and the walls 274, 27 and the bottom 272 of the at least one feature 270. As illustrated in FIG. 3B, in one or more embodiments, the amorphous carbon film 290 is seam free within the width, W_f, of the at least one feature 270.

[0066] In some embodiments, the amorphous carbon film 290 forms conformally on the at least one feature 270. As used herein, the term "conformal", or "conformally", refers to a layer that adheres to and uniformly covers exposed surfaces with a thickness having a variation of less than 1% relative to the average thickness of the film. For example, a 1,000 Å thick film would have less than 10 Å variations in thickness. This thickness and variation includes edges, corners, sides, and the bottom of recesses. For example, a conformal layer deposited by PECVD in various embodiments of the disclosure would provide coverage over the deposited region of essentially uniform thickness on complex surfaces.

[0067] In some embodiments, the amorphous carbon film 290 is a continuous film. As used herein, the term "continuous" refers to a layer that covers an entire exposed surface without gaps or bare spots that reveal material underlying the deposited layer. A continuous layer may have gaps or bare spots with a surface area less than about 1% of the total surface area of the film. In some embodiments, the amorphous carbon film 290 is a pinhole-free film. As used herein, the term "pinhole-free" refers to a layer that covers an entire exposed surface without gaps, bare spots, holes, pinholes, and the like that reveal material underlying the deposited layer. A pinhole-free layer may have holes or pinholes with a surface area less than about 1% of the total surface area of the film.

[0068] With reference to FIG. 5, one or more embodiments of the disclosure are directed to method 500 of depositing a film. In some embodiments, the method 500 includes a pre-treatment operation 506. The pre-treatment can be any suitable pre-treatment known to the skilled artisan. Suitable pre-treatments include, but are not limited to, pre-heating, cleaning, soaking, native oxide removal, or deposition of an adhesion layer (e.g. titanium nitride (TiN)).

[0069] At deposition 510, a process cycle is performed to deposit a film on the substrate (or substrate surface). The deposition process can include one or more operations to form a film on the substrate. In operation 512 a hydrocarbon source is introduced into the processing chamber. At operation 514, a plasma initiating gas is

introduced into the processing chamber. At operation 516, a plasma is generated in the processing chamber at a temperature of greater than 600 °C.

[0070] At operation 518, an amorphous carbon layer is formed on the substrate. At operation 520, the processing chamber is purged.

[0071] At decision point 522, the thickness of the deposited film, or number of cycles is considered. If the deposited film has reached a predetermined thickness or a predetermined number of process cycles have been performed, the method 500 moves to an optional post-processing operation 524. If the thickness of the deposited film or the number of process cycles has not reached the predetermined threshold, the method 500 returns to operation 510 to introduce a hydrocarbon source again in operation 512, and continuing.

[0072] The optional post-processing operation 524 can be, for example, a process to modify film properties (e.g., annealing) or a further film deposition process (e.g., additional ALD or CVD processes) to grow additional films. In some embodiments, the post-processing operation 524 can be a process that modifies a property of the deposited film. In some embodiments, the post-processing operation 524 comprises annealing the film. In some embodiments, annealing is done at temperatures in the range of about 300 ºC, 400 ºC, 500 ºC, 600 ºC, 700 ºC, 800 ºC, 900 ºC or 1000 ºC. The annealing environment of some embodiments comprises one or more of an inert gas (e.g., molecular nitrogen (N_2), argon (Ar)) or a reducing gas (e.g., molecular hydrogen (H_2) or ammonia (NH_3)) or an oxidant, such as, but not limited to, oxygen (O_2), ozone (O_3), or peroxides. Annealing can be performed for any suitable length of time. In some embodiments, the film is annealed for a predetermined time in the range of about 15 seconds to about 90 minutes, or in the range of about 1 minute to about 60 minutes. In some embodiments, annealing the as-deposited film increases the density, decreases the resistivity and/or increases the purity of the film.

[0073] A variety of multi-processing platforms, including the Centura®, Dual ACP, Producer® GT, Precision®, and Endura® platform, available from Applied Materials® as well as other processing systems may be utilized. With reference to FIG. 4, a cluster tool 300 includes at least one central transfer station 314 with a plurality of sides. A

robot 316 is positioned within the central transfer station 314 and is configured to move a robot blade and a wafer to each of the plurality of sides.

[0074] Generally, a cluster tool is a modular system comprising multiple chambers which perform various functions including substrate center-finding and orientation, degassing, annealing, deposition and/or etching. According to one or more embodiments, a cluster tool includes at least a first chamber and a central transfer chamber. The central transfer chamber may house a robot that can shuttle substrates between and among processing chambers and load lock chambers. The transfer chamber is typically maintained at a vacuum condition and provides an intermediate stage for shuttling substrates from one chamber to another and/or to a load lock chamber positioned at a front end of the cluster tool. However, the exact arrangement and combination of chambers may be altered for purposes of performing specific steps of a process as described herein. Other processing chambers which may be used include, but are not limited to, cyclical layer deposition (CLD), atomic layer deposition (ALD), chemical vapor deposition (CVD), physical vapor deposition (PVD), etch, pre-clean, chemical clean, thermal treatment such as RTP, plasma nitridation, degas, orientation, hydroxylation and other substrate processes. By carrying out processes in a chamber on a cluster tool, surface contamination of the substrate with atmospheric impurities can be avoided without oxidation prior to depositing a subsequent film.

[0075] Referring to FIG. 4, the cluster tool 300 comprises a plurality of processing chambers 308, 310, and 312, also referred to as process stations, connected to the central transfer station. The various processing chambers provide separate processing regions isolated from adjacent process stations. The processing chamber can be any suitable chamber including, but not limited to, a preclean chamber, a deposition chamber, an annealing chamber, an etching chamber, a selective etching chamber, and the like. The particular arrangement of process chambers and components can be varied depending on the cluster tool and should not be taken as limiting the scope of the disclosure.

[0076] In some embodiments, the cluster tool 300 includes an isotropic etching chamber for selectively etching/trimming the semiconductor material layers 224. The isotropic etching chamber of some embodiments comprises one or more a fluorine-

based dry etching chamber. In some embodiments, the cluster tool 300 includes a pre-cleaning chamber connected to the central transfer station.

[0077] In the embodiment shown in FIG. 4, a factory interface 318 is connected to a front of the cluster tool 300. The factory interface 318 includes chambers 302 for loading and unloading on a front 319 of the factory interface 318.

[0078] The size and shape of the loading chamber and unloading chamber 302 can vary depending on, for example, the substrates being processed in the cluster tool 300. In the embodiment shown, the loading chamber and unloading chamber 302 are sized to hold a wafer cassette with a plurality of wafers positioned within the cassette.

[0079] Robots 304 are within the factory interface 318 and can move between the loading and unloading chambers 302. The robots 304 are capable of transferring a wafer from a cassette in the loading chamber 302 through the factory interface 318 to load lock chamber 320. The robots 304 are also capable of transferring a wafer from the load lock chamber 320 through the factory interface 318 to a cassette in the unloading chamber 302.

[0080] The robot 316 of some embodiments is a multi-arm robot capable of independently moving more than one wafer at a time. The robot 316 is configured to move wafers between the chambers around the transfer chamber 314. Individual wafers are carried upon a wafer transport blade that is located at a distal end of the first robotic mechanism.

[0081] A system controller 357 is in communication with the robot 316, and a plurality of processing chambers 308, 310 and 312. The system controller 357 can be any suitable component that can control the processing chambers and robots. For example, the system controller 357 can be a computer including a central processing unit (CPU) 392, memory 394, inputs/outputs 396, suitable circuits 398, and storage.

[0082] Processes may generally be stored in the memory of the system controller 357 as a software routine that, when executed by the processor, causes the process chamber to perform processes of the present disclosure. The software routine may also be stored and/or executed by a second processor (not shown) that is remotely located from the hardware being controlled by the processor. Some or all of the method of the present disclosure may also be performed in hardware. As such, the process may be

implemented in software and executed using a computer system, in hardware as, e.g., an application specific integrated circuit or other type of hardware implementation, or as a combination of software and hardware. The software routine, when executed by the processor, transforms the general purpose computer into a specific purpose computer (controller) that controls the chamber operation such that the processes are performed.

[0083] In some embodiments, the system controller 357 has a configuration to control the deposition of amorphous carbon on the substrate.

[0084] In one or more embodiments, a processing tool comprises: a central transfer station comprising a robot configured to move a wafer; a plurality of process stations, each process station connected to the central transfer station and providing a processing region separated from processing regions of adjacent process stations, the plurality of process stations comprising a deposition chamber, a plasma chamber, a curing chamber, an etching chamber; and a controller connected to the central transfer station and the plurality of process stations, the controller configured to activate the robot to move the wafer between process stations, and to control a process occurring in each of the process stations.

[0085] The disclosure is now described with reference to the following examples. Before describing several exemplary embodiments of the disclosure, it is to be understood that the disclosure is not limited to the details of construction or process steps set forth in the following description. The disclosure is capable of other embodiments and of being practiced or being carried out in various ways.

[0086] EXAMPLES

[0087] Example 1

[0088] An amorphous carbon layer was deposited by providing a flow rate of Argon to the processing chamber at about 2000 sccm, providing a flow rate of C2H2 to the processing chamber at about 300 sccm, applying a high frequency RF power (13.56MHz) at about 200 W, maintaining a deposition temperature of about 650° C., maintaining a chamber pressure of about 10 Torr, with a spacing of about 300 mils to produce a deposition rate of 1800 nm/hr and it was observed to achieve conformalities of about 83% dense area to about 96% open area step coverage (measure of conformality).

[0089] Example 2: Comparative

[0090] An amorphous carbon layer was deposited by providing a flow rate of helium to the processing chamber at about 100 sccm, providing a flow rate of C3H6 to the processing chamber at about 100 sccm, providing a flow rate of NH3 to the processing chamber at about 100 sccm, applying a high frequency RF power (13.56MHz) at about 600 W, maintaining a deposition temperature of about 400° C., maintaining a chamber pressure of about 9 Torr, with a spacing of about 400 mils to produce a deposition rate of 30 nm/hr and it was observed to achieve conformalities of about 83% dense area to about 96% open area step coverage (measure of conformality).

[0091] Spatially relative terms, such as "beneath," "below," "lower," "above," "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the exemplary term "below" may encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0092] The use of the terms "a" and "an" and "the" and similar referents in the context of describing the materials and methods discussed herein (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., "such as") provided herein, is intended merely to better illuminate the materials and methods and

does not pose a limitation on the scope unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the disclosed materials and methods.

[0093] Reference throughout this specification to "one embodiment," "certain embodiments," "one or more embodiments" or "an embodiment" means that a particular feature, structure, material, or characteristic described in connection with the embodiment is included in at least one embodiment of the disclosure. Thus, the appearances of the phrases such as "in one or more embodiments," "in certain embodiments," "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily referring to the same embodiment of the disclosure. In one or more embodiments, the particular features, structures, materials, or characteristics are combined in any suitable manner.

[0094] Although the disclosure herein has been described with reference to particular embodiments, it is to be understood that these embodiments are merely illustrative of the principles and applications of the present disclosure. It will be apparent to those skilled in the art that various modifications and variations can be made to the method and apparatus of the present disclosure without departing from the spirit and scope of the disclosure. Thus, it is intended that the present disclosure include modifications and variations that are within the scope of the appended claims and their equivalents.