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(12) **United States Patent**  
**Chistyakov**

(10) **Patent No.:** **US 6,853,142 B2**  
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- (54) **METHODS AND APPARATUS FOR GENERATING HIGH-DENSITY PLASMA**
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- (\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(51) **Int. Cl.**<sup>7</sup> ..... **C23C 16/452**

(52) **U.S. Cl.** ..... **315/111.41; 156/345.33; 118/723.1**

(58) **Field of Search** ..... 315/111.01-111.91; 156/345.21, 345.29, 345.33, 345.42, 345.44, 345; 204/298.06, 298.04, 298.08; 118/723 FE, 723.1, 723 MP; 423/210, 246, 248

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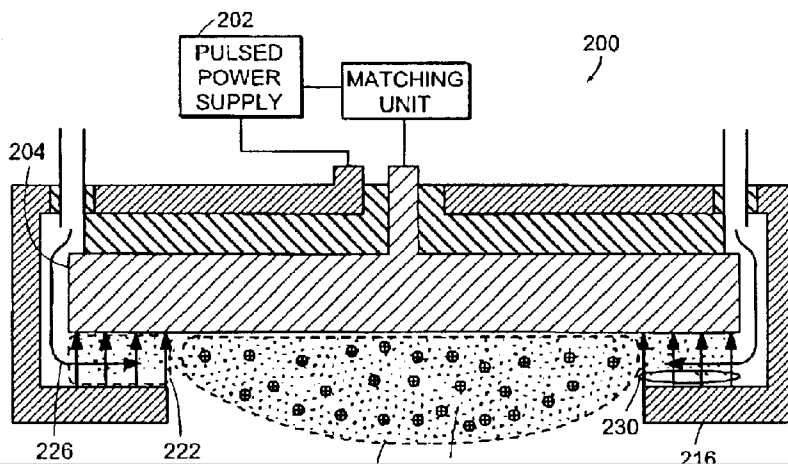
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(57) **ABSTRACT**

Methods and apparatus for generating a strongly-ionized plasma are described. An apparatus for generating a strongly-ionized plasma according to the present invention includes an anode and a cathode that is positioned adjacent to the anode to form a gap there between. An ionization source generates a weakly-ionized plasma proximate to the cathode. A power supply produces an electric field in the gap between the anode and the cathode. The electric field generates excited atoms in the weakly-ionized plasma and generates secondary electrons from the cathode. The secondary electrons ionize the excited atoms, thereby creating the strongly-ionized plasma

**43 Claims, 13 Drawing Sheets**



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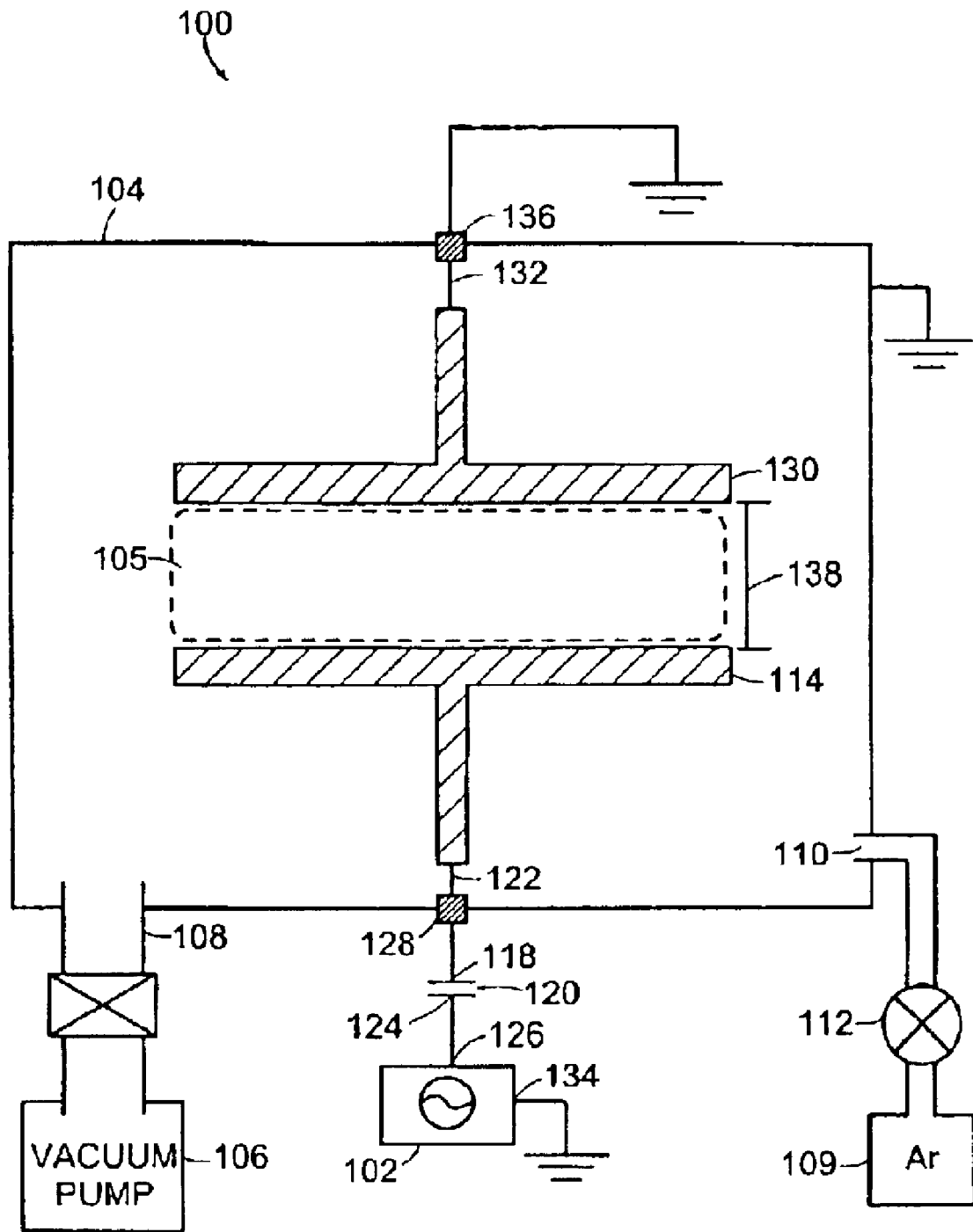


FIG. 1  
PRIOR ART

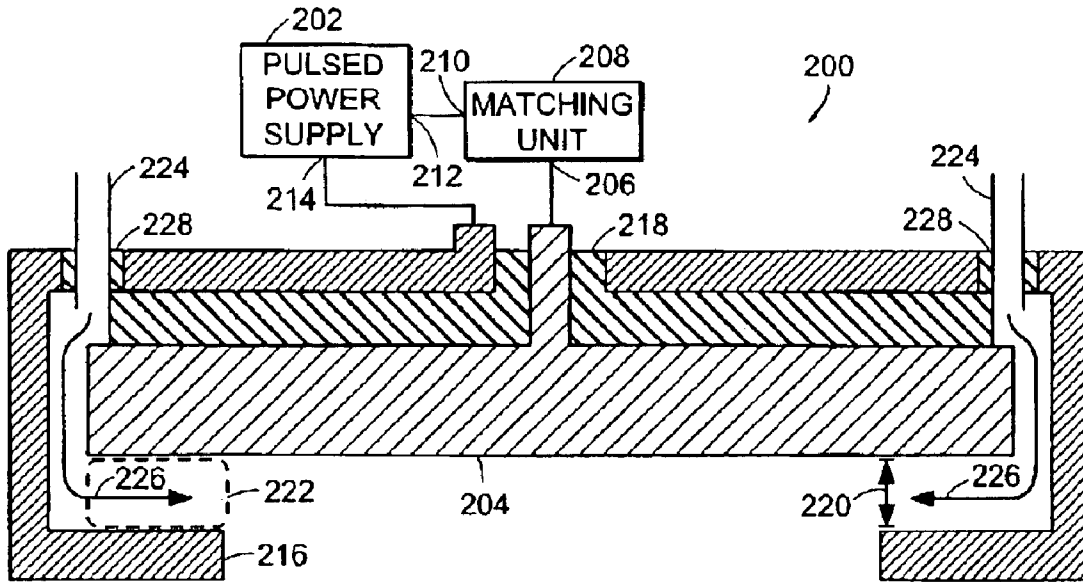


FIG. 2A

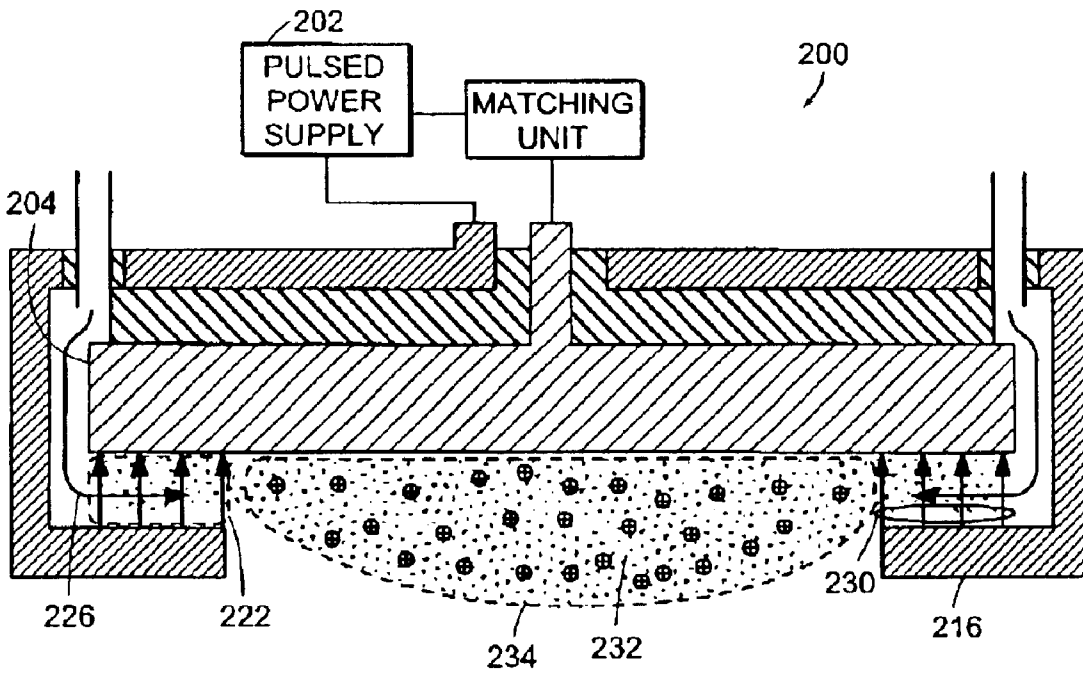


FIG. 2B

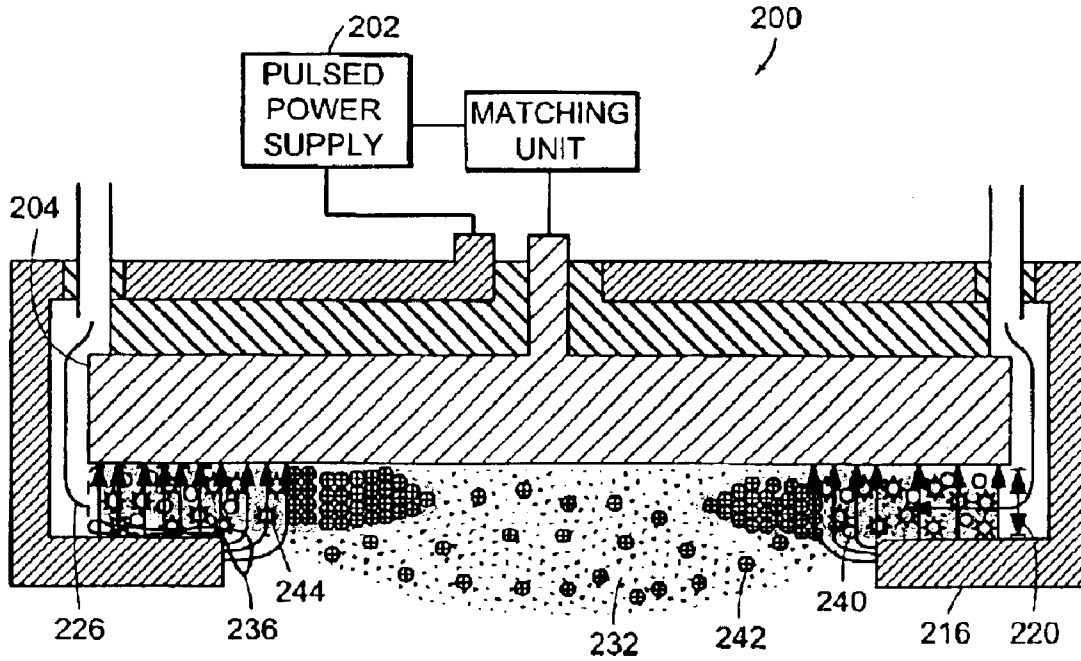


FIG. 2C

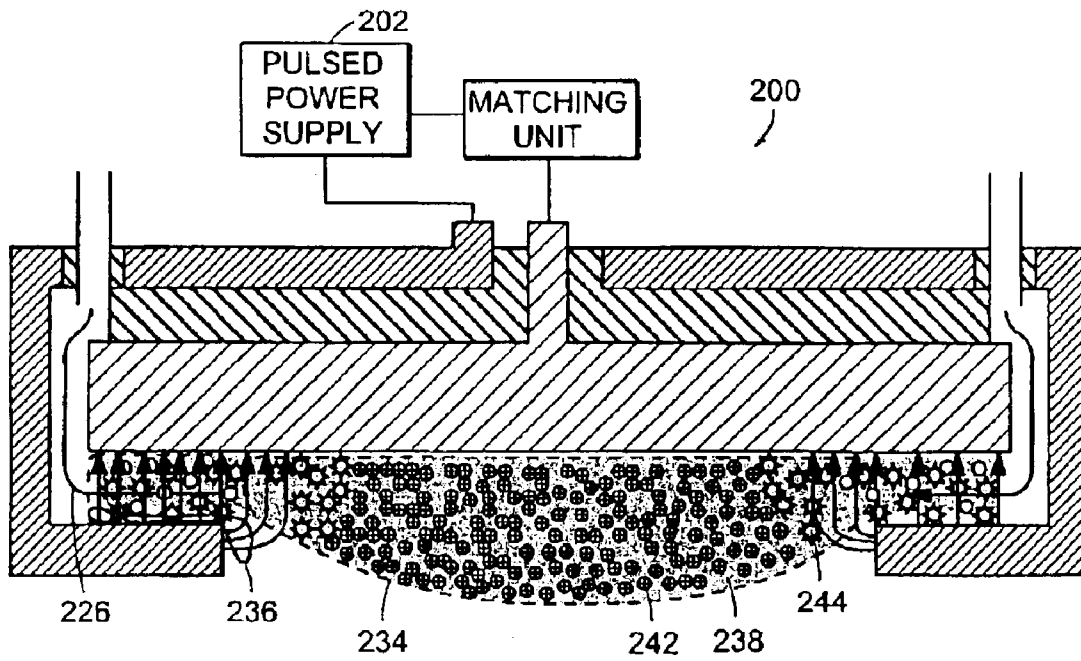


FIG. 2D

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