SiC, sapphire and GaN materials status into Opto and RF businesses.

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Abstract

With more than 2.8 million 2" equivalent substrates consumption in 2005, LED business is driving 90% of SiC material and is representing about 2.5 million sapphire wafers. The emergence of bulk single crystal GaN will certainly take market shares over SiC and sapphire substrates, especially for high end devices like ultra HB-LEDs and blue laser diodes. In RF business, GaN HEMT and SiC MESFET are both competing for the base stations segment, targeting 3G, WCDMA, WiMax or even defense applications.

INTRODUCTION

SiC, GaN and sapphire are used as substrates for GaN active layers epitaxy. Sapphire is widely used for LED business but cannot fit with high-power RF devices requirements. GaN bulk material is now challenging SiC or sapphire for blue lasers manufacturing and is seen as a possible solution for the next white LED generation targeting the general illumination market.

SAPPHIRE IS LEADING GaN-BASED LEDS MARKET FACING SiC

90% of SiC material production is dedicated to blue/white LEDs and is captive for Cree, Osram and related Sumitomo agreement, but changes are expected [1].
Recent Osram announcements showed that the company is now involved in blue/white LEDs production not using SiC but Sapphire. They proved that "Thin-film" technology using GaN onto removed sapphire substrates allows reaching roughly the same luminous efficiency for the final device. Question is now open to know if Osram will transfer all the production using that technique so that they will give up SiC-based LEDs.

At the same time, Cree is announcing that it will now propose packaged LEDs and not only LED dies as they did until now. Cree is then going one step beyond in the LED business food-chain, certainly looking for more added value products [2].

Today SiC-based LEDs production is in the range of 320,000 x 2" equivalent substrates. Production is now migrating onto 3" wafers at Cree. The total 2" equivalent wafers production for blue/white LED worldwide is estimated to 2.8 millions in 2005, so that SiC will only represent 12% of the material consumption facing 2.5 million sapphire wafers (Fig. 1).

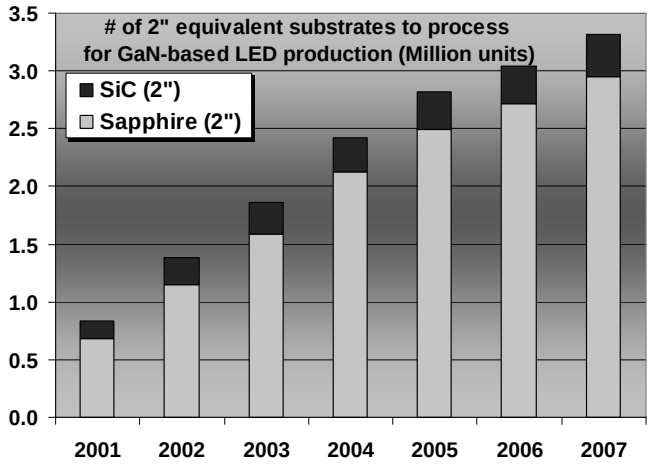

Fig. 1 : SiC vs. Sapphire substrates volume for GaN-based LEDs production

Moreover, all others worldwide players are using sapphire and some of the best available performances have been achieved onto it. Is there any advantage using SiC today ? Will SiC allow more rapidly to reach the ultimate > 200 lm/watt efficiency that will be the starting point for large white LED production targeting general illumination business ?

BULK-GaN IS THE KEY MATERIAL FOR BLUE LASER DIODES

Bulk GaN is now ready to enter the market place. Players like Cree, Kyma, Sumitomo, Lumilog or Hitachi Cable are proposing bulk or free-standing GaN material on a commercial basis. Those substrates show very low dislocation density (< 10^7/cm²) in a standard 2" diameter. Japanese company Nichia has already started to use this material for their blue laser diodes production. On the other hand, LEDs main manufacturers are reluctant to use it because of its very high price (from $1,500 to more than $6,000 per wafer depending on the quality). They don't see bulk-GaN introduction for LED manufacturing in a near

future. We estimate that blue lasers production for next DVD generation could handle about 60,000 x 2" bulk GaN substrates by 2009 if this material is chosen.

HIGH POWER RF DEVICES: A BATTELFIELD FOR GaN & SiC

SiC MESFET and GaN HEMT are competing on the RF devices market segment as a replacement technology for silicon or GaAs. Companies like Cree or Rockwell announced first commercial offers in SiC MESFET from baseband up to S-band. At the same time, Cree, Nitronex, Fujitsu, NEC or RFMD are showing impressive results on GaN FET structures [3].

The challenge for these components is now to achieve long life-time, high power efficiency (PAE), good reliability, flat frequency response on whole bandwidth and to be price competitive. Base stations manufacturers are expecting reliable components in the 1$/watt price range. SiC or GaN technologies have to face this situation proposing new solutions to break the silicon LDMOS monopole (Fig.2).

WiMax is certainly the most promising new incoming application for GaN or SiC RF devices. Nitronex has already demonstrated a GaN-based PA for WiMax application and competitors are now challenging it.

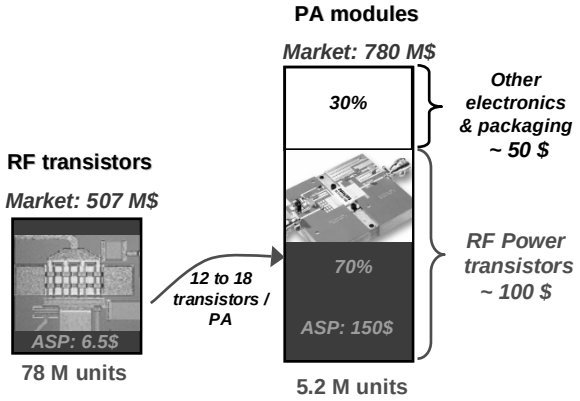

Fig. 2 : 2004 foodchain analysis for GaAs or Si RF transistors in base stations market for which SiC or GaN technologies are promising.

CONCLUSIONS

2" sapphire is representing 80% of substrates volume for GaN-based LEDs. Wider diameters are being introduced in order to decrease the production cost but 2" still dominates. SiC is captive from Cree and Osram but things are moving on the Osram side. Bulk-GaN substrates are slowly entering in production in Japan but are targeting high-end applications like blue laser diodes where material quality is a key factor of success. The battle between SiC and GaN-based RF devices is now engaged not only on 3G base stations side but also on defense, spatial and future WiMax front.

ACKNOWLEDGEMENTS

The author would like to point out that these data are extracted from numerous market reports YOLE DEVELOPPEMENT is editing.

REFERENCES

[1] YOLE DEVELOPPEMENT, SiC market 2005 edition report: from material to devices, 2005.

[2] YOLE DEVELOPPEMENT, LED2Light report: HB-LEDS for General Illumination and Automotive Lighting, 2005

[3] YOLE DEVELOPPEMENT, WIDE report: World market for wide bandgap materials and devices for RF applications, 2005

ACRONYMS

LED: Light Emitting Diodes
SiC: Silicon Carbide
GaN: Gallium Nitride
PAE: Power Added Efficiency
MESFET: MEtal-Semiconductor Field Effect Transistor
HEMT: High Electron Mobility Transistor
PA: Power Amplifier