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

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(54) **HIGH-POWER PULSED MAGNETICALLY ENHANCED PLASMA PROCESSING**

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(75) Inventor: **Roman Chistyakov**, Andover, MA (US)

(73) Assignee: **Zond, Inc.**, Mansfield, MA (US)

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(51) **Int. Cl.**<sup>7</sup> ..... **C23C 14/34**; C23F 1/00

(52) **U.S. Cl.** ..... **204/192.32**; 204/298.31; 204/298.33; 204/298.34; 204/298.37; 216/67; 216/71; 156/345.43; 156/345.44; 156/345.46

(58) **Field of Search** ..... 204/192.32, 298.31, 204/298.33, 298.34, 298.37; 216/67, 71; 156/345.43, 345.44, 345.46

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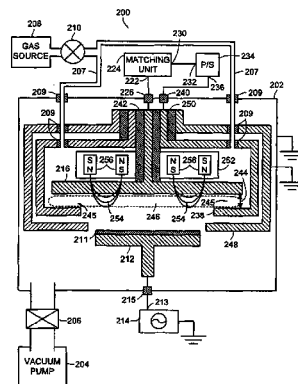
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*Primary Examiner*—Rodney G. McDonald  
(74) *Attorney, Agent, or Firm*—Kurt Rauschenbach; Rauschenbach Patent Law Group, LLC

(57) **ABSTRACT**

Magnetically enhanced plasma processing methods and apparatus are described. A magnetically enhanced plasma processing apparatus according to the present invention includes an anode and a cathode that is positioned adjacent to the anode. An ionization source generates a weakly-ionized plasma proximate to the cathode. A magnet is positioned to generate a magnetic field proximate to the weakly-ionized plasma. The magnetic field substantially traps electrons in the weakly-ionized plasma proximate to the cathode. A power supply produces an electric field in a 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 a strongly-ionized plasma. A voltage supply applies a bias voltage to a substrate that is positioned proximate to the cathode that causes ions in the plurality of ions to impact a surface of the substrate in a manner that causes etching of the surface of the substrate.

**37 Claims, 18 Drawing Sheets**



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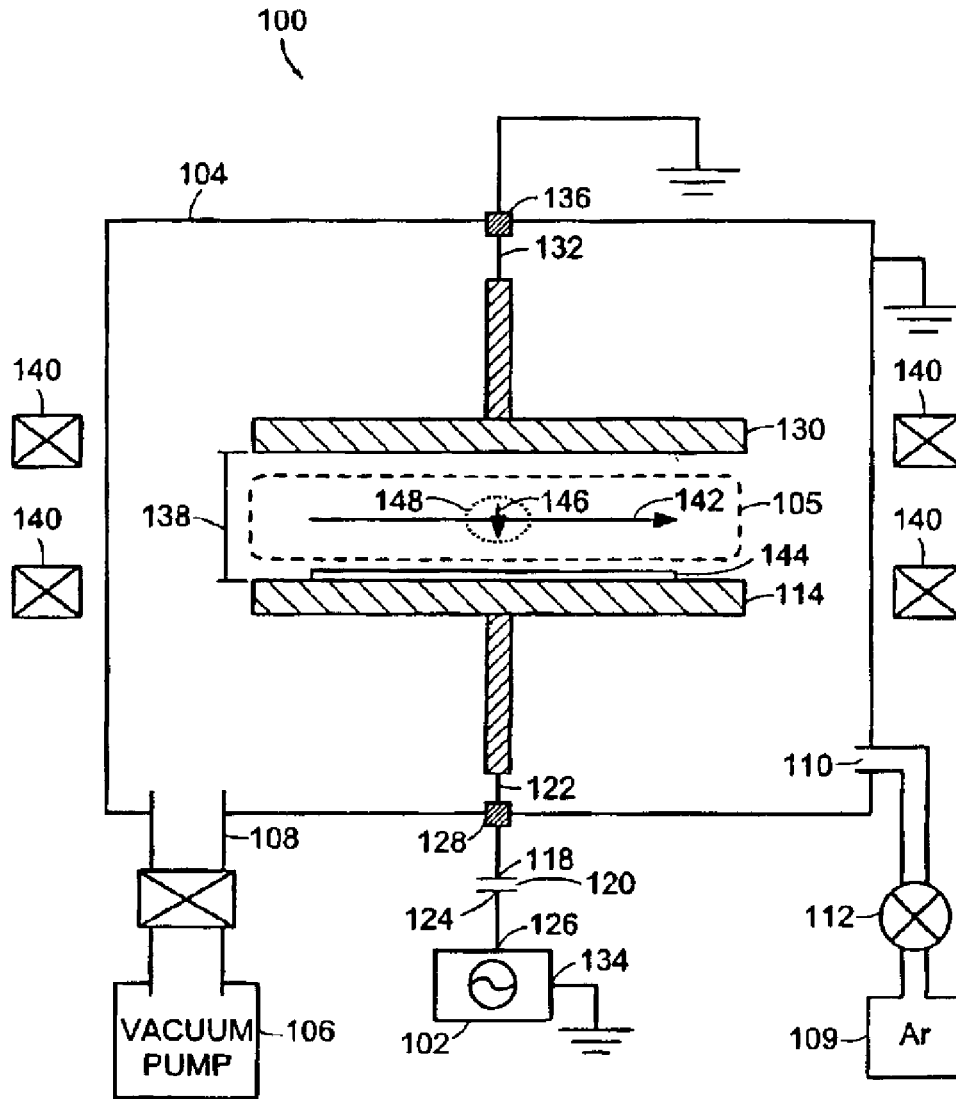


FIG. 1  
PRIOR ART

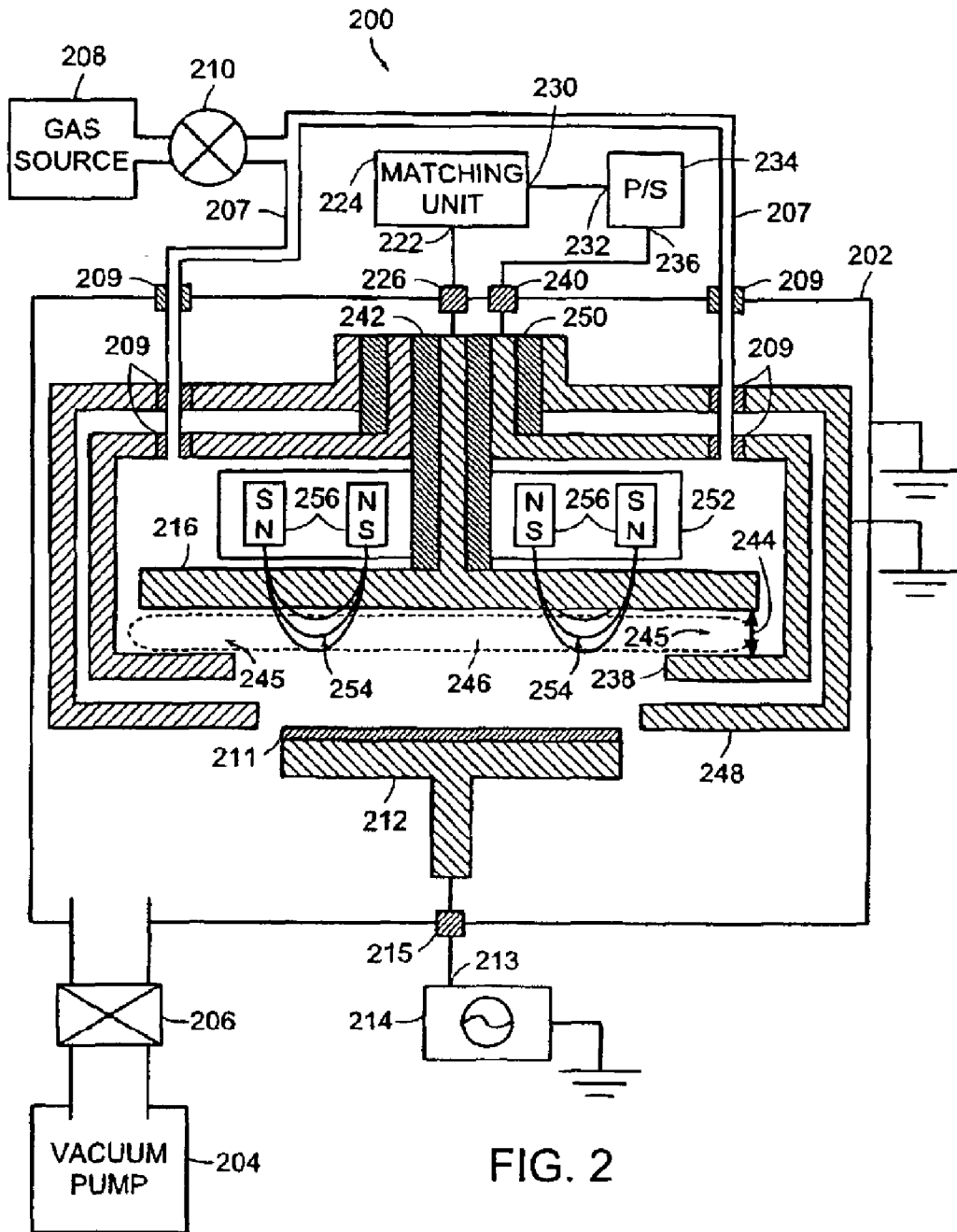


FIG. 2

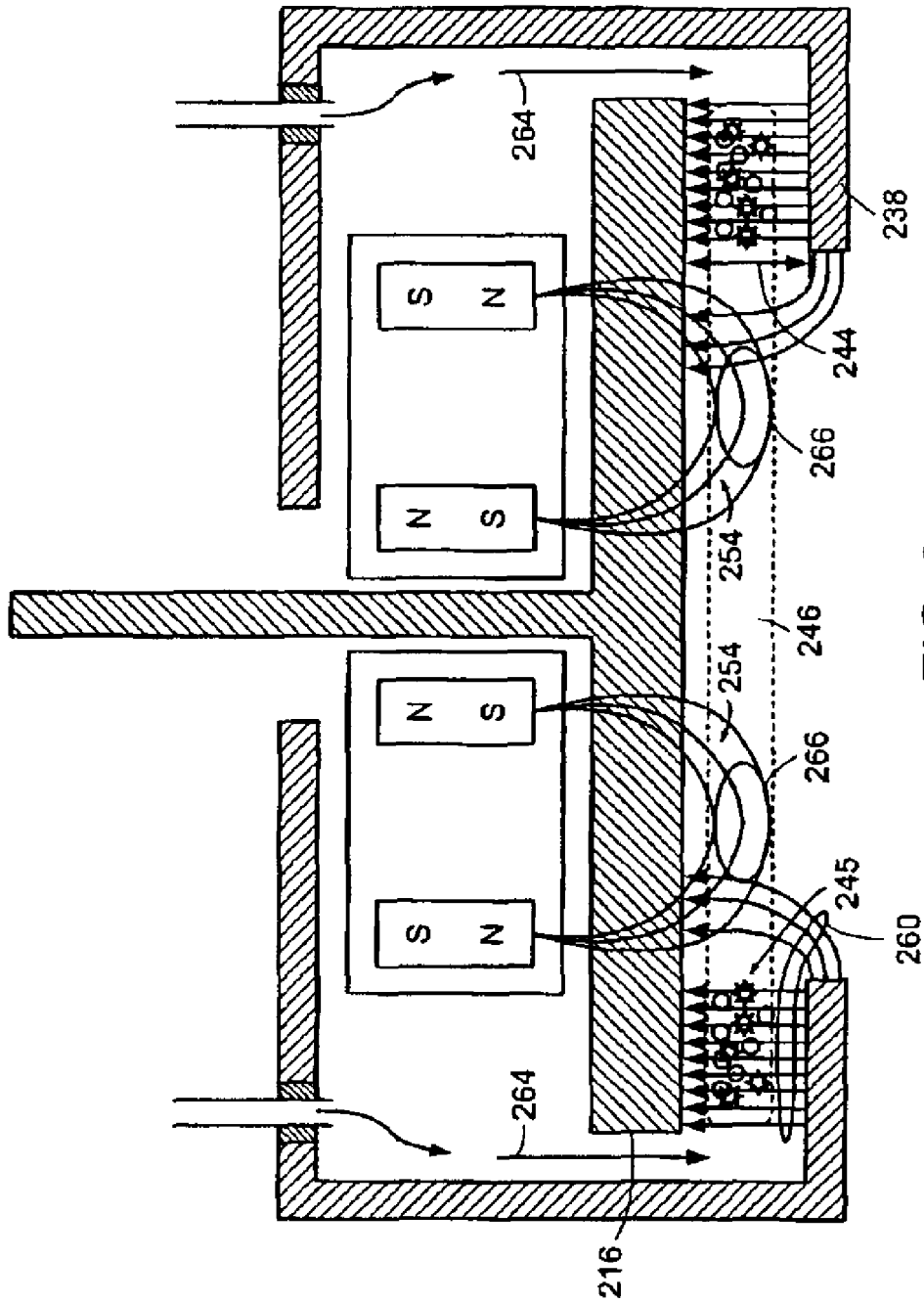


FIG. 3

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