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Hite et al.

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(54) **METHOD FOR VERTICAL AND LATERAL CONTROL OF III-N POLARITY**

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H01L 21/02 (2006.01)

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2008/0087876 A1* 4/2008 Nash H01L 33/02 257/13
2010/0320505 A1* 12/2010 Okamoto H01L 29/045 257/192

* cited by examiner

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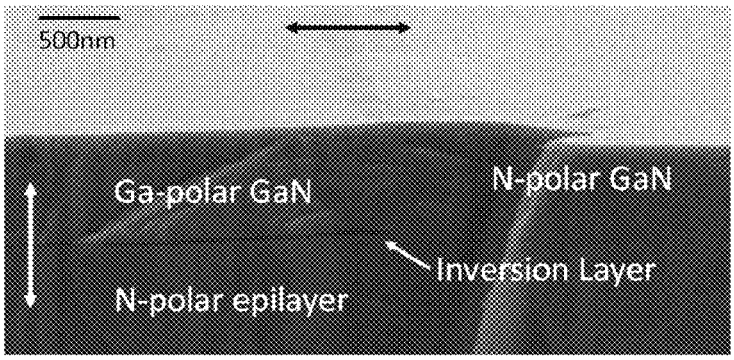
(57) **ABSTRACT**

Disclosed herein is a method of: depositing a patterned mask layer on an N-polar GaN epitaxial layer of a sapphire, silicon, or silicon carbide substrate; depositing an AlN inversion layer on the open areas; removing any remaining mask; and depositing a III-N epitaxial layer to simultaneously produce N-polar material and III-polar material. Also disclosed herein is: depositing an AlN inversion layer on an N-polar bulk III-N substrate and depositing a III-N epitaxial layer to produce III-polar material. Also disclosed herein is: depositing an inversion layer on a III-polar bulk III-N substrate and depositing a III-N epitaxial layer to produce N-polar material. Also disclosed herein is a composition having: a bulk III-N substrate; an inversion layer on portions of the substrate; and a III-N epitaxial layer on the inversion layer. The III-N epitaxial layer is of the opposite polarity of the surface of the substrate.

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