Microelectronics Research Group (MRG)

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INSTITUTE OF ELECTRONIC STRUCTURE AND LASER

(I E S L)

Matter and Light !

IESL/FORTH

LASER AND APPLICATIONS DIVISION
- Atomic Physics (Strong field effects, Quantum gases)
- Molecular Physics, Chemical Dynamics
- Laser Interactions with Materials and Applications
- Biomedical Applications

MATERIALS and STRUCTURES
- Materials Science (Magnetic, Photonic and Electronic Materials)
- *Microelectronics (Compound Semiconductors)*
- Polymer Science (Soft matter Physics)

THEORETICAL AND COMPUTATIONAL PHYSICS AND CHEMISTRY DIVISION
- Theoretical Physics and Chemistry
- Environmental Studies

MRG at a glance

-
-Started in 1985 by A. Christou, focused on III-arsenide microwaves
-By 1990 a full laboratory with material and fabrication capabilities
-A joint effort between IESL & University of Crete
-Since 1993 moved towards wide band gap semiconductors (SiC, III-nitrides)
2008
-Group of 40 persons, including graduate students

- Molecular beam epitaxy of compound semiconductors (III-nitrides, III-arsenides, SiC)
  thin films, heterojunctions, quantum wells, quantum dots

- Device processing and characterization:
  microelectronics (HEMTs, MMICs, RF-MEMS, RTDs, sensors…)
  optoelectronics (LDs, LEDs, detectors, solar cells,QDs…)

-Targeted areas of applications:
  information society and nanotechnology, space, security, biotechnology

"Vertical" manufacturing unit

- Material production by MBE
- Material assessment
- Device or circuit fabrication
- Characterisation

Main infrastructure

- 200 m² clean rooms (class 1000), 50m² clean room (class 10000)
- three MBE systems (III-arsenides, III-nitrides, SiC)
- Deep-UV lithography (feature size 0.3µm)

UV mask aligner, PECVD, RIE, e-gun beam evaporator, sputtering

-Characterization

Electrical (C-V, I-V, Hall, RF-measurements up to 20GHz)

Optical (including at cryogenic temperatures)

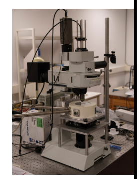
Structural (AFM, XRD, SEM, FESEM),

-Recent upgrades

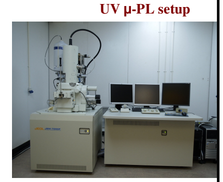
UV micro-photoluminescence setup

Triple-axis high-resolution XRD

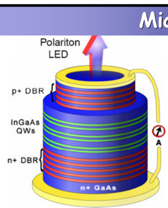
Thermal FE-SEM, e-beam lithography (1.5nm)


UV µ-PL setup

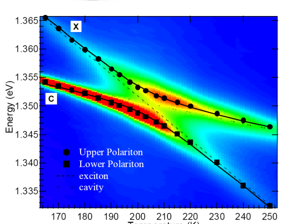

HRXRD apparatus


Thermal Field emssion SEM for nanopatterning

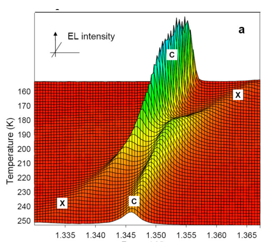
Microcavity Physics and Devices



Microcavity polariton LED at 240K



Polariton electroluminescence



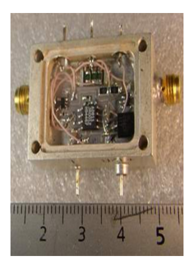
-polariton lasers and amplifiers
-ultra-efficient light emitters
-strong coupling at RT

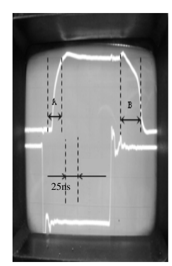
Nature, Vol.453, p. 372, 2008

3 diode (SP3T) Modulator

- Multiple diode modulators => isolation increase.


Diodes side

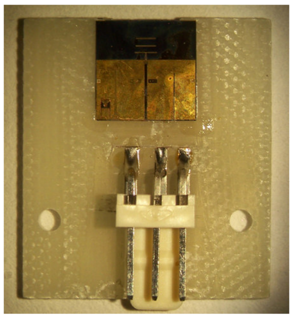

Control side

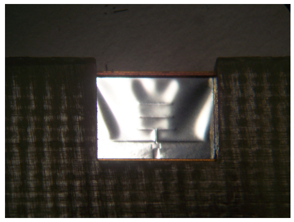


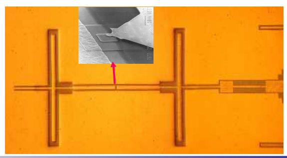
Switching speed

State of the art devices, best in the world in operating at high temperature>300°C

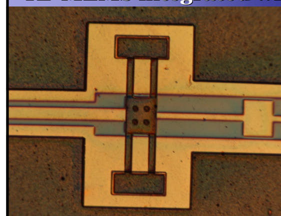
77 GHz Schottky diode receiver monilithic integrated with an antenna on a membrane

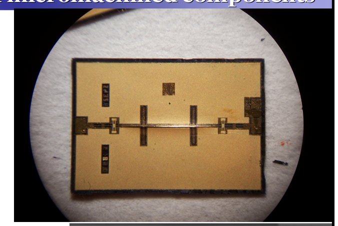


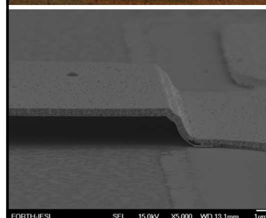


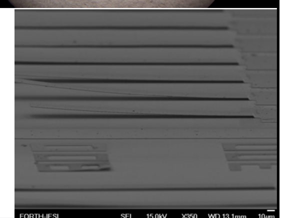


RF MEMS integrated with micromachined components

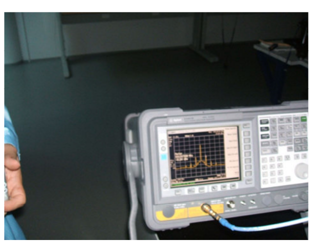






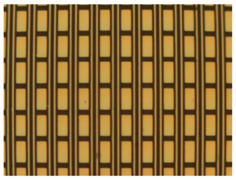


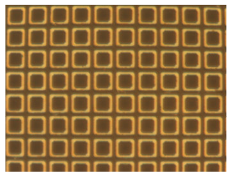
GaAs micromachined 60 GHz Yagi-Uda antennae based receiver used as MMID tag

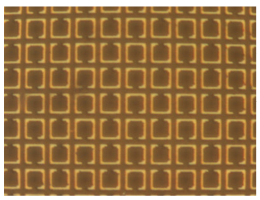


The MMID concept was demonstrated at a distance of about 1.5 m.

Multistacking

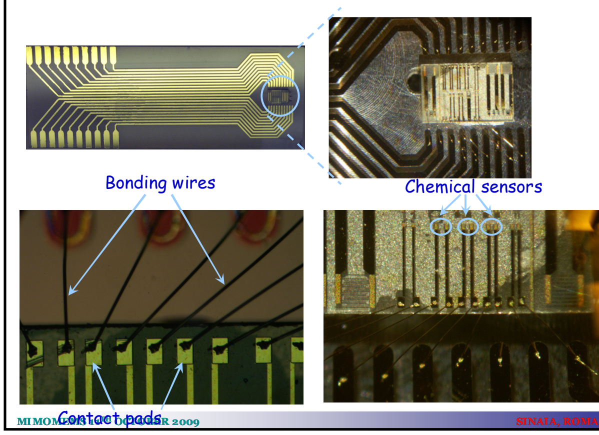






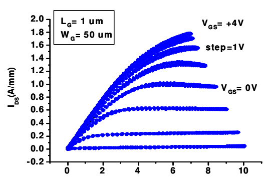
Winners
DESCARTES 2005

Fabrication of III-nitride based chemical sensors

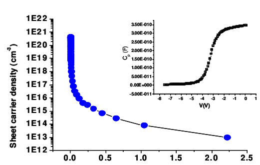


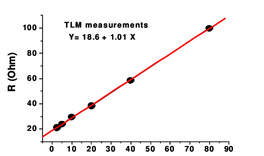
Electrical Characterisation of AlN barrier HEMTs

I-V characteristics of RF transistors



C-V measurements





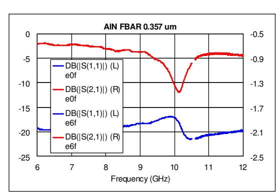
Results:

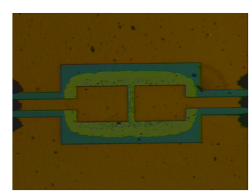
DC performance:

- I_{DS}=1.92A/mm, (L_G=1µm)
- g_m=400mS/mm
- Record low channel sheet resistance: R_{sh}=82 Ohm/sq
- Contact resistance R_T= 0.9 Ohm mm

Very thin membrane

FBAR series connection (AlN membrane W= 0.357 µm)

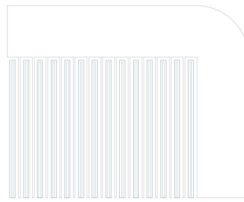




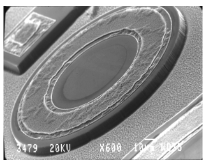
Operation at 10GHz, best result, unpublished)

Collaboration with European Space Agency

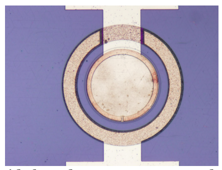
Aerogel for ultra light mirrors



SiC JFETs



SiC based avalanche photodiodes



Nitride based RDTs & Quantum dots

MRG effort to “link” with the “ market”

Actions

- 1996 establish (with GSRT funding) an open services laboratory with detailed offered services/products and corresponding costs
- ISO 9001 certification of the device &IC fabrication lab and part of material & electrical characterisation

Results

- Satisfactory load of “orders”
- Small income due to the fact that the majority of the “customers” were other academic laboratories

TÜV CERT

CERTIFICATE

The TÜV CERT Certification Body of Rheinisch-Westfälischer TÜV e.V.

hereby certifies in accordance with TÜV CERT procedure that

FOUNDATION FOR RESEARCH AND TECHNOLOGY HELLAS
Institute of Electronic Structure & Lasers
Microelectronics Research Group
Processing Unit
Heraklion / Hellas

Has established and applies a quality system for

Design and fabrication of compound semiconductor based discrete devices and integrated circuits

An audit was performed, Report No. 3.0.2-1855/2000

Proof has been furnished that the requirements according to ISO 9001 : 1994 / EN ISO 9001 : 1994 are fulfilled. The certificate is valid until October 2003

Certificate Registration No. 04100 01338

DAR TGA-ZM-30-96-00

Essen, 05.10.2000

RWTÜV

TÜV CERT Certification Body of Rheinisch-Westfälischer TÜV e.V.

Clarifications

- Costs refer to equipment only
- Short means immediately and up to 3 years
- **Medium means 5 to 6 years**
- **Long means 6 to 10**
- **TBD means that the final cost will depend on volume of order and time scale**

MRG potentially exploitable services

Service	Specifics	Cost
MBE (3inch) material	GaAs MESFET GaAs/AlGaAs HEMT	TBD
Metallization (E-BEAM)	Common metals, Noble metals, Refractory metals Up to 1 micron thickness	TBD
Metallization (sputtering)	Alloys	TBD
Bonding	Wire bonding from device to package	TBD
High resolution SEM	1nm resolution	TBD

Interest by Ciphotonics (UK) for our Au/Sn solder bump technology

MRG potentially exploitable know-how in III-nitrides/1

Know-how	MRG key advantages	Prospect	Target market (size)	Investement type	Investment cost (M€)
AlN barrier HEMT material	Unique technique for the specific material in terms of quality	Short	Base stations Radars Harsh environment operation	MBE	1.5
AlN barrier HEMTs	Home grown material available	Medium	Base stations Radars	Stepper Atomic layer oxide deposition system	1.5
III-nitride based ISFETs	Access to a broad range of HEMT material	Medium	Bioanalysis		
III-nitride based acoustic devices	Best performance due to high velocity of the acoustic waves, co-integration with electronics	Medium	Gas sensors Electronic filters (mobile phones) Harsh environment operation	ICP etcher	0.5

Διπλ. Ευρεσιτεχνίας OBI, Αριθ. 1004675, Αθήνα 13/09/2004, *"Ανάπτυξη με την μέθοδο Επίταξης με Μοριακές Δέσμες με Πηγή Πλάσματος Αζώτου ετεροδομών ημιαγωγών Νιτριδίων που περιλαμβάνουν στρώματα κραμάτων Νιτριδίου του Ινδίου-Αργιλίου-Γαλλίου"*, Α. Γεωργακίλας, Ε. Δημάκης, Ν. Πελεκάνος.
Αίτηση Ελληνικής Πατέντας (OBI), Αριθμός Αίτησης: 20040100117(2-4-2004), *«Χρήση Ημιαγωγού Νιτριδίου του Γαλλίου (GaN) για την Ανίχνευση και Μέτρηση Αρνητικά Φορτισμένων Ουσιών και Συσκευές Μέτρησης»*, Ν. Χανιωτάκης, Ι. Αλιφραγκής, Γ. Κωνσταντινίδης και Α. Γεωργακίλας

MRG potentially exploitable know-how in III-nitrides/2

Know-how	MRG key advantages	Prospect	Target market (size)	Investement type	Investment cost (M€)
AlGaN/GaN resonant tunelling diodes	The 1st demonstration of iii-nitride RTDs	Medium	*Terahertz imaging* Security, ultra fast electronics, control electronics for harsh environment	New generation of III-nitride MBE	1.5
Tunable UV-VIS PDs	UV-VIS spectral region RT operation	Long	*Hyperspectral imaging* Earth imaging, Remote sensing Medical applications	New generation of III-nitride MBE	1.5
InGaN based high efficiency solar cells	Full solar spectrum coverage	Long	Space solar cells Environmetally friendly solar cells	New generation of III-nitride MBE	1.5

MRG potentially exploitable know-how in SiC

Know-how	MRG key advantages	Prospect	Target market (size)	Investement type	Investment cost (M€)
SiC IMPATT & PIN diodes	Unique performance especially at elevated temperatures	Short	Defense Commercial space Base stations for mobiles Low to medium power radars (3M$ 2010 to 30M$ 2016)	LPCVD Oxidation furnace	0.5 0.3
	"Method of making an ohmic contact to p-type silicon carbide, comprising titanium carbide and nickel silicide", K. Vassilevski, K. Zekentes, **U.S. Patent No. 6,599,644** issued on July 29, 2003 and **Canadian patent No 08-888998CA** issued on September 3, 2008.				

Interest by MICROSEMI (USA) for our SiC based diodes

MRG potentially exploitable know-how in optoelectronics

Know-how	MRG key advantages	Prospect	Target market (size)	Investement type	Investment cost (M€)
Polariton based devices	1st demonstration of polariton LEDs at room temperature	Medium	WDMs (billion$)	In situ monitoring of thickness MBE upgrade ICP RIE	2
Quantum dot based devices	Strong advance on (211)B piezoelectric quantum dots	Long	Single photon emitters for Cryptography (tens of millions$)	Sophisticated instrumentation for handling & measuring single photons (eg. SensitivedDetectors)	1

MRG potentially exploitable know-how in oxide TCOs & TFTs

Know-how	MRG key advantages	Prospect	Target market (size)	Investement type	Investment cost (M€)
Thin oxide technology	P type oxides	Medium	UV LEDs emitters UV-detector arrays Solar cells (millions of $)	Multi-target sputtering system	1
TFTs	Transparent thin film transistors	Medium	Displays Transparent electronic Flexible electronics (billions of $)	Multi-target sputtering system	1

MRG potentially exploitable know-how in micromachining

Know-how	MRG key advantages	Prospect	Target market (size)	Investement type	Investment cost (M€)
Very thin Membrane technology	1st demonstration of passive & active devices monolithically integrated on a membrane	Medium	Short range communication Ambient intelligence	E-beam aligner ICP etcher	1 .05

MRG potentially exploitable know-how in ESA related activities

Know-how	MRG key advantages	Prospect	Target market (size)	Investement type	Investment cost (M€)
Ultra light mirrors & other optical components on aerogel substrates	1st demonstration	Short	Space	Dedicated metal evaporator with slow pumping and venting accessories	0.3

Final comments

- MRG have technologies to exploited <u>**immediatel**</u>y
- There is a growing "microelectronics" environment in Greece (HSIA, Cluster Coralia, Micro&Nano) but targets (at the moment) very focused areas and is fabless and Si or Si-Ge
- Difficult to develop products within an academic laboratory
- There is a need for significant and steady investment in equipment and people
- Latest example : FBH institute in Berlin has created a spin off company in GaN/AlGaN MMICs (BeMiTec), with a facility 700m2 clean rooms and an annual state funding of 9 M€ from which 2-3 are for new equipment