-III Nitride Materials and Devices (AlN, GaN, InN, BN, etc.)
- III-V Semiconductors and Devices (Arsenides, Phosphides, Antimonides and Dilute Nitrides)
- Narrow Bandgap Materials and Devices (InAs, Antimonides, Bismides)
- II-VI Materials and Devices (CdTe, ZnO, ZnSe, ZnS, MCT, etc.)
- Semiconducting Oxides and Epitaxial Dielectrics (TCO, Ga<sub>2</sub>O<sub>3</sub>, SnO<sub>2</sub>, etc.)
- Epitaxy of 2D Materials and van der Waal Heterostructures
- Heteroepitaxy of Mismatched Alloys and III-V's on Si
- Growth of Nanowires, Nanostructures and Low-dimensional Structures (Dots, Wires and Quantum Wells)
- Patterned Growth and Selective Area Epitaxy
- Atomic Layer Deposition and Epitaxy
- Pseudo-substrates and Epitaxial Lift-off Processes
- In Situ Monitoring, Process Control and Reactor Modeling

### **ICMOVPE XVIII Organizers and International Advisory Committee**

The ICMOVPE XVIII was organized by the Materials Research Society (MRS). The technical portion of the conference was organized by a team of US-based experts in the field (listed above) and the choice of Plenary and Invited speakers was based upon inputs from the International Advisory Committee composed of active MOVPE researchers from all over the world as shown below in the table. Also shown below is the ICMOVPE-XVIII Program Committee.

### **ICMOVPE XVIII International Advisory Committee**

- 1 Hiroshi Amano, Nagoya University, Japan
- 2 Rajaram Bhat, Consultant
- 3 Jean Decobert, III-V Lab, Thales Research, France
- 4 Steve DenBaars, University of California, Santa Barbara, USA
- 5 Russell Dupuis, Georgia Institute of Technology, USA
- 6 Eduard Hulicius, Institute of Physics, Czech Republic
- 7 Stuart Irvine, Glyndwr University, UK
- 8 Eli Kapon, École Polytechnique Fédérale de Lausanne, Switzerland
- 9 Thomas F. Kuech, University of Wisconsin-Madison, USA
- 10 Tien-Chang Lu, National Chiao Tung University, Taiwan
- 11 Nigel Mason, Consultant, UK
- 12 Abdallah Ougazzaden, Georgia Tech, USA and CNRS, France
- 13 Seong-Ju Park, Gwangju Institute of Science & Technology, Korea
- 14 Alok Rudra, École Polytechnique Fédérale de Lausanne, Switzerland
- 15 Ferdinand Scholz, Ulm University, Germany
- 16 Wolfgang Stolz, Phillips University of Marburg, Germany
- 17 Jerry Stringfellow, University of Utah, USA
- 18 Masakazu Sugiyama, University of Tokyo, Japan
- 19 Christine Wang, MIT Lincoln Lab, USA
- 20 Hui Yang, Suzhou Institute of Nano-Tech and Nano-Bionics, China

### **ICMOVPE XVIII Program Committee**

	<b>Last Name</b>	<b>Name</b>	<b>Affiliation</b>	<b>Country</b>
Co-Chair	Allerman	Andrew Allerman	Sandia National Laboratories	USA
Co-Chair	Wang	Christine Wang	MIT Lincoln Laboratory	USA
<b>Americas</b>				
1	Pitts	Oliver Pitts	National Research Council	Canada
2	Springthorpe	Tony Springthorpe	NRC	Canada
3	Watkins	Simon Watkins	Simon Fraser University	Canada
4	Bhat	Rajaram Bhat	Corning	USA
5	Caneau	Catherine Caneau	Corning	USA
6	Cederberg	Jeff Cederberg	Sandia National Laboratories	USA
7	Geisz	John Geisz	NREL	USA

8	Mawst	Luke Mawst	University of Wisconsin Madison	USA
9	Redwing	Joan Redwing	Penn. State University	USA
10	Tansu	Nelson Tansu	Lehigh University	USA
11	Sitar	Zlatko Sitar	North Carolina State University	USA

### Europe

1	Decobert	Jean Decobert	III-V Lab	France
2	Hardtdegen	Hilde Hardtdegen	Forschungszentrum Jülich	Germany
3	Kneissl	Michael Kneissl	Technische Universität Berlin	Germany
5	Volz	Kerstin Volz	Philipps-University Marburg	Germany
6	Weyers	Markus Weyers	Ferdinand-Braun-Institute	Germany
7	Lundin	Wsevolod Lundin	Ioffe Physical-Technical Institute	Russia
8	Irvine	Stuart Irvine	Glyndŵr University	UK
9	Grandjean	Nicolas Grandjean	EPFL	Switzerland
10	Kunert	Bernadette	IMEC	
11	Hannapel	Thomas Hannapel	Hahn Meitner Institute	Germany

### Asia/Australia

1	Bhattacharya	Arnab Bhattacharya	Tata Institute of Fundamental Research	India
2	Tan	Hoe Tan	Australian National University	Australia
3	Sugiyama	Masakazu Sugiyama	University Tokyo	Japan
4	Lau	Kei May Lau	Hongkong UST	Hong Kong
5	Miyake	Hideto Miyake	Mie University	Japan
6	Yang	Yang	National Taiwan University	Taiwan
7	Tomioka	Katsuhiko Tomioka	Hokkaido University	Japan
8	Chang	Shoou-Jinn Chang	National Cheng Kung University	Taiwan
9	Nam	Ok-Hyun Nam	Korea Polytechnic University	Korea
10	Xu	Xiangang Xu	Shandong University	China

### Activities and Registration

The ICMOVPE-XVIII program had fourteen regular sessions and two poster sessions over four days. The total number of USA attendees was 90 and the total registration was 223.

Registration Category	Registration Number
Registration - Pre-Reg Regular	136
Registration - Onsite Regular	16
Registration - Pre-Reg Student	51
Registration - Onsite Student	5
Registration - Exhibitors	15
Total	223

**ICMOVPE XVIII Sponsors and Exhibitors**

ICMOVPE XVIII had significant financial support from Agnitron, Alliance MOCVD, Laytech, Taiyo Nippon Sanso/Matheson, and Umicore, Sandia National Laboratories, the US Army Research Office, the DoE Office of Basic Energy Sciences, and the National Science Foundation.

We were fortunate to have the additional on-site support of nineteen commercial vendors of equipment and services related to III-N materials and devices who arranged to have a booth at ICMOVPE XVIII to display and demonstrate their products. These companies are listed below.

Advanced Furnace Technology Ltd.  
MOVPE Susceptor Cleaning and Graphite Purification  
[advancedfurnacetechnology.com](http://advancedfurnacetechnology.com)

Agnitron Technology, Inc.  
Custom R&D MOCVD Equipment; Imperium-MOCVD Control Software; Refurbished and Upgraded Legacy MOCVD Equipment  
[www.agnitron.com](http://www.agnitron.com)

AIXTRON SE  
MOCVD, PECVD, CVD, OVPD, PVPD and ALD Deposition Equipment  
[www.aixtron.com](http://www.aixtron.com)

AkzoNobel High Purity Metalorganics  
High Purity Metalorganics  
[www.akzonobel.com/hpmo](http://www.akzonobel.com/hpmo)

Alliance MOCVD, LLC  
Parts; Service; Upgrade/Refurbishment; System Sales; Process Development  
[www.alliancemocvd.com](http://www.alliancemocvd.com)

CS Clean Solutions  
Dry Scrubber; Chemisorption System; Hydride Abatement; Plasma PFC Destruction; Emergency Release Scrubber  
[www.cscleansystems-usa.com](http://www.cscleansystems-usa.com)

Dockweiler Chemicals GmbH  
TBAs; TBP; TMGa; TMIn; TMAI; Full Range of Dopants; 2D Materials  
[www.dockchemicals.com](http://www.dockchemicals.com)

DOWA International Corporation  
GaAs Substrates; High Purity Metals  
[www.dowa.co.jp/index\\_e.html](http://www.dowa.co.jp/index_e.html)

EMD Performance Materials  
High-tech Materials  
[www.emd-performance-materials.com](http://www.emd-performance-materials.com)

Evans Analytical Group  
Analytical Services  
[www.eag.com](http://www.eag.com)

k-Space Associates, Inc.  
In situ and Ex situ Metrology Tools for Epitaxy  
[www.k-space.com](http://www.k-space.com)

KITEC GmbH  
Non-contact Sheet Resistance Measurement Tools  
[kitec-resistance-measurement.com](http://kitec-resistance-measurement.com)

LayTec  
Compound Semiconductor Process Monitoring Instrumentation  
[www.laytec.de](http://www.laytec.de)

Semiconductor Technology Research, STR Group  
Software Products: SimuLED, SimuLAMP, CVDSim, Virtual Reactor  
[www.str-soft.com/contact](http://www.str-soft.com/contact)

Structured Materials Industries, Inc.  
CVD, MOCVD, PECVD and ALD Systems and Components; Deposition Services; Electronic Materials; Contract Research  
[www.structuredmaterials.com](http://www.structuredmaterials.com)

Taiyo Nippon Sanso/MATHESON  
MOCVD; HVPE; Cleaning; Annealing; AsH<sub>3</sub>, PH<sub>3</sub>, NH<sub>3</sub> Specialty Gases; Purifier; Abatement  
[www.mocvd.jp](http://www.mocvd.jp)

Umicore AG & Co. KG  
Sustainable Metals; Organometallic Chemistry; Direct Vapor; Trimethylgallium; Triethylgallium; Trimethylaluminum; Trimethylindium  
[www.chemistry.umicore.com](http://www.chemistry.umicore.com)

Wafer Technology Ltd.  
III-V Substrates: GaAs, InP, GaSb, InSb, InAs  
[www.wafertech.co.uk](http://www.wafertech.co.uk)

WEP  
Electrochemical Capacitance-Voltage (ECV) Profiler  
[www.wepcontrol.com](http://www.wepcontrol.com)

### **Registration Fees**

The ICMOVPE XVIII registration fees where: Regular-\$1,100 and Student-\$850

### **Attendance and Program**

The ICMOVPE XVIII conference program consisted of 26 sessions (including the Industrial Rump session. The technical program contained 96 posters and 111 oral presentations including 7 in the Rump session.

### **Support for Student and Post-Doctoral Attendees**

ICMOVPE XVIII had a total of 216 presentations and of these; there were 70 Student oral or poster presentations. The funds we obtained for student support from the **Army Research Office** were distributed among the registered students and Post Docs to supplement the full cost of registration of \$1,100 each for regular registration to the reduced rate of at \$850 each for graduate students and Post Docs.

ICMOVPE XVIII program may be viewed here: <http://www.mrs.org/icmovpe-xviii>