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Department of Semiconductor Processing for Photonics

Hybrid Substrates for Competitive High Frequency Electronics
HYPHEN Contract No. 027455

information society technologies

COORDINATOR

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- Research Institute for Technical Physics and Material Science, Hungary
- Norstel, Sweden
- Institute of Electron Technology, Poland
- Centre National de la Recherche Scientifique, France
- United Monolithic Semiconductors, Germany

OUR ROLE IN THE PROJECT

- Advanced characterisation of composite substrates and epitaxial structures:
  - development of stress analysis procedure for 2” epitaxial films on composite substrates using TENCOR FLX-2320 thin film stress measurement apparatus; stress - temperature measurements will be carried out to facilitate the diagnostics of stress relaxation
  - optimisation of stress measurement procedure for epitaxial structures on 3” and 4” composite substrates
  - development of thermal conductivity of composite substrates by photothermal measurements
- Development of passivation process for GaN/AlGaN HEMT on composite substrates

PROJECT DESCRIPTION

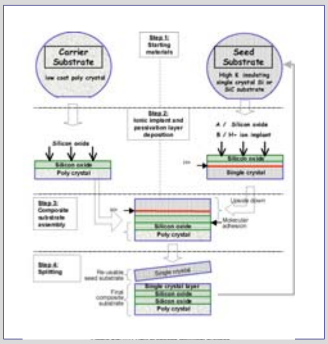
The overall objective of the HYPHEN project is to demonstrate the feasibility and assess the performances of a new kind of composite substrate for high frequency high power circuits. For such applications, the major substrates requirements are high thermal conductivity and high electrical resistivity with low microwave loss factor up to at least 20 GHz, together with perfectly ordered single crystal top layer stack as required for any kind of top performance semiconductor device.

The combination of those properties in a homogeneous material is extremely rare. The existing high performance substrates, such as SiC or diamond exhibit a cost, which is higher than the one of Silicon by at least two orders of magnitude, and it is generally admitted that this cost is not likely to decrease substantially in the future years.

HYPHEN’s main objective is to bridge the gap between the low-performance and low-cost single crystal silicon and the high-performance and high-cost single crystal SiC substrate currently used for GaN based RF devices.

The main physical properties of HYPHEN substrates expected are:

- Resistivity and microwave losses - equal or better than the values currently obtained on semi-insulating GaAs ($1x10^5$ Ωcm), which does represent state-of-the-art material today that is used to manufacture excellent high frequency devices.
- Thermal conductivity - twice that of silicon (1.5 $Wcm^{-1}K^{-1}$), 6 times that of GaAs (0.5 $Wcm^{-1}K^{-1}$), 65% that of the best single crystal SiC (4.5 $Wcm^{-1}K^{-1}$).



The substrate properties targeted for the HYPHEN project have been chosen to meet the requirements for the next generation of microwave power devices, expected to be based on wide bandgap semiconductors such as GaN and related materials. The same requirements refer to the substrates for advanced VLSI circuits and for nanoelectronics. The basic innovative idea of the HYPHEN proposal is to explore composite substrates combining the excellent physical properties of existing cheap polycrystalline substrates, such as poli-SiC, together with the quasi-perfect surface order of the best single crystal SiC or silicon substrates. A low-cost carrier substrate is bonded on a high quality seed substrate; the resulting part is again split into two substrates:

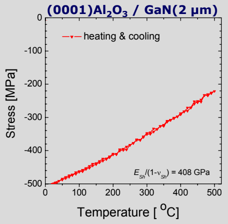
- The HYPHEN substrate composed of the initial carrier substrate with, on top of it, a thin layer of high quality single crystal layer generated by the seed substrate,
- The re-usable high-quality seed substrate.

The important milestone of HYPHEN project will be demonstration of GaN-based HEMT devices made on samples of the new composite substrates, with electrical properties comparable to reference devices on Si and SiC. We assume that a final result of the project will be HEMTs with power density 10 W/mm^2 (for U_{drain} = 50 V) and 5 W/mm^2 (for U_{drain} = 25 V) at frequencies 2 GHz and 10 GHz respectively.

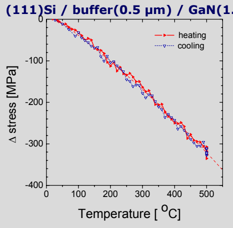
RESULTS

Stress measurements

$(0001)Al_2O_3$ / GaN(2 µm)



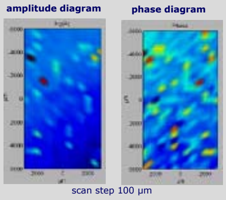
(111)Si / buffer(0.5 µm) / GaN(1.5 µm)

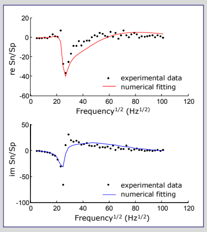


Photothermal measurements

poli SiC:

thermal conductivity
κ = 0.47 - 0.53 $Wcm^{-1}K^{-1}$



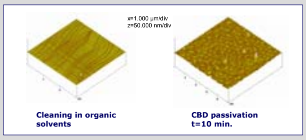


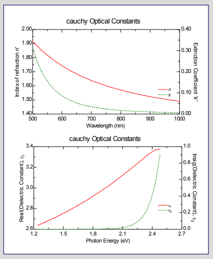
4H SiC/epi-SiC: → thermal conductivity κ = 2.00 $Wcm^{-1}K^{-1}$

Surface passivation

Passivation of GaN-based surfaces by Chemical Bath Deposition (CBD) of CdS

Semiconductor material: p-GaN:Mg (d=2µm) on (0001) Al_2O_3
Processing: **step 1 -** surface pretreatment
0.1M $SC(NH_2)_2$ + 2.4M NH_4OH (35ml+35ml)
@ T=65°C; t=5min.
step 2 - chemical passivation
0.1M $SC(NH_2)_2$ + 0.1M $CdSO_4$ (30ml+30ml)+2.4M NH_4OH (7ml)
@=65°C; t=10min.





Height of the Schottky barrier

Schottky contact - Ir
d=60nm, ϕ=300µm
sputter deposition (Leybold Z400)

Ohmic contact - Ti/Al
d=30nm/200nm
sputter deposition (Leybold Z550)

without passivation	CBD passivation
Φ_B = 0.57 eV	Φ_B = 0.81 eV

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