



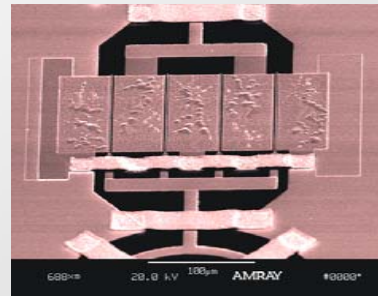
GALLIUM NITRIDE

GaN-based systems

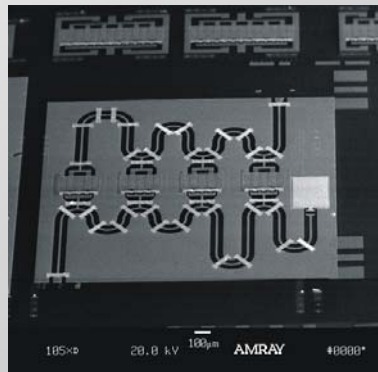
Optoelectronic devices



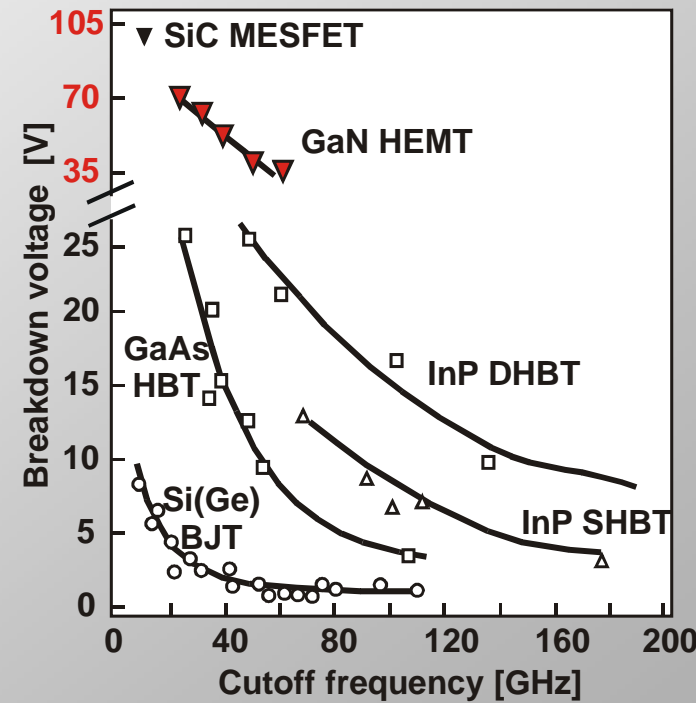
Power microwave amplifiers



4x125 μm Gates



Microwave Amplifier



100 W (11 W/mm) at 10 GHz

GaN potentials

- GaN (and its heterostructures with AlGaN and InGaN alloys) provide a valuable system for MEMS and NEMS.
- The electronic, optical, mechanical, and thermal properties of this material system offer a unique opportunity for a class of multifunctional devices and sensors, which can operate at microwave also in harsh environments.
- The proven ability to use Silicon as a substrate opens the possibility of micro and nanomachining conventional technologies

Wide Gap Semiconductors

Wide Bandgap Power Components: Why

- ▶ The intrinsic properties of wide bandgap semiconductor materials, such as for example SiC and GaN, are almost ideal for high power / high efficiency microwave components

PROPERTY	Si	GaAs	4H-SiC	GaN	ADVANTAGES OF SiC/GaN DEVICES
BANDGAP (eV)	1.12	1.43	3.25	3.4	HIGH TEMPERATURE OPERATION
BREAKDOWN FIELD (MV / cm)	0.25	0.3	3	3	HIGH VOLTAGE OPERATION
SATURATED ELECTRON VELOCITY (10^7 cm/s)	1	2.0 (peak) 1.2 (sat.)	2.0	2.5 (peak) 1.5 (sat.)	HIGH FREQUENCY OPERATION LIKE GaAs
THERMAL CONDUCTIVITY (W/cm K)	1.5	0.5	4.9	1.3 (on sapphire)	RELIABILITY AT HIGH POWER DENSITY



Wide Gap Semiconductors

Wide Bandgap Power Components: Why

- ▶ **The need for solid state microwave sources that can operate at high RF output power and high power-added efficiency over a large bandwidth;**
 - ▶ Mobile communication base station transmitters
 - ▶ Phased Array Radars
 - ▶ Satellite transponders

- ▶ **The difficulty in fabricating solid state microwave amplifiers from conventional semiconductors;**
 - ▶ GaAs and Si limited to 10's or 100's watt levels
 - ▶ Kilowatt amplifiers reported, which combine outputs of a large number of devices, are difficult to make
 - ▶ Reliability issue



GaN electronic components

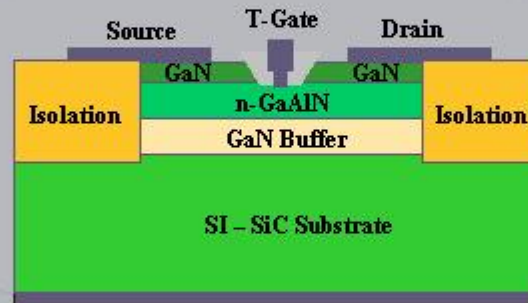
Wide Bandgap Power Components: What and How

GaN High Mobility Transistor (HEMT)

SI - SiC Substrate

Design
Device simulation
Implant profiles

R.F. Test & Models
Microwave performance
Preliminary models
Reliability evaluation



Material
Epilayer growth on
SI-SiC Substrate
Undoped GaN Buffer
Doped GaAlN layer

Characterisation
Elec. and Morph. Prop.
Doped GaAlN layers
Buffer / SI -SiC interface
GaN / GaAlN interface

Processing
Isolation / Mesa etch
(MMIC compatibility)
Stepper lithography
E.B. Lithography
Gate recessing



GaN properties for power applications

- **Large on-to-off ratio**
- **High breakdown voltage**
- **Excellent temperature properties**
- **High drift velocity in large electric fields**
- **Mobility higher than Silicon**
- **Inertness**
- **High current carrying capabilities**
- **Low thermal impedance (on SiC substrates)**

... and more

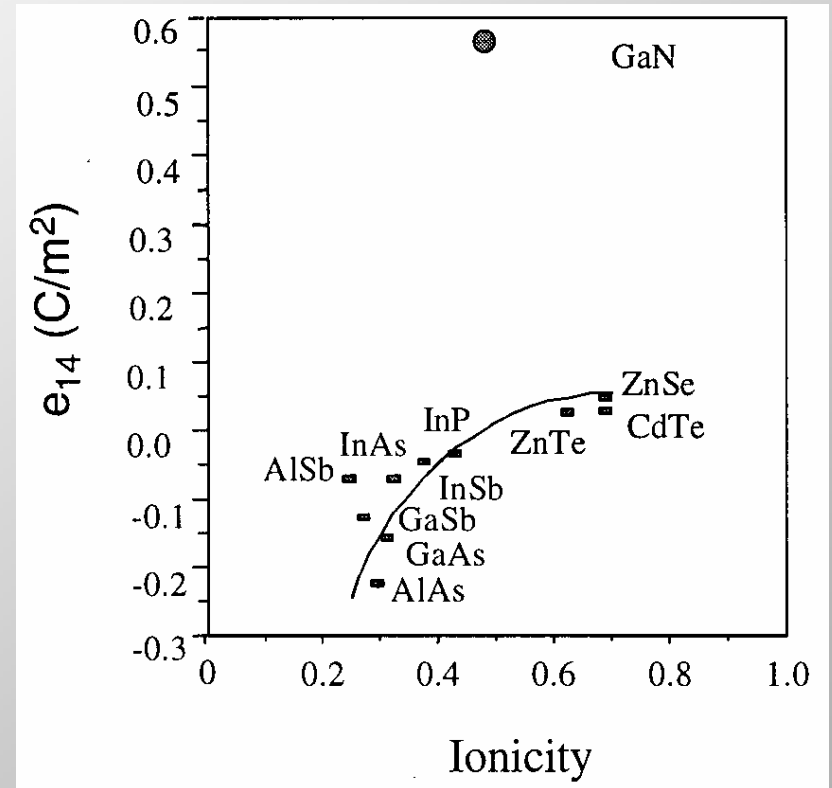
Thanks to the large energy gap, GaN-based solar blind detectors can be built

GaN is also a strongly piezoelectric material.

It also has a large piezoelectric coefficient



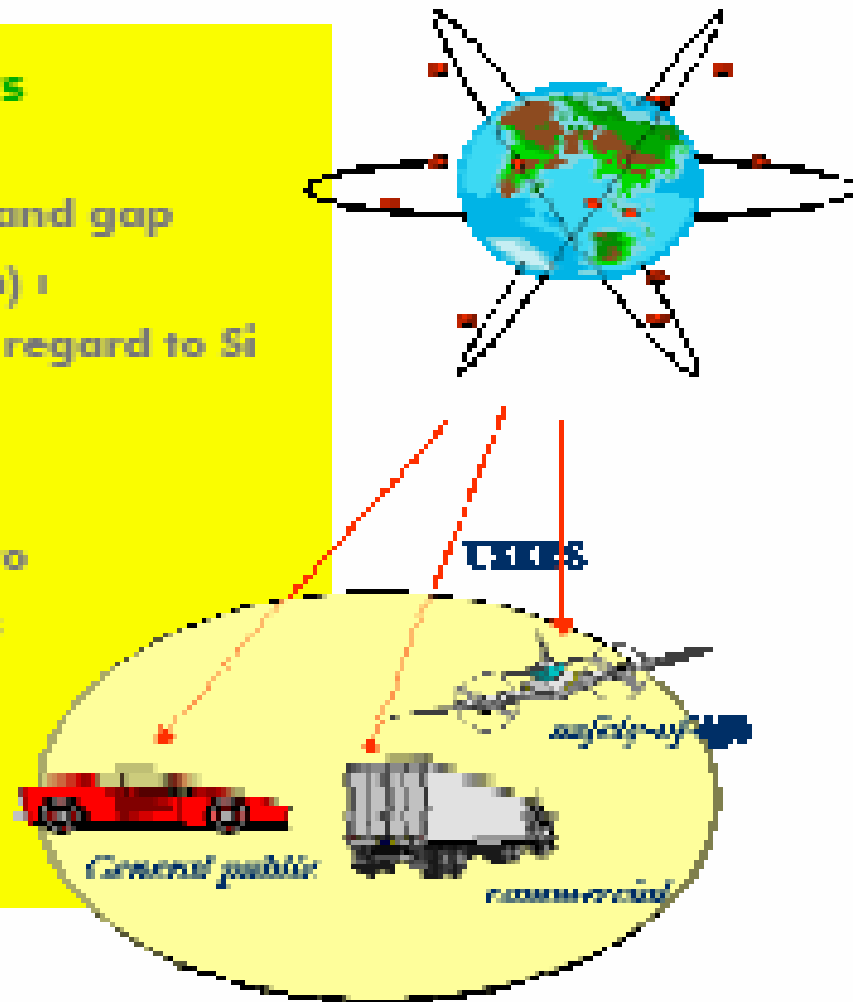
Very promising material for sensor applications (thermal, pressure, stress, optical), and in micromachining



GaN: a Disruptive Technology for Space Applications

Wide Band Gap Transistors

- Emergence of new SiC and GaN wide-band gap technologies (in the USA, Europe, Japan) : a real technological breakthrough with regard to Si and GaAs
- Space represents the ideal application to demonstrate wide-band gap transistors superiority:
 - Strong thermal constraints,
 - Availability of high voltages (100V).



Advantages of wide-band gap technologies

- ◆ **Very high breakdown field (SiC (100V) and GaN (70 V)),**
- ◆ **Able to work in high temperatures (easier thermal control),**
- ◆ **Excellent thermal conductivity of SiC either as a bulk substrate material (MESFET SiC) or as a epitaxial substrate (GaN HEMT on SiC),**
- ◆ **Load impedance close to 50 Ω (simplified output matching network**
 - **less losses, easier design of wide-band circuits),**
- ◆ **Stable and inert materials (improved immunity to radiations),**
- ◆ **Able to convey high power densities: from 2 to 6W/mm (even 10 W/mm),**
- ◆ **Able to work with high biases** □ **simplified DC/DC converters**
(bus voltage 50 to 100 V).

