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(12) **United States Patent**  
**Cuomo et al.**

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(54) **METHOD AND APPARATUS FOR PRODUCING M<sup>III</sup>N COLUMNS AND M<sup>III</sup>N MATERIALS GROWN THEREON**

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(57) **ABSTRACT**

A method utilizes sputter transport techniques to produce arrays or layers of self-forming, self-oriented columnar structures characterized as discrete, single-crystal Group III nitride posts or columns on various substrates. The columnar structure is formed in a single growth step, and therefore does not require processing steps for depositing, patterning, and etching growth masks. A Group III metal source vapor is produced by sputtering a target, for combination with nitrogen supplied from a nitrogen-containing source gas. The III/V ratio is adjusted or controlled to create a Group III metal-rich environment within the reaction chamber conducive to preferential column growth. The reactant vapor species are deposited on the growth surface to produce single-crystal M<sup>III</sup>N columns thereon. The columns can be employed as a strain-relieving platform for the growth of continuous, low defect-density, bulk materials. Additionally, the growth conditions can be readjusted to effect columnar epitaxial overgrowth, wherein coalescence of the Group III nitride material occurs at the tops of the columns, thereby forming a substantially continuous layer upon which additional layers can be deposited. The intervening presence of the column structure mitigates thermal mismatch stress between substrates, films, or other layers above and below the columns. A high deposition rate sputter method utilizing a non-thermionic electron/plasma injector assembly is provided to carrying out one or more of the growth steps.

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(51) **Int. Cl.**<sup>7</sup> ..... **C30B 25/02**; C30B 25/04

(52) **U.S. Cl.** ..... **117/84**; 117/89; 117/95; 117/97; 117/106; 117/952; 117/953

(58) **Field of Search** ..... 117/84, 89, 95, 117/97, 106, 952, 953

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**93 Claims, 20 Drawing Sheets**

