# Growth of $AlP_yN_{1-y}$ on GaN by Metal-Organic Vapour Phase Epitaxy

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AlPN is a new material which was first grown epitaxially in 2020 [1]. $AlP_yN_{1-y}$ becomes lattice matched to GaN at around 10% P. Hence, AlPN could have many interesting applications by replacing lattice-matched AlInN. But AlPN would have a larger band gap, can be grown at similar temperatures as GaN, and with faster growth rates than AlInN. The research currently focused on the development of $AlP_yN_{1-y}$ strained barrier layers in High Electron Mobility Transistors (HEMTs) [2]. For HEMT barrier layers, one would aim for a P content of 7% which results in the same strain as conventional $Al_{0.3}Ga_{0.7}N$ barrier layers with a five times higher polarization charge.

The challenge of epitaxy is the very small size of N (covalent radius 71 pm) compared to P (107 pm) compared to Al (121 pm). Hence, there is a strong driving force to incorporate P in the group III sublattice. And indeed, trials 15 years ago to incorporate P into GaN showed that more P was incorporated in the group III sublattice than in the group V sublattice [3]. Moreover, the P incorporated on a group III site is a strong donor (two unpaired electrons) which would be not suitable for an insulating barrier layer.

AlPN barrier layers for HEMTs would be tensile strained. Thus, strain counteracts the geometrical force and can keep P on the group V sublattice. However, at typical growth conditions, strain is only enough to incorporate 2-3 % before P also incorporates on the group III sublattice. The reasons are the relatively high V-III ratios of 100 or even 1000. The high excess of N drives P also on the group III sublattice and offering that much P is detrimental to subsequent growth. (Apart from the fact that the P precursor, tertiary-butylphosphine is an expensive metal-organic). Thus, increasing growth rate and decreasing V/III ratio are preferred.

We have obtained $AlP_yN_{1-y}$ layers up to about 7% P using low V/III ratios below 20. Such low V/III ratios pose new challenges, especially how to maintain a smooth interface/surface, i.e. how to avoid roughening of the GaN or the AlPN layers. We have developed a growth sequence to address this, starting with a thin AlN layer at high V/III ratios, followed by a growth interruption to introduce P and reduce V/III ratio, and subsequent AlPN growth. All under nitrogen carrier gas, since the best growth conditions are above 1050°C where hydrogen strongly etches the GaN at low V/III ratios. The high temperatures and high growth rates are favourable for application since it would eliminate temperature ramping after buffer growth.

**References**

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