



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

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(54) **PLASMA REACTOR AND SHIELDS  
GENERATING SELF-IONIZED PLASMA FOR  
SPUTTERING**

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(57) **ABSTRACT**

A DC magnetron sputter reactor for sputtering copper, its method of use, and shields and other parts promoting self-ionized plasma (SIP) sputtering, preferably at pressures below 5 milli Torr, preferably below 1 milli Torr. Also, a method of coating copper into a narrow and deep via or trench using SIP for a first copper layer. SIP is promoted by a small magnetron having poles of unequal magnetic strength and a high power applied to the target during sputtering. The target power for a 200 mm wafer is preferably at least 10 kW; more preferably, at least 18 kW; and most preferably, at least 24 kW. Hole filling with SIP is improved by long-throw sputtering in which the target-to-substrate spacing is at least 50% of substrate diameter, more preferably at least 80%, most preferably at least 140%. The SIP copper layer can act as a seed and nucleation layer for hole filling with conventional sputtering (PVD) or with electrochemical plating (ECP). For very high aspect-ratio holes, a copper seed layer is deposited by chemical vapor deposition (CVD) over the SIP copper nucleation layer, and PVD or ECP completes the hole filling. The copper seed layer may be deposited by a combination of SIP and high-density plasma sputtering. For very narrow holes, the CVD copper layer may fill the hole. Preferably, the plasma is ignited in a cool process in which low power is applied to the target in the presence of a higher pressure of argon working gas. After ignition, the pressure is reduced, and target power is ramped up to a relatively high operational level to sputter deposit the film.

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(51) **Int. Cl.<sup>7</sup>** ..... **C23C 14/34**

(52) **U.S. Cl.** ..... **204/298.11**

(58) **Field of Search** ..... 204/298.11

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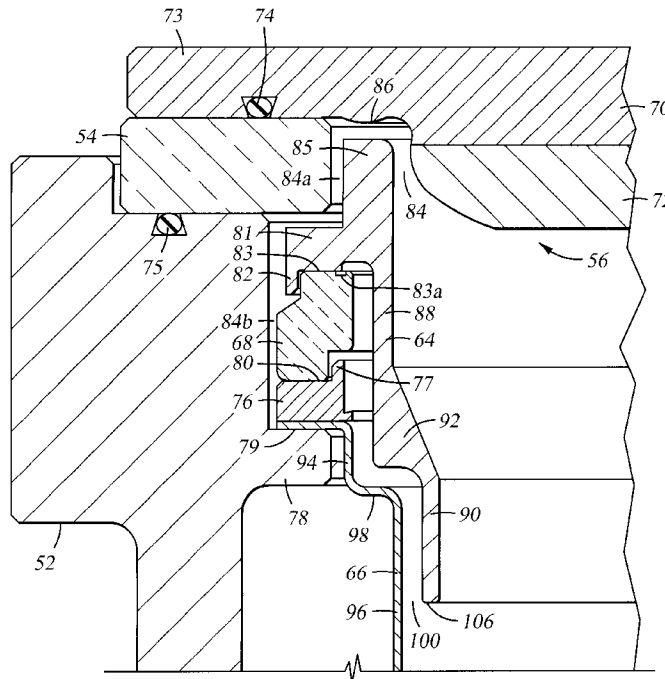
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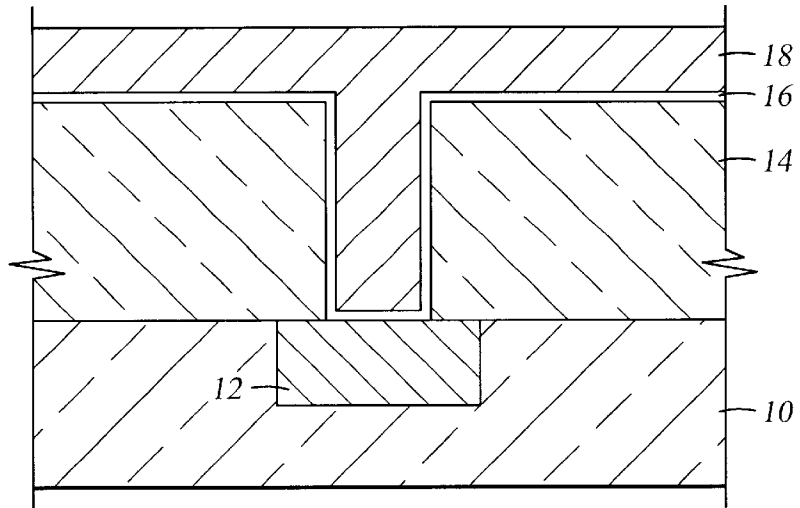
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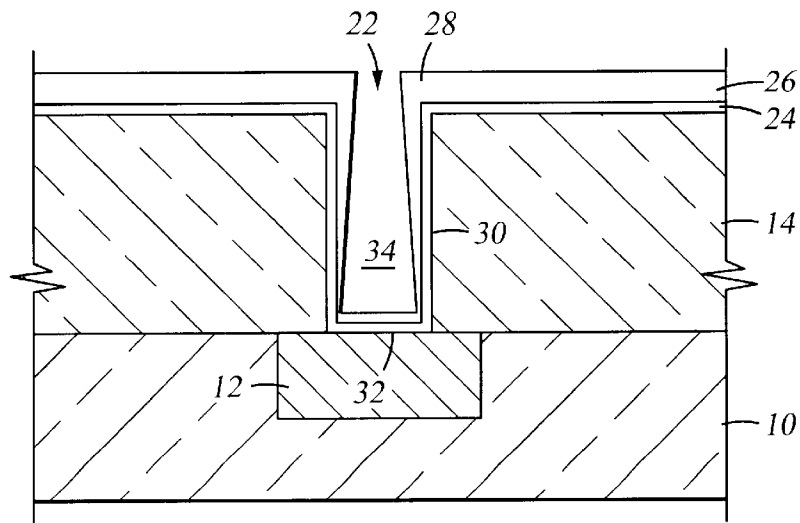
**22 Claims, 6 Drawing Sheets**



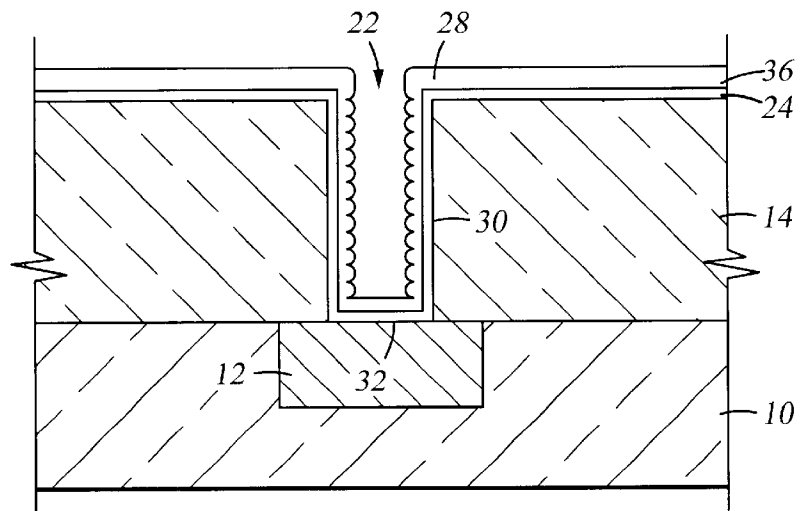
*Fig. 1*  
(PRIOR ART)



*Fig. 2*  
(PRIOR ART)



*Fig. 3*  
(PRIOR ART)



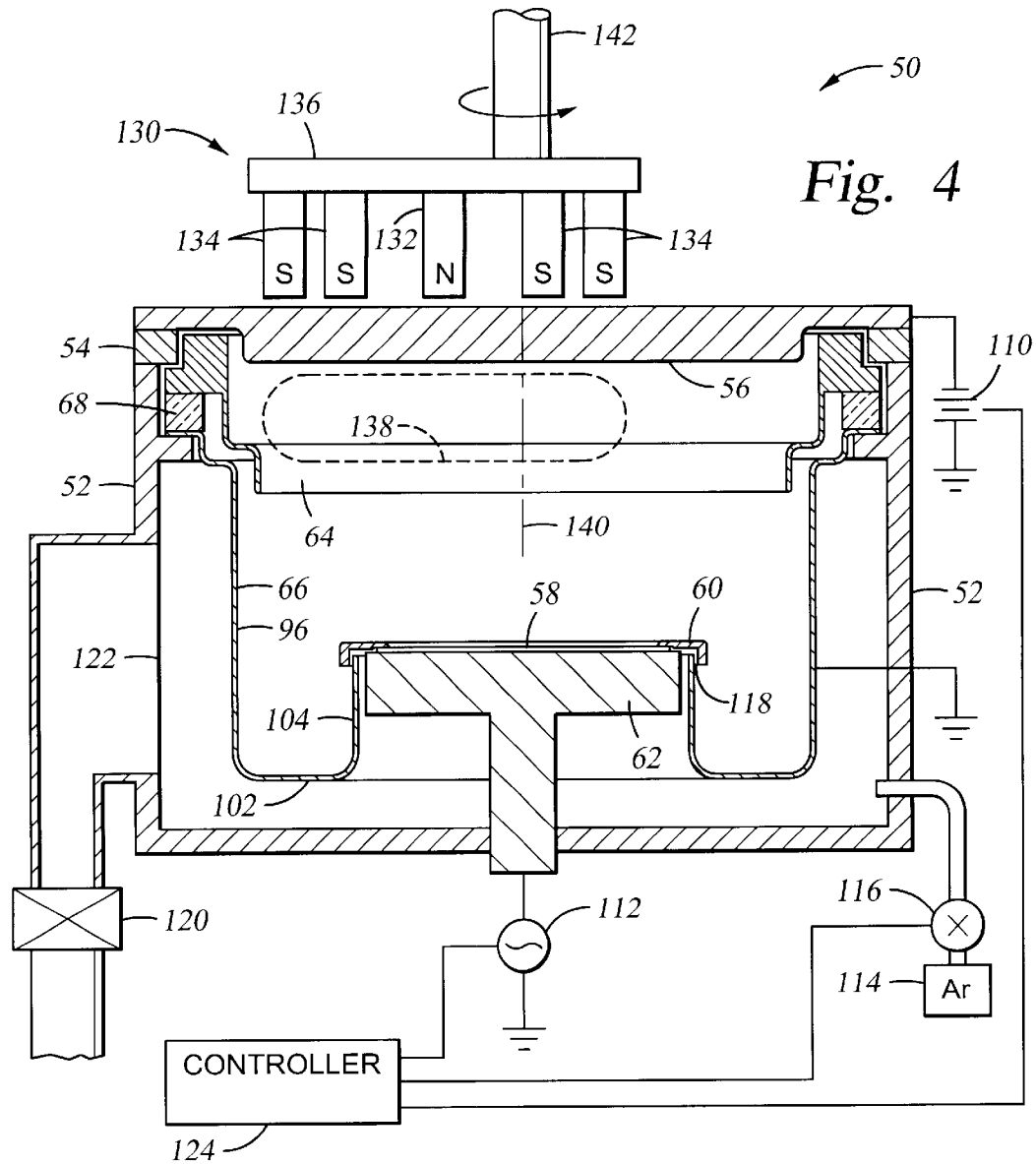


Fig. 4

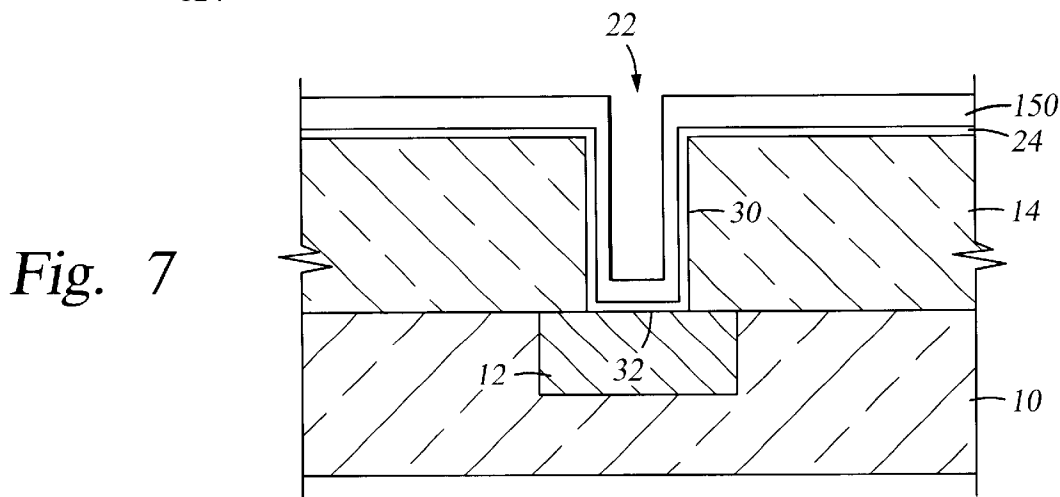


Fig. 7

Fig. 5

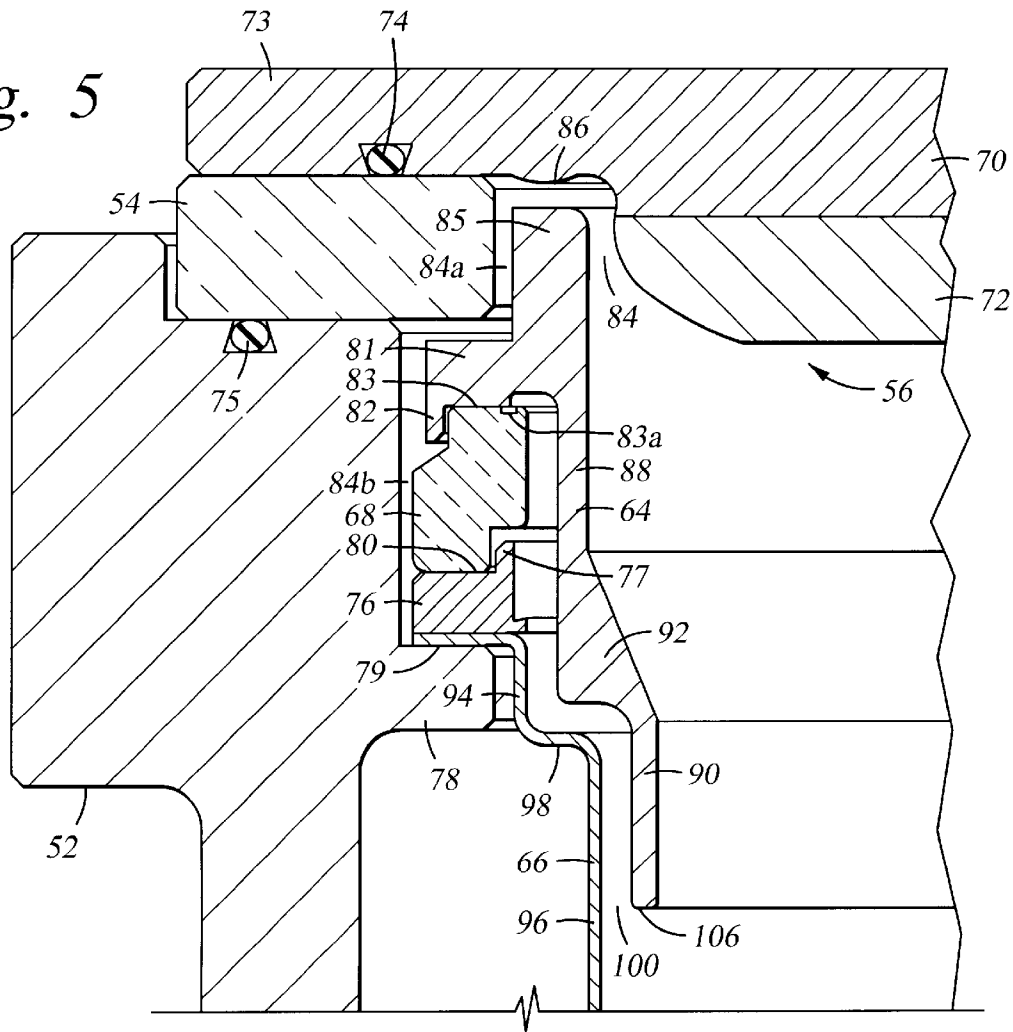
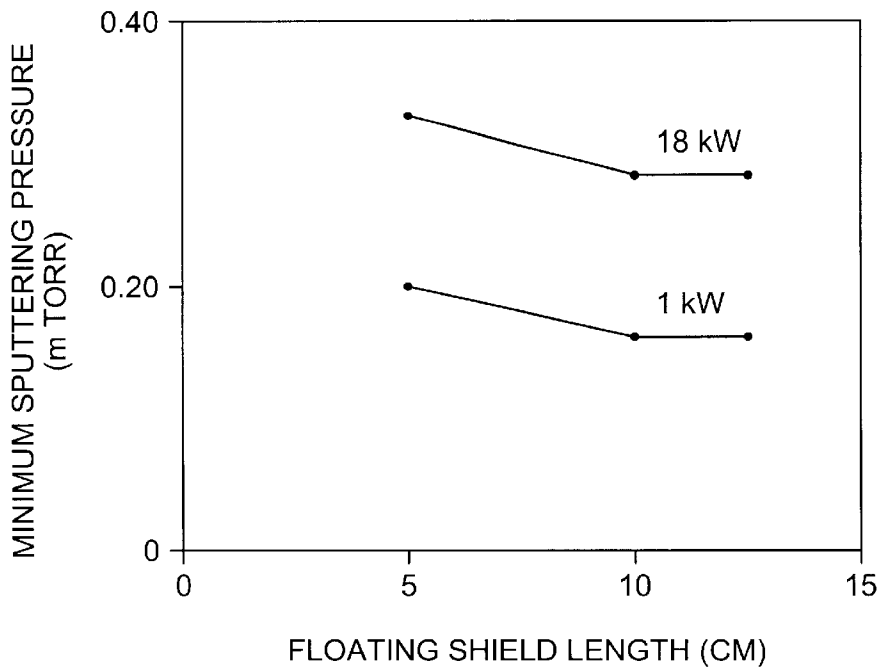


Fig. 6



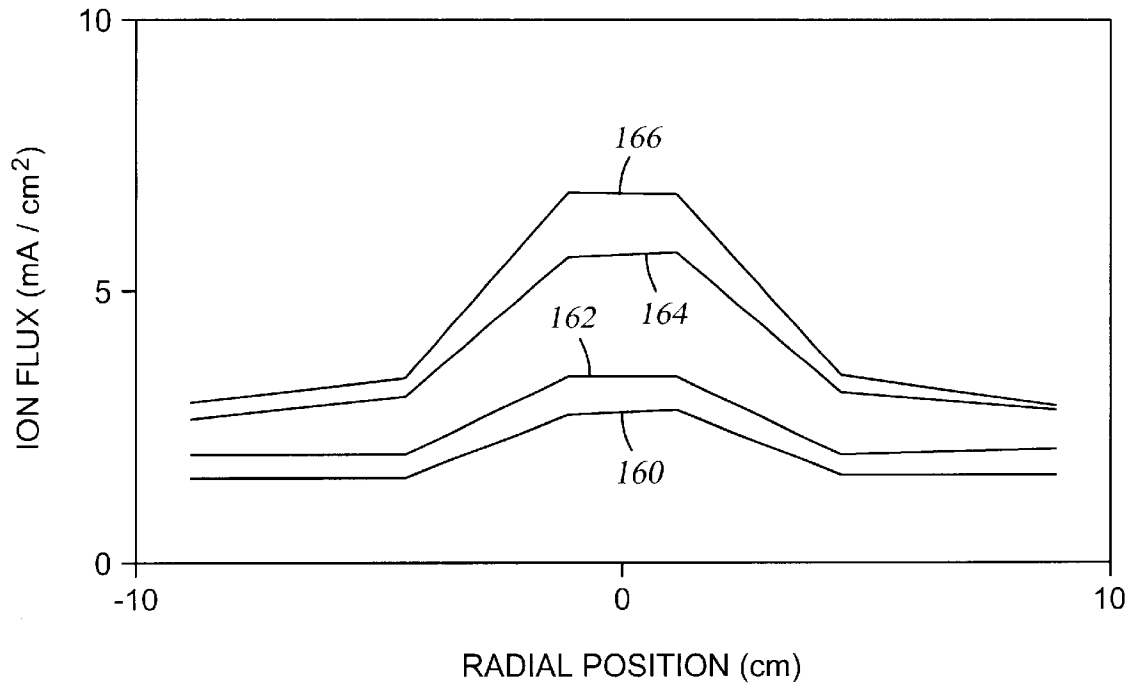


Fig. 8

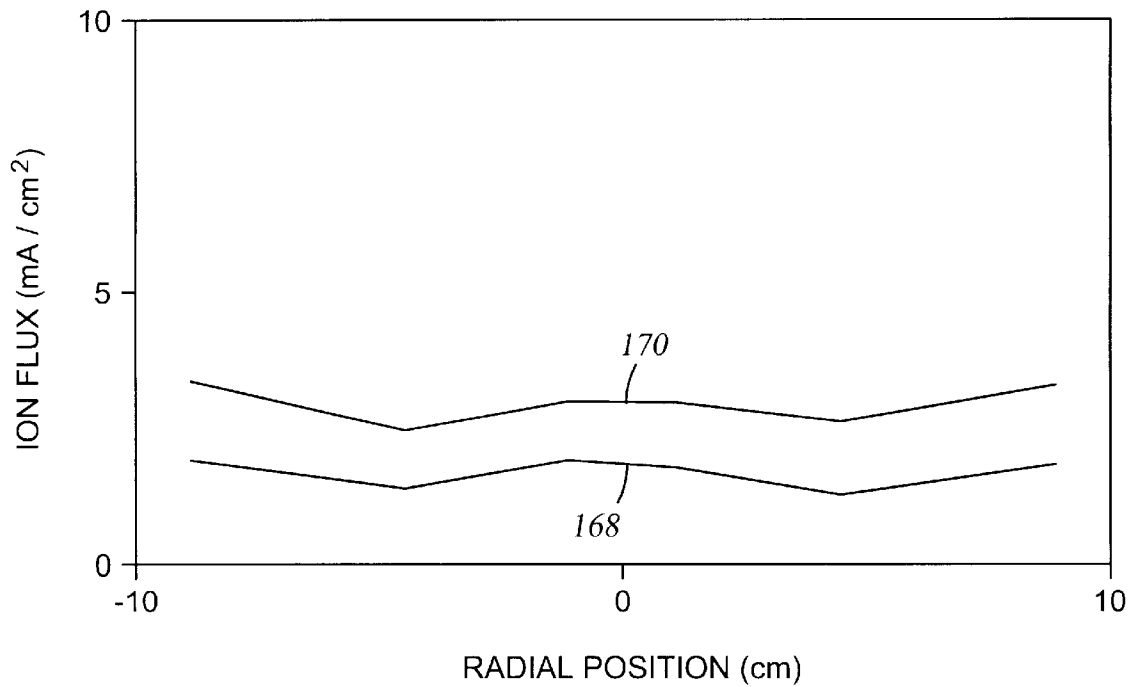


Fig. 9

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