

# **Exhibit 1**

Annotated 6,042,998 Patent



US006042998A

# United States Patent [19]

[11] **Patent Number:** **6,042,998**

**Brueck et al.**

[45] **Date of Patent:** **\*Mar. 28, 2000**

[54] **METHOD AND APPARATUS FOR EXTENDING SPATIAL FREQUENCIES IN PHOTOLITHOGRAPHY IMAGES**

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[73] Assignee: **The University of New Mexico,** Albuquerque, N.Mex.

[\*] Notice: This patent is subject to a terminal disclaimer.

[21] Appl. No.: **08/932,428**

[22] Filed: **Sep. 17, 1997**

[51] Int. Cl.<sup>7</sup> ..... **G03C 5/00**

[52] U.S. Cl. .... **430/316; 430/312; 430/323; 430/394**

[58] **Field of Search** ..... 430/396, 397, 430/313, 312, 314, 316, 322, 323, 394

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*Assistant Examiner*—Jill N. Holloman  
*Attorney, Agent, or Firm*—Snell & Wilmer, L.L.P.

[57] **ABSTRACT**

The present invention extends the available spatial frequency content of an image through the use of a method and apparatus for combining nonlinear functions of intensity to form three dimensional patterns with spatial frequencies that are not present in either of the individual exposures and that are beyond  $2/\lambda$  in all three spatial directions. The resulting pattern has spatial frequency content beyond the limits set by optical propagation of spatial frequencies limited to  $2/\lambda$ . (e.g. pitch reduction from  $-\lambda/2$  to at least  $-\lambda/4$ ). The extension of spatial frequencies preferably extends the use of currently existing photolithography capabilities, thereby resulting in a significant economic impact. Multiplying the spatial frequency of lithographically defined structures suitably allows for substantial improvements in, inter alia, crystal growth, quantum structure growth and fabrication, flux pinning sites for high- $T_c$  superconductors, form birefringent materials, reflective optical coatings, photonic bandgap, electronics, optical/magnetic storage media, arrays of field emitters, DRAM (Dynamic Random Access Memory) capacitors and in other applications requiring large areas of nm-scale features.

Support for "high spatial frequencies"

**32 Claims, 19 Drawing Sheets**

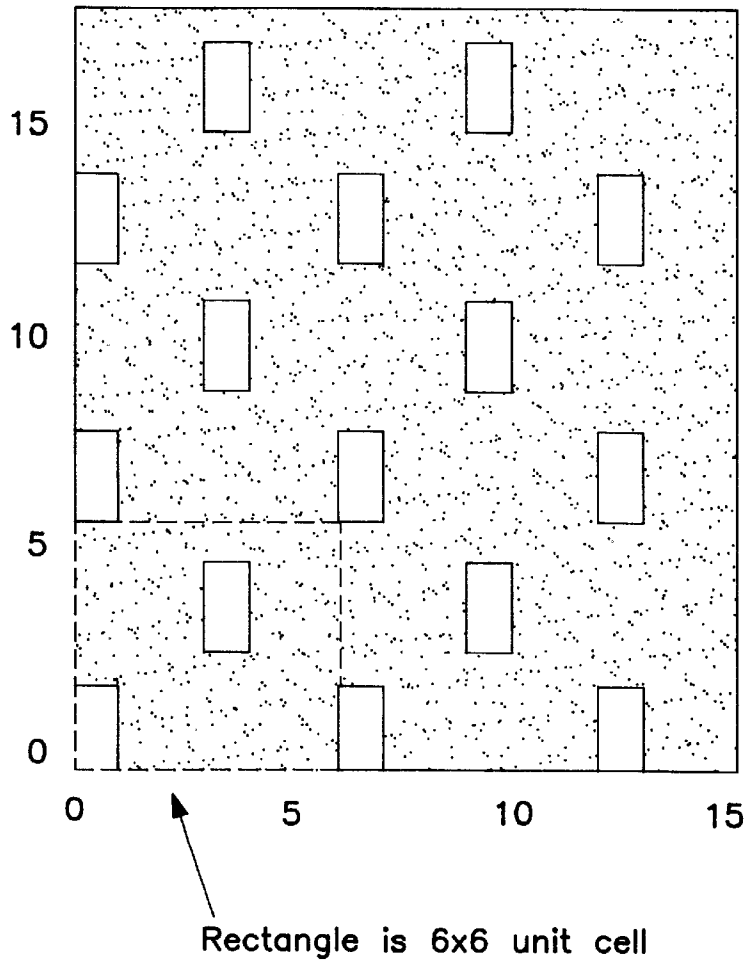


FIG. 1

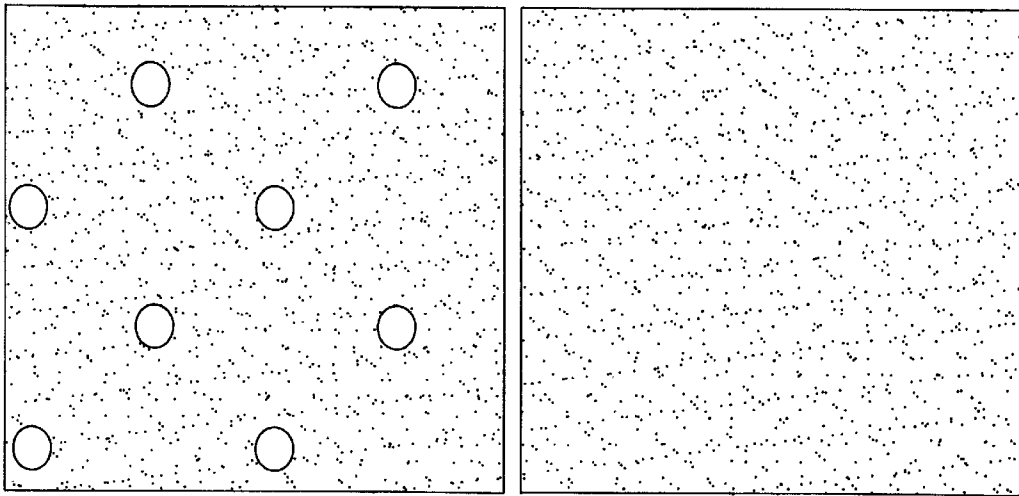


FIG. 2A

FIG. 2B

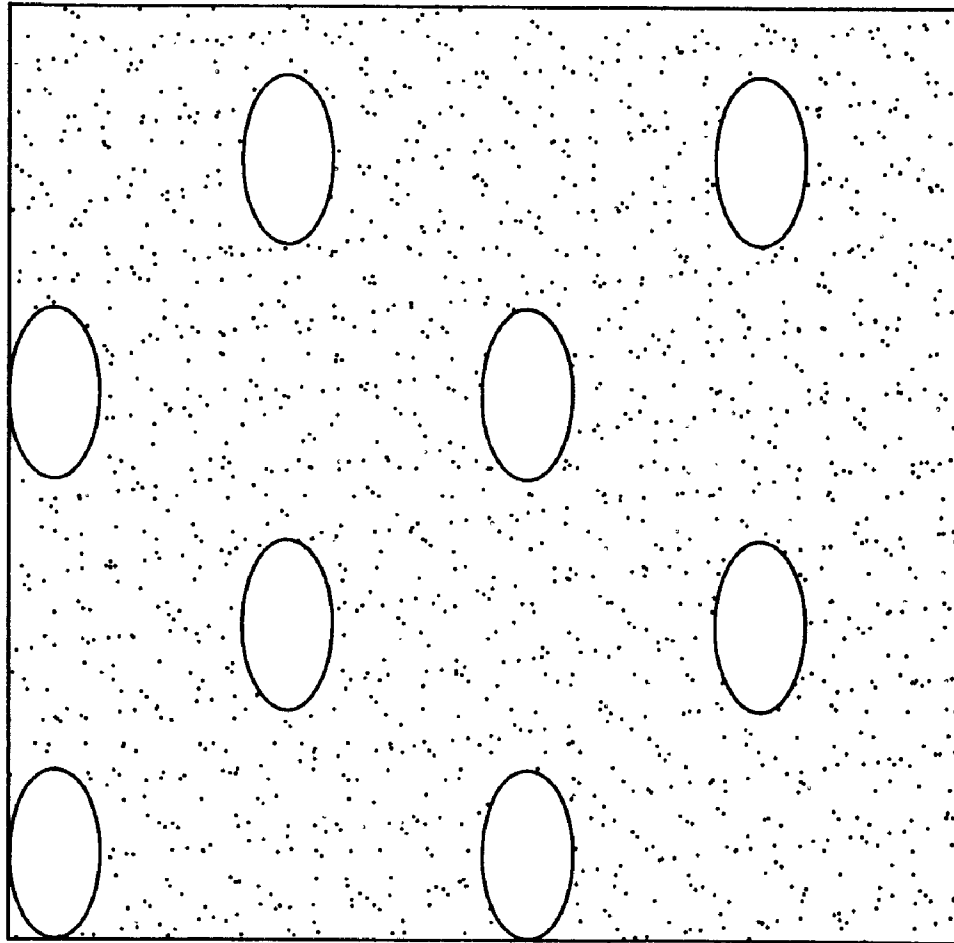


FIG. 3

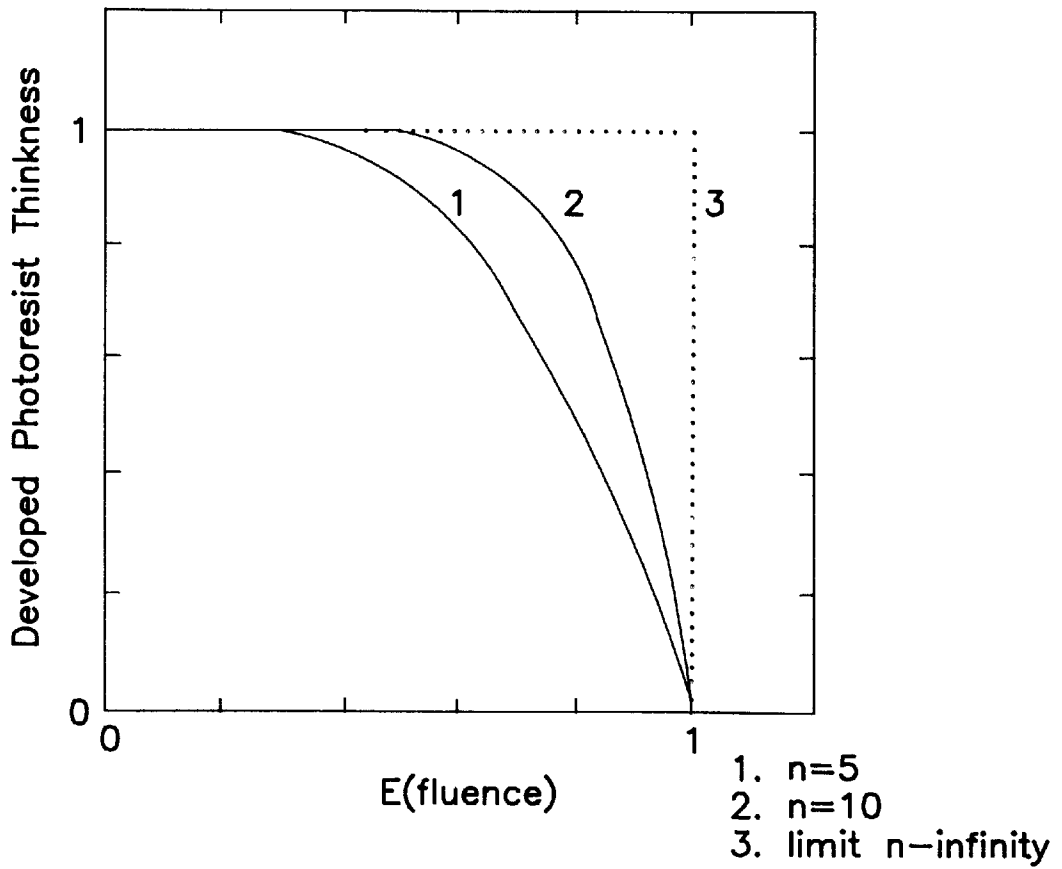


FIG. 4

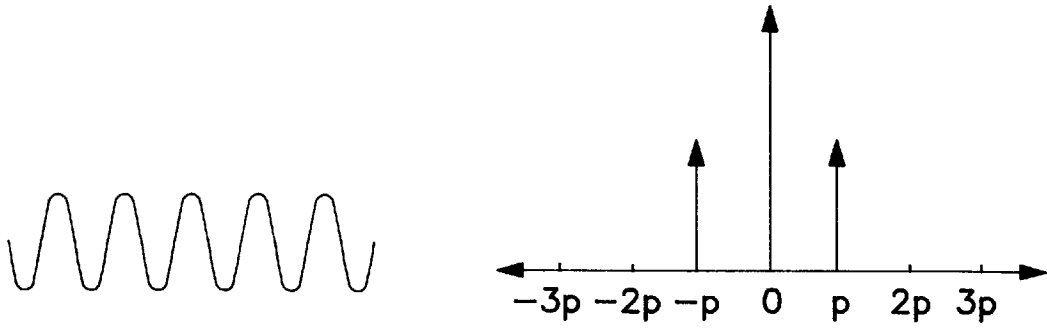


FIG. 5A

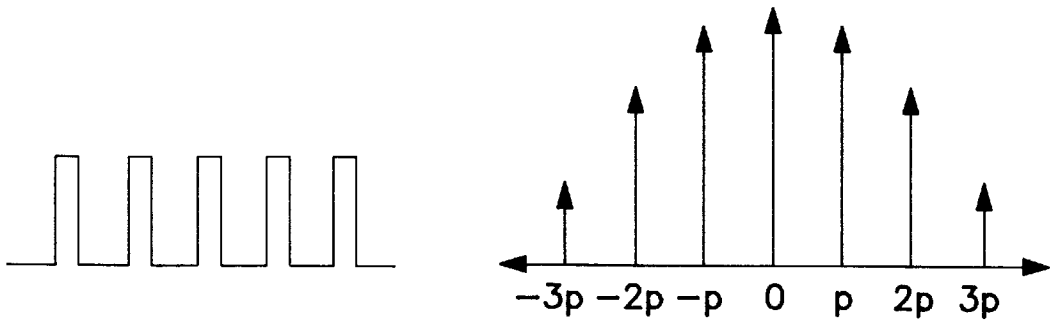


FIG. 5B

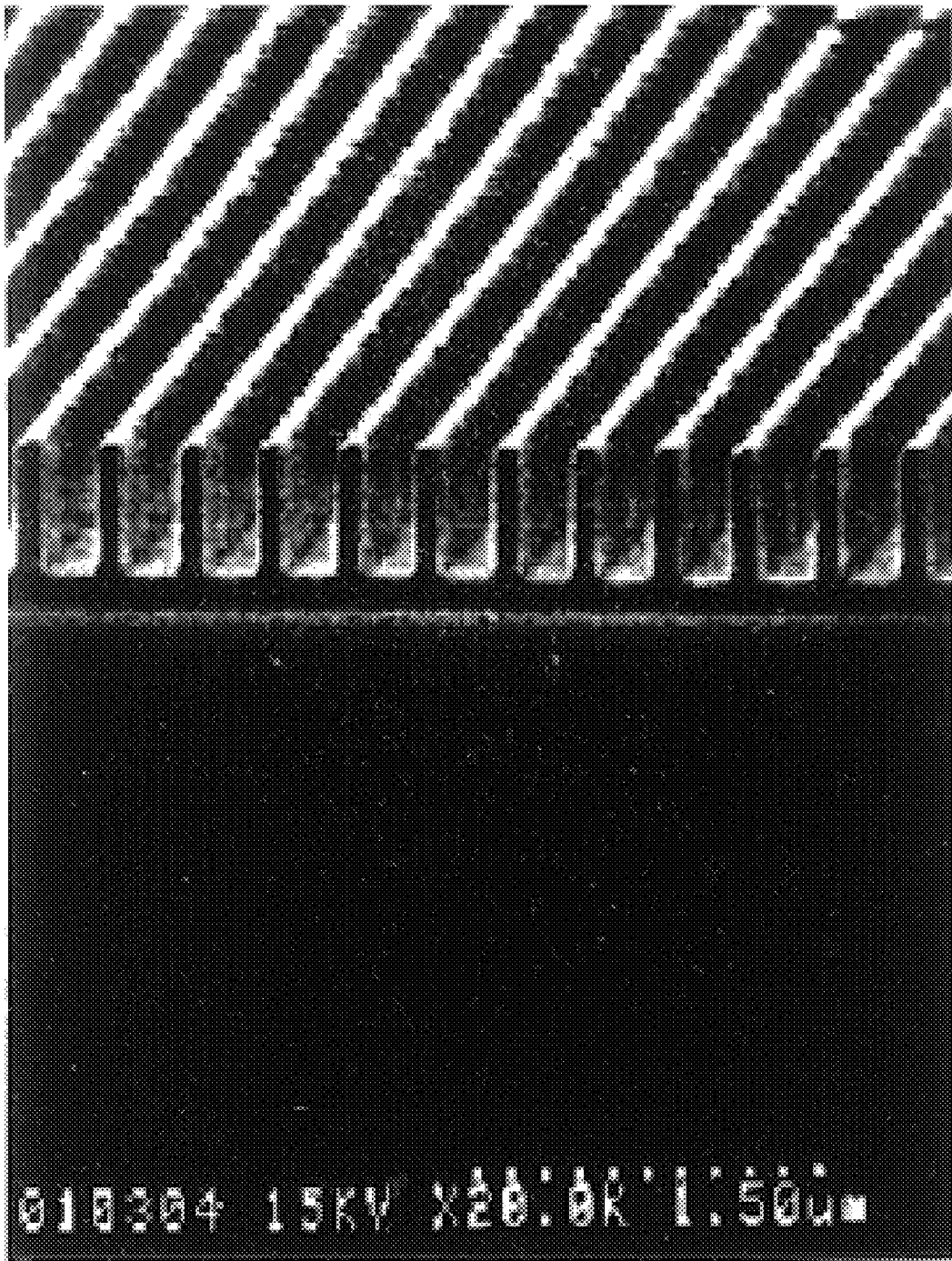


FIG. 5C



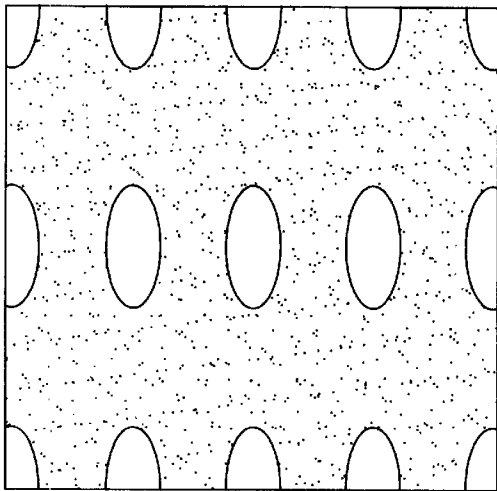


FIG. 6A

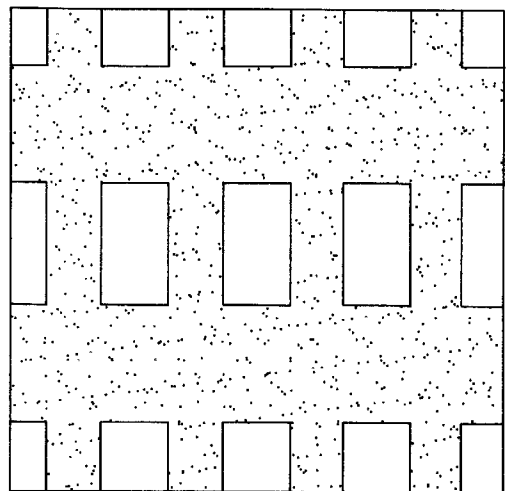


FIG. 6B

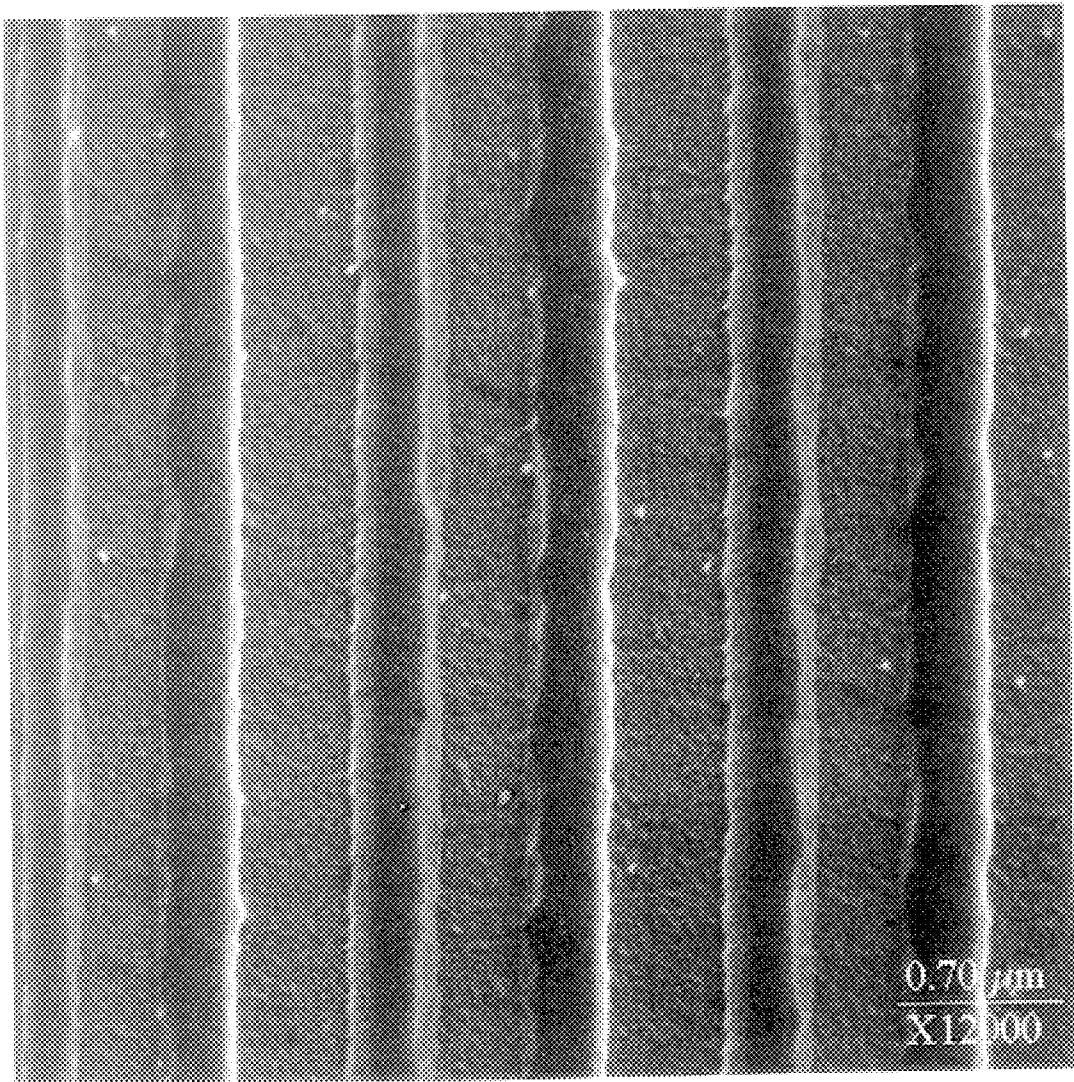


FIG. 7A

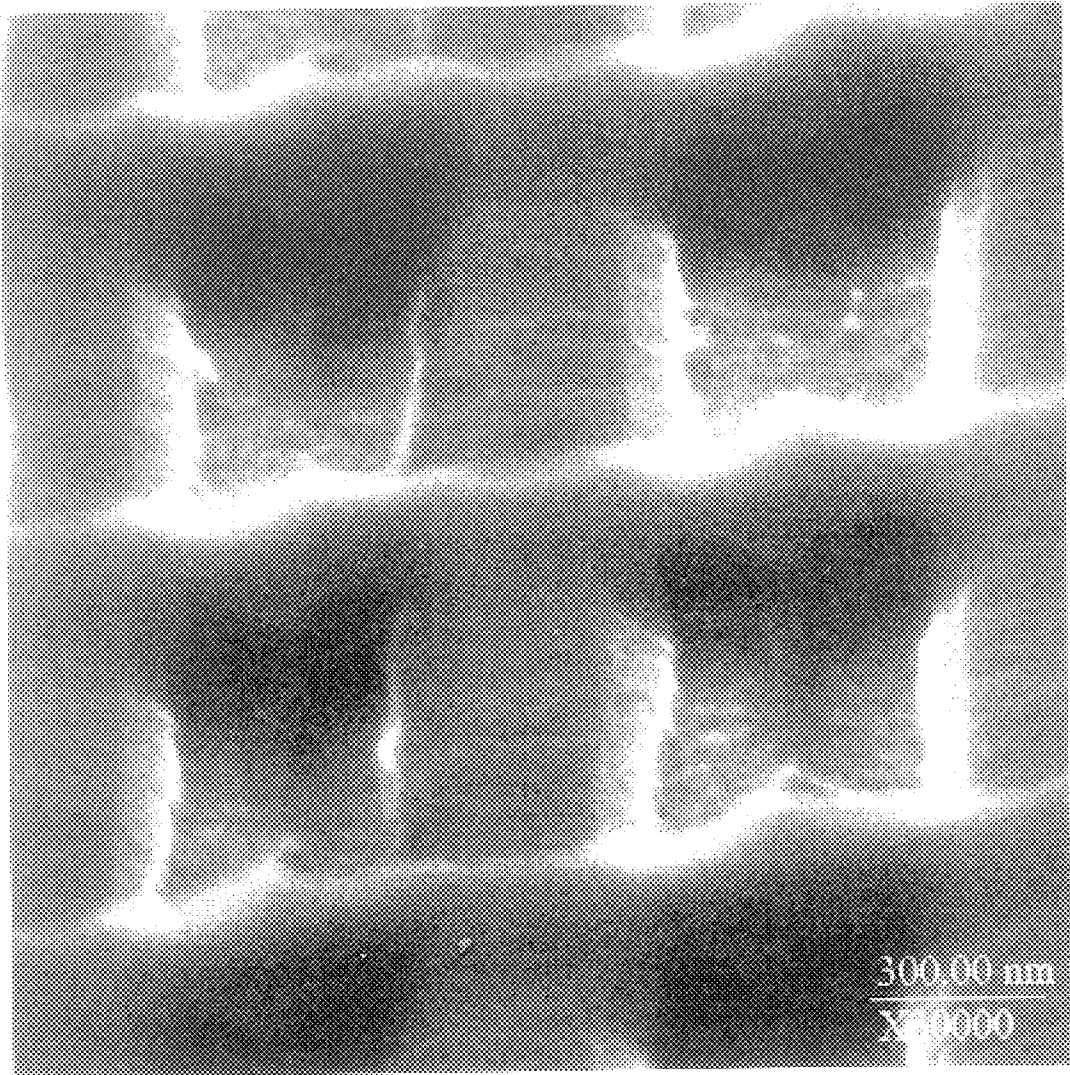


FIG. 7B

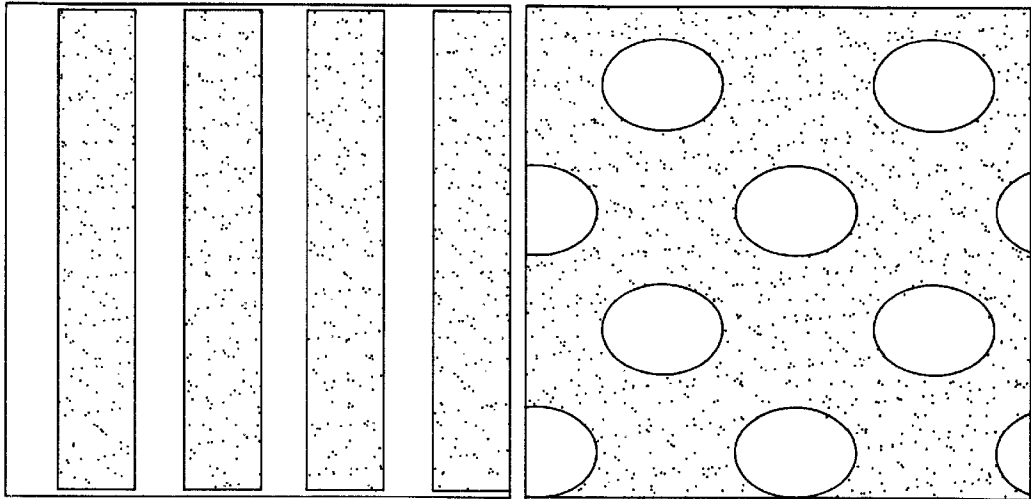


FIG. 8A

FIG. 8B

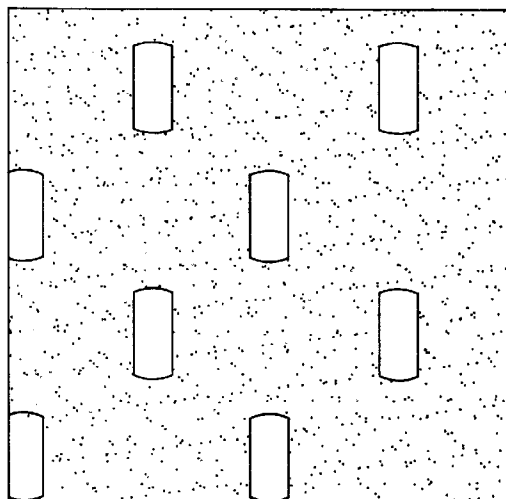


FIG. 8C

FIG. 9A

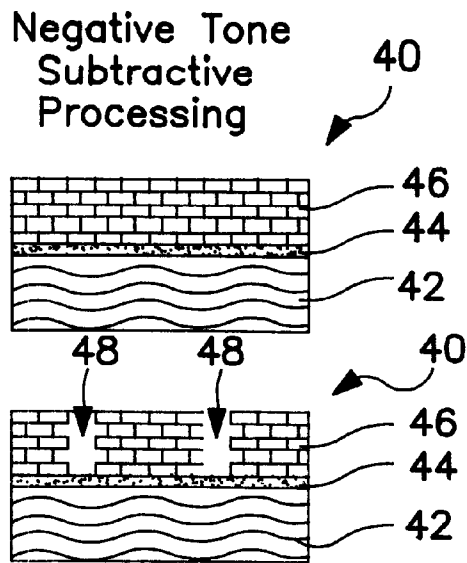


FIG. 9B

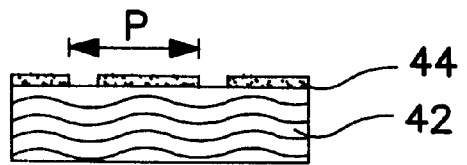


FIG. 9C

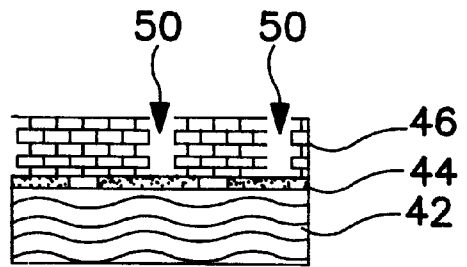


FIG. 9D

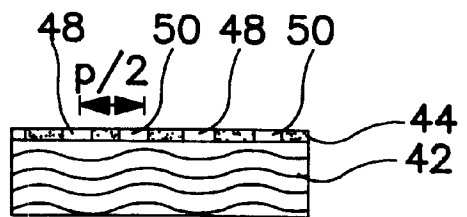


FIG. 9E

Positive Tone  
Additive/Subtractive  
Processing 60

FIG. IOA

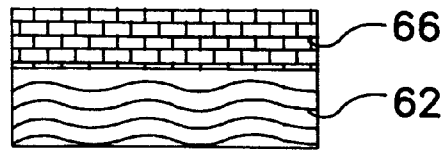


FIG. IOB

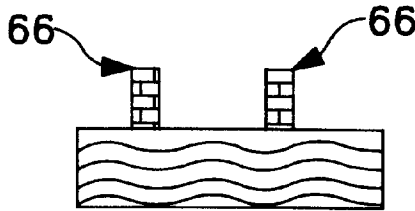


FIG. IOC

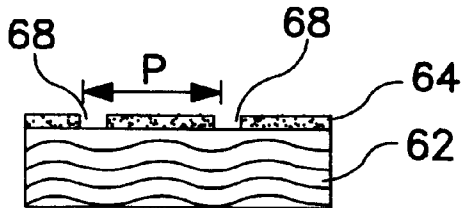


FIG. IOD

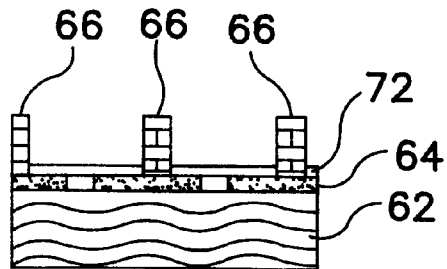


FIG. IOE

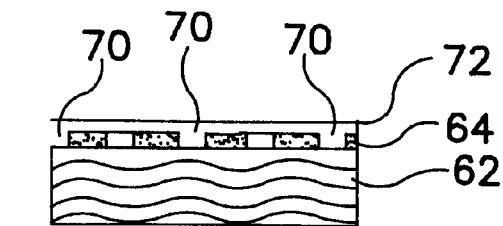
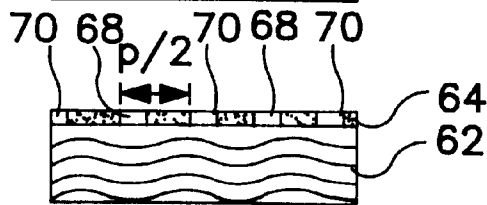


FIG. IOF



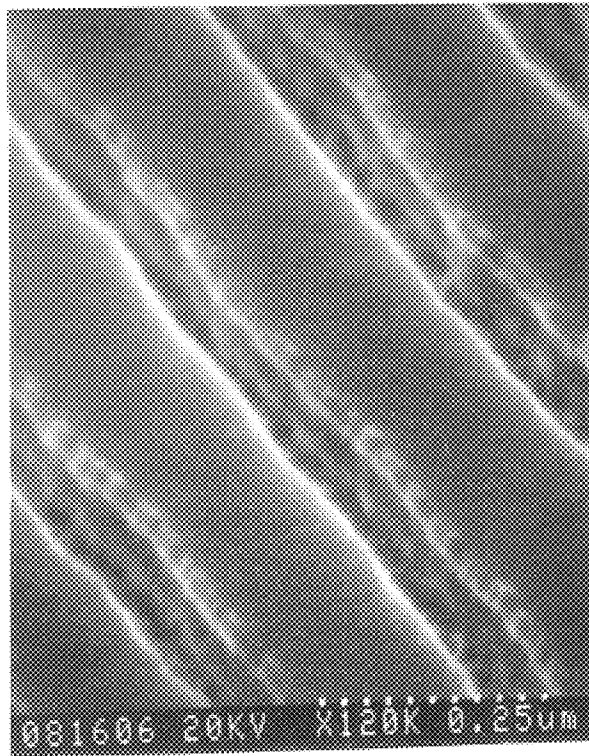


FIG. IIA

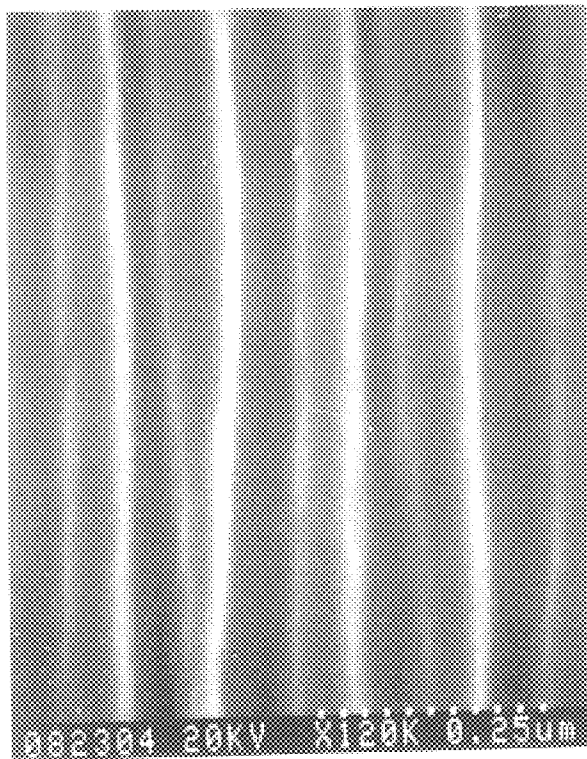


FIG. IIB