# UltraGaN project: Breakthrough in GaN devices thanks to InAlN/GaN Heterostructure

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## Project objectives

Next generation wireless network base stations, satellite communication systems and compact digital radar are just few examples where GaN-based devices can multiply the efficiency of amplifiers. However, improvements in GaN-based High Electron Mobility Transistors (HEMTs) are limited by the physics of already established AlGaN/GaNheterostructure system. ULTRAGAN project was aiming to explore new **stress-free** heterostructures using InAlN/(In)GaN alloys. The objective was **to triple the HEMTs power density** if compared to the state-of-the-art large periphery AlGaN/GaN HEMTs, InAlN/(In)GaN HEMTs are to demonstrate power densities of **30W/mm** at **2 to 12 GHz.** These parameters can be achieved primarily because of expected extremely high 2- dimensional electron gas density coupled with polarisation fields in the InAlN/(In)GaN heterojunction. This spontaneous polarisation would be obtained without mechanical stress and lead to higher reliability. Molecular Beam Epitaxy (**MBE**) and Metal Organic Chemical Vapour Deposition (**MOCVD**) techniques was to be explored to develop devices including **InAlN/GaN single heterojunction (SH) and InAlN /(In)GaN/(In,Al)GaN double heterojunction (DH)** systems. Chemistry of InAlN surface was expected to be different to GaN or AlGaN and more stable device surface could be discovered. Thanks to the chemistry of surface and passivation effort, transistor **I-V instabilities such as drain lags were thought to be eliminated.** The project also includes **physical and thermal simulation, device processing and a full AC/DC** HEMT **characterization** for a thorough device optimization.

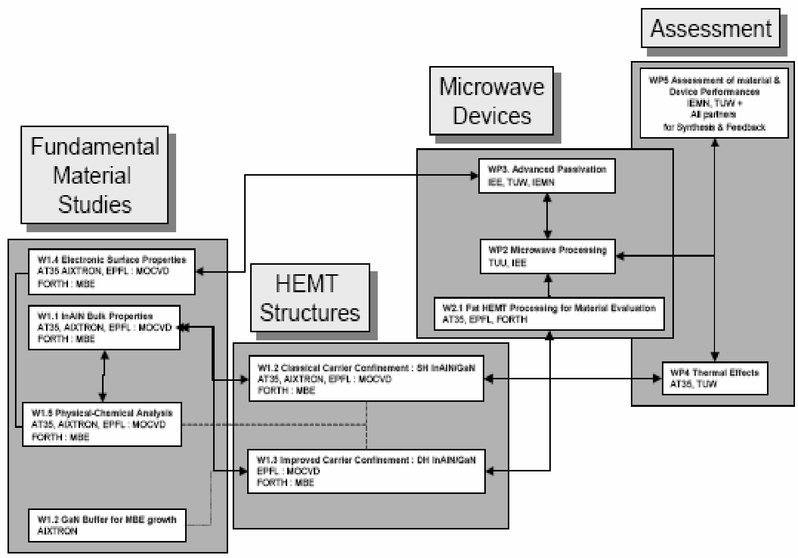


**Figure 1. UltraGaN Work Breakdown**

## UltraGaN progress

1. **<u>Optimisation of InAlN/GaN structure</u>** to get :
    a. High current (carrier sheet density, mobility, saturation velocity) up to 3A/mm (i.e.twice better as AlGaN/GaN). The introduction of an AlN exclusion layer between the 2D-gas and the InAlN was very efficient to guarantee sharp interface and lower alloy scattering.
    b. Sufficiently high breakdown voltage notably by buffer optimisation (>100V).
    c. Low contact resistance (Al is difficult to diffuse through) (down to 0.2Ωmm).
    d. High cut-off frequency (ft > 70GHz demonstrated)

2. **<u>Demonstration of HEMT structure for Al+InAlN wide bandgap layer as thin as 2.5nm!</u>**
a. 1.5 x 1013 cm-2 sheet carrier densities were achieved with thickness as low as 6nm. **This is <u>4 times thinner than typical AlGaN/GaN heterostructure</u>**.

3. This property will be crucial to GaN technology to operate at higher frequency.

4. **<u>Demonstration of microwave HEMT with current cut-off frequency up to 70GHz</u>**.

5. **<u>Demonstration of 6.8W/mm operation at 10GHz in CW</u>**. This is twice the power density recently demonstrated by US Air Force Laboratory using InAlN heterostructure.

6. **<u>Realisation of HEMT and MOSHEMT</u>**.
    a. Surprisingly the introduction of thin Al2O3 insulator below the gate doesn't degrade strongly the current gain cut-off frequency. 53GHz was measured for both structures comparing favourably with best AlGaN/GaN processed routinely at ATL and IEMN (routine value is 40GHz).

**7. <u>Lag effects.</u>**
    a. Lower lag effects (down to few %) were found by the Consortium using different approaches. Since the GaN buffers are very similar for both InAlN and AlGaN HEMT, this improvement is most probably stemming from InAlN chemistry (either InAlN crystal or free-surface).

## UltraGaN project key results

- UltraGaN project was launched on the basis of scientific hypothesis.
- A complementary Consortium was set-up and technical progresses have been fast.
- The partners' origin improves the chance to implement the work results in real world application.
- UltraGaN has been already an excellent platform of scientific production (crystal growth, physics of InAlN alloys, thermal behaviour, device processing optimisation, electrical transport). The last year will be dedicated to improve again the pure device performances.