[0014] Figures 4A-4~~E~~F are schematic sectional views of a semiconductor substrate that illustrate aspects of the method of Figure 3.

[0015] Figures 5A-5C, 6A-6D, 7A-7D, and 8 graphically illustrate various material properties of titanium nitride (TiN) layers formed using the methods set forth herein.

[0016] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

[0017] Embodiments herein are directed to methods of forming titanium nitride films suitable for use as a bulk fill material for conductive features in a semiconductor device, such as for capacitor electrodes and/or buried word lines in a dynamic random-access memory (DRAM) device. Titanium nitride is a ceramic material that is conductive enough to provide low ohmic contacts between metal features and/or metal-semiconductor junctions while serving as a barrier material to prevent reaction and interdiffusion between the respective materials thereof. Thus, when used as a relatively thin barrier or liner for a conductive metal, titanium nitride is considered as a "barrier metal."

[0018] Typically, although relatively thin layers of titanium nitride exhibit metallic-type electrical behavior, the resistivity of conventionally formed titanium nitride layers is too high for the material to be useful as a bulk-fill conductive material in most semiconductor device applications. Thus, embodiments herein provide for hydrogen radical assisted thermal treatment of titanium nitride films to desirably reduce the electrical resistivity thereof. Beneficially, in addition to reducing the electrical resistivity of deposited titanium nitride layers, the methods herein remove undesirable impurities therefrom resulting in increased device performance and improved device reliability and yield.

[0019] Figure 1A schematically illustrates an exemplary thermal processing system, processing chamber 100, which may be used to perform aspects of the