Chapter 1 : Chemical mechanical polishing with electrochemical control - Advanced Micro Devices, Inc.

Chemical Mechanical Planarization PT/01//JT 4 A 2-Phase process is adopted in our inlaid copper pattern wafer polishing, which means changing slurry and working.

What is claimed is: A device for planarizing a surface of a semiconductor workpiece, comprising: The device of claim 1, wherein the solution comprises an abrasive slurry. The device of claim 1, wherein the table comprises an abrasive surface for abrading the surface of the semiconductor workpiece. The device of claim 1, wherein the member comprises a retaining ring. The device of claim 1, wherein the first conductor comprises a metallic member operable to maintain compliant contact with the semiconductor workpiece. The device of claim 1, wherein the counter electrode comprises a platinum wire. The device of claim 1, wherein the reference electrode comprises a quasi-reference electrode at a floating potential. The device of claim 8, wherein the quasi-reference electrode comprises a platinum wire. The device of claim 1, wherein the reference electrode and the counter electrode are coupled to the member. The device of claim 1, wherein the table is operable to rotate. The device of claim 1, wherein the member is operable to rotate the semiconductor workpiece. The device of claim 11, wherein the member is operable to rotate the semiconductor workpiece. A method of planarizing a surface of a semiconductor workpiece, comprising: The method of claim 14, wherein the abrasive slurry comprises alumina particulates. The method of claim 14, comprising monitoring the potential applied between the surface and the slurry by measuring a potential difference between the slurry and a reference electrode in contact with the slurry. The method of claim 14, wherein the step of applying the potential between the surface and the slurry comprising connecting a power supply to the semiconductor workpiece and to a counter electrode, and connecting the counter electrode to the slurry so that current flows from the surface to the counter electrode. The method of claim 14, wherein the surface comprises tungsten. The method of claim 14, wherein the surface comprises copper. The method of claim 14, wherein the relative movement between the slurry and the oxidized surface is provided by rotating the semiconductor workpiece. The method of claim 14, wherein the relative movement between the slurry and the oxidized surface is provided by applying the slurry to a table and rotating the table relative to the semiconductor workpiece. The method of claim 20, wherein the relative movement between the slurry and the oxidized surface is provided by applying the slurry to a table and rotating the table relative to the semiconductor workpiece. A method of planarizing a surface of a semiconductor workpiece comprising: The method of claim 23, wherein the electrically conducting solution comprises water. The method of claim 23, comprising monitoring the potential applied between the workpiece surface and the electrically conducting solution by measuring a potential difference between the electrically conducting solution and a reference electrode in contact with the electrically conducting solution. The method of claim 23, wherein the step of applying the potential between the workpiece surface and the electrically conducting solution comprising connecting a power supply to the semiconductor workpiece and to a counter electrode, and connecting the counter electrode to the electrically conducting solution so that current flows from the workpiece surface to the counter electrode. The method of claim 23, wherein the workpiece surface comprises tungsten. The method of claim 23, wherein the workpiece surface comprises copper. The method of claim 23, wherein the relative movement between the electrically conducting solution and the oxidized surface is provided by rotating the semiconductor workpiece. The method of claim 23, wherein the relative movement between the electrically conducting solution and the oxidized surface is provided by rotating the table relative to the semiconductor workpiece. The method of claim 29, wherein the relative movement between the electrically conducting solution and the oxidized surface is provided by rotating the table relative to the semiconductor workpiece. Field of the Invention This invention relates generally to semiconductor processing, and more particularly to a chemical mechanical polishing system utilizing electrochemistry and to methods of using the same. Thereafter, the semiconductor wafer is brought into contact with the slurry and the polish pad and relative motion is provided between the wafer and the polish pad. Conventional slurries normally contain several components, such as one or more types of abrasive particles, a stabilizer that is designed to keep the abrasive particles from going into solution, and one or more oxidizing agents. In the CMP of various metals used in semiconductor processing, such as tungsten, the oxidizing agent of the slurry reacts with the tungsten to form a passivation layer of metal oxide. In the case of tungsten, the passivation layer consists of soft WO x.

Chapter 2 : Chemical-mechanical polishing slurry that reduces wafer defects - BURKE PETER A.

11/14/ 1 Scratch Evolution during Chemical Mechanical Polishing SFR Workshop November 14, Andrew Chang, David Dornfeld Berkeley, CA GOAL: Build integrated CMP model for basic mechanical.

Right getting hold of the contact form between the wafer and the pad is the precondition of fully understanding the material removal mechanism in wafer chemical mechanical polishing CMP process. In this paper, according to friction and abrasion theory, the differentiating method of contact form between the wafer and the pad has been obtained firstly. Then, the material removal rate MRR produced by mechanical action, chemical action and their interaction has been achieved by test results of MRR. According to analysis on test results of MRR, it is concluded that the mechanical action produced by abrasives is the main mechanical action, the MRR produced by the interaction between the mechanical action of abrasives and chemical action of slurry is the main MRR and the contact form between the wafer and the pad is solid-solid contact in wafer CMP. These results will provide theoretical guide to further understand the material removal mechanism of in wafer CMP. Chemical mechanical polishing CMP has already become a mainstream technology in global planarization of wafer. The nonuniformity of material removal on wafer surface has a main influence on surface profile of silicon wafer in CMP process. However, the formation mechanism of nonuniformity in wafer CMP has not been fully understood and the influences of CMP process variables on nonuniformity are not fully clear. The nonuniformity of material removal on wafer surface has not been fully understood and the influences of CMP process variables on nonuniformity are not fully clear in CMP process. In this paper, firstly, the equation of particle movement trajectories on wafer surface was built by the movement relationship between the wafer and the polishing pad on a single head CMP machine with line oscillation of carrier. Then the distribution of abrasive trajectories on wafer surface was analyzed at different rotational speed. The analysis results are in accord with experimental results. The results will provide some theoretical guide for designing the CMP equipment, selecting the movement variables in CMP and further understanding the material removal mechanism in wafer CMP. In order to understand the material removal mechanism in the process of chemical mechanical polishing CMP , the states of abrasives in the slurry and on the polishing pad in CMP process have been studied by testing. It was concluded that although the abrasive in the slurry is in the form of agglomeration, but the abrasive on the polishing pad are in approximately uniform layer distribution. According to analyzing the test results, it was concluded that the mechanical action produced by the abrasive is the main mechanical action in wafer CMP process and the MRR mainly results from the interaction between the mechanical action of the abrasives and the chemical action of slurry. These results will provide a reliable basis for the building of abrasive trajectory model and a theoretical guide to further understanding the material removal mechanism in wafer CMP. The results show that: The polishing time also play a very important role and affect the surface quality and surface damage of the wafer after polishing. Chemical mechanical polishing CMP has become the most widely used planarization technology in the semiconductor manufacturing process. In this paper, the distinguish method of lubricating behavior in wafer CMP had been analyzed in theory firstly. Then, the tests of wafer CMP with silicon wafer and deposited copper wafer at different polishing pressure had been done. By the test results, the Stribeck curves obtained showed obvious smooth. But in normal wafer CMP conditions, the friction coefficient of polishing area was above 0. By analyzing the experimental results, it was concluded that the lubrication state in CMP interface is belong to the boundary lubrication and the material removal is the process of bringing and removed of the chemical reaction boundary lubricating film on wafer surface constantly. The contact form between the Wafer and the polishing pad is the solid-solid contact. Chemical mechanical polishing, material removal mechanism, lubrication form, boundary lubrication.

Chapter 3 : CMP - chemical mechanical planarization and polishing equipment

With copper and barrier-layer integration firmly in place, several other exciting developments are occurring in the practice of chemical-mechanical polishing (CMP), and many advances are described in this book, first published in

The slurry of claim 36, wherein the suspension agent is an aqueous surfactant. A polishing system for polishing a semiconductor wafer, comprising: Field of the Invention [] The present invention relates to polishing slurry, and more particularly to a chemical-mechanical polishing slurry that reduces wafer defects and its method of making. Description of Related Art [] In the manufacture of integrated circuits, the planarization of semiconductor wafers is becoming increasingly important as the number of layers used to form integrated circuits increases. For instance, metallization layers formed to provide interconnects between various devices may result in nonuniform surfaces. The surface nonuniformities may interfere with the optical resolution of subsequent lithographic steps, leading to difficulty with printing high resolution patterns. The surface nonuniformities may also interfere with step coverage of subsequently deposited metal layers and possibly cause open or shorted circuits. One such approach involves polishing the wafer using a polishing slurry that includes abrasive particles mixed in a suspension agent. With this approach, the wafer is mounted in a wafer holder, a polishing pad has its polishing surface coated with the slurry, the pad and the wafer are rotated such that the wafer provides a planetary motion with respect to the pad, the polishing surface is pressed against an exposed surface of the wafer, and the slurry is used as a hydrodynamic layer between the polishing surface and the wafer. The polishing erodes the wafer surface, and the process continues until the wafer topography is largely flattened. Additives can also be added to enhance the removal rate, uniformity, selectivity, etc. With proper process parameters, CMP tungsten processing has shown significantly improved process windows and defect levels over standard tungsten dry etching. One significant advantage of CMP tungsten processing is that it has a highly selective polish rate for tungsten as compared to the dielectric. This selectivity allows for over-polishing while still achieving a flat tungsten stud. When overetching occurs using dry etching, the contact or via becomes further recessed, which creates a serious disadvantage since overetching is frequently required to remove defects. The prior art teaches that scratching can be controlled by the proper manufacturing, size control and filtering of the abrasive particles. The prior art also teaches that the proper mining sequence of the abrasive particles with the suspension agent leads to lower defects. In particular, deep or wide scratch defects in the polished surface continue to cause problems. This may arise since conventional slurry filtering tends to remove only those particles that are significantly larger than most of the abrasive particles. Therefore, a need exists for an improved CMP slurry that reduces scratching defects. These objects are achieved by filtering a solution with a dissolved oxidizer before adding the abrasive particles to the mixture, thereby removing a substantial amount of preexisting particles in the solution. Advantageously, when polishing occurs, scratching by the preexisting particles is dramatically reduced due to the filtering operation. The commercially available slurries, however, exhibit problems such as high scratch counts. Our slurry substantially addresses and reduces these problems. We specifically believe, for instance, that a contaminant is dust, and a reaction product of a ferric nitrate oxidizer is an organic nitro compound. As a result, when polishing occurs, the preexisting particles can cause substantial wafer damage. In this manner, the preexisting particles that remain in the slurry exhibit relatively little growth or coalescence before polishing occurs. Furthermore, as polishing occurs, the preexisting particles cause very little scratching since most of the abrasive particles have a far larger particle size than that of the preexisting particles. However, if undissolved ferric salt oxidizer remains, the filtering removes most of these particles which exceed a selected particle size. For instance, the suspension agent can added to the mixture before filtering the mixture. Likewise, the suspension agent can be added to the mixture after filtering the mixture, and then the abrasive particles can be added to the mixture. It is essential, however, that the abrasive particles be added to mixture after filtering the mixture.

Chapter 4 : Development of Theory Model in Chemical Mechanical Polishing

Chemical mechanical polishing of copper and tantalum was performed using fumed amorphous silica abrasive particles dispersed in H 2 O 2, Fe(NO 3) 3, and glycine solutions. Results showed that in DI water silica did not polish Cu but Ta had a relatively high polish rate.

Each groove has a desired depth, width, and shape. The chemical mechanical polishing pad provides effects of effectively controlling a flow of slurry during a polishing process, thereby achieving a stability in the polishing process in terms of a polishing rate, and achieving an enhancement in the planarization of a wafer. Description TECHNICAL FIELD The present invention relates to a polishing pad used in a chemical mechanical polishing process, and more particularly to a chemical mechanical polishing pad formed at a polishing surface thereof with a plurality of wave-shaped concentric grooves of different diameters each having a desired depth, width and shape. In accordance with such CMP, a slurry is supplied between a polishing pad and a wafer to be polished, so as to chemically etch the surface of the wafer. Using the polishing pad, the etched surface of the wafer is mechanically polished. The CMP method includes a chemical etching reaction process and a mechanical polishing process, which are conducted using a polishing pad 10 included in the CMP machine 1. The chemical etching reaction is carried out by a slurry That is, the slurry 42 serves to chemically react with the surface of a wafer 30 to be polished, thereby making it possible for the mechanical polishing process, following the chemical etching reaction, to be easily carried out. In the mechanical polishing process, the polishing pad 10, which is fixedly mounted on a platen 20, rotates. The wafer 30, which is firmly held by a retainer ring 32, rotates while oscillating. A slurry containing abrasive particles is supplied to the polishing pad 10 by a slurry supply means The supplied slurry is introduced between the polishing pad 10 and the wafer The introduced abrasive particles come into frictional contact with the wafer 30 by virtue of a relative rotating speed difference between the polishing pad 10 and the wafer 30, so that they conduct mechanical polishing. The slurry 42 is a colloidal liquid containing abrasive particles having a grain size of nanometers. This slurry 42 is spread on the polishing pad 10 during the polishing process. As the polishing pad 10 rotates during the polishing process, the slurry 42 supplied to the polishing pad 10 is outwardly discharged from the periphery of the polishing pad 10 due to a centrifugal force caused by the rotation of the polishing pad In order to achieve an enhanced polishing efficiency, many abrasive particles should remain for a desirable lengthy period of time on the upper surface of the polishing pad 10 so that they participate in the polishing of the wafer. That is, the polishing pad 10 should make the slurry 42 be held on the surface thereof for as long a period of time as possible. Centrifugal force generated during the rotation of the CMP pad is higher at a position nearer to the periphery of the polishing pad. Due to such a centrifugal force difference between different radial positions on the polishing pad, the slurry on the polishing pad exhibits an increased flow rate as it approaches the periphery of the polishing pad. Thus, the slurry is non-uniformly distributed in the radial direction of the polishing pad. Such a variation in polishing rate affects the planarization of the wafer. As a result, the polishing pad exhibits a considerable difference in polishing rate between its central portion and its peripheral portion. For this reason, it is necessary to uniformly distribute the slurry over the polishing pad by controlling the flow of slurry on the polishing pad. During the polishing process, the wafer is pressed against the polishing pad so that it comes into frictional contact with abrasive particles. Due to this pressure, however, it may be difficult for the slurry to reach the central portion of the wafer. For this reason, the slurry may be distributed at the central portion of the wafer in, a relatively reduced amount, as compared to the amount at the peripheral portion of the wafer. As a result, the wafer is non-uniformly polished. In order to solve such a problem, a method has been proposed, in which holes or grooves having a desired width, depth and shape are formed on a CMP pad. Such holes or grooves act to control the flow and distribution of the slurry continuously supplied during the polishing process. Now, holes or grooves conventionally formed on a polishing pad will be described in conjunction with the annexed drawings. As shown in FIGS. The slurry, which is continuously supplied onto the polishing pad, is forced to move outwardly by a centrifugal force generated as the polishing pad rotates. As a result, during the polishing process, the slurry is temporarily collected in the concentric circular grooves, and then outwardly discharged from those grooves. An example of such concentric circular grooves is disclosed in U. The polishing pad shown in FIG. Such lattice-shaped grooves serve to collect a slurry continuously supplied onto the polishing pad, thereby retarding the discharge of the slurry caused by centrifugal force. In the case of the conventional polishing pad having grooves uniformly spaced apart from one another, the slurry supplied onto the polishing pad is hindered from flowing toward the central portion of a wafer being polished at regions where the polishing pad is in contact with the wafer. As a result, a degradation in polishing rate occurs at the central portion of the wafer. Since lattice-shaped grooves extend in an opened state to the periphery of the polishing pad without having any closed portion, the slurry supplied onto the polishing pad is easily discharged from the polishing pad. As a result, the lattice-shaped grooves cause an increased consumption of slurry, as compared to concentric circular grooves. It was also reported that holes cause increased consumption of slurry, as compared to lattice-shaped grooves, because those holes involve a reduction of the cross-sectional area capable of storing slurry. In the case of concentric circular grooves, a superior slurry storage capacity is obtained because each groove has a partially closed structure having vertical groove walls capable of retaining the slurry in the groove against centrifugal force, as compared to other structures. Since the conventional method, which is used to form grooves at a polishing pad, utilize a cutting process conducted by a lathe or milling, the grooves have a fixed pattern such as concentric circles or a lattice. For this reason, it is difficult to form a groove pattern capable of effectively controlling the flow of a slurry. In order to solve such a problem, it is necessary to design the shape, density and distribution of grooves, taking into consideration given polishing process conditions such as centrifugal force and wafer position. Another object of the invention is to provide a CMP pad formed with wave-shaped grooves capable of effectively controlling the flow of a slurry supplied onto the polishing pad during a CMP process. In accordance with the present invention, these objects are accomplished by providing a CMP pad used for a CMP process, wherein a plurality of wave-shaped concentric grooves of different diameters each having a desired depth, a desired width and a desired shape are formed at a polishing surface of the pad. In accordance with the present invention, a CMP pad is provided which has, at a polishing surface thereof, a plurality of wave-shaped concentric grooves of different diameters each having a desired depth, width and shape. The wave-shaped grooves of the present invention have the form of concentric sinusoidal loops each having a desired amplitude and a desired number of cycles. Various examples of such wave-shaped grooves are illustrated in FIGS. Such wave-shaped concentric grooves each having the form of a sinusoidal loop have diverse shapes in accordance with the number of cycles and amplitude of the sinusoidal loop. For example, the wave-shaped concentric grooves may have an asteroid shape. Preferably, the sinusoidal loop has a number of cycles corresponding to 3 to 1, The shape of the grooves may be varied by adjusting the number of cycles and amplitude of the sinusoidal loop in accordance with the given polishing conditions. Such concentric grooves, which have the same wave shape, are formed on a polishing pad while being spaced apart from one another in accordance with the present invention. The wave-shaped concentric grooves formed on the polishing pad may be uniformly or non-uniformly spaced apart from one another. The groove space may vary in accordance with the radius thereof. Preferably, the polishing pad has at least two sets of grooves having different groove spaces in order to minimize the non-uniformity of the slurry caused by centrifugal force generated during a polishing process. For example, the groove space may be gradually reduced from the central portion to the peripheral portion of the polishing pad while being inversely proportional to an increase in the radius thereof. In accordance with the present invention, the polishing pad may be divided into a plurality of radial regions. Each radial region of the polishing pad may be formed with a plurality of grooves having the same shape while being uniformly spaced apart from one another. Each radial region may have a groove depth, groove width, or groove different from that of the remaining radial region. As shown in FIG. Each of the inner and outer radial regions has a uniform groove space. Also, the inner radial region may have a larger groove space than that of the outer radial region. Concentric circles or lines each composed of holes, grooves, or a combination thereof may be additionally formed on the polishing pad formed with the above described wave-shaped concentric grooves. The space between adjacent ones of the concentric circles may be uniform or non-uniform. Also, the circle space may vary gradually in accordance with the radius thereof.

Preferably, the straight lines formed on the polishing pad are symmetrical in a diametrical direction. Of course, it is possible to form straight lines in the form of a lattice or oblique lines. As apparent from the above description, the present invention provides a polishing pad formed with a plurality of wave-shaped concentric grooves of the same shape while having different diameters. It is possible to make the grooves with diverse patterns by varying the wave shape, groove width, groove depth or groove space. The pattern of the grooves may be further diversified where the polishing pad is additionally formed with a plurality of concentric circles or straight lines each composed of grooves, holes or a combination thereof. In order to allow the slurry to easily approach the central portion of the wafer during the polishing process, the groove space, width or depth at a portion of the polishing pad most frequently contacting the central portion of the wafer may also be adjusted. Preferably, the formation of holes or grooves according to the present invention is achieved using a laser machining process. The laser machining process provides advantages in that it is capable of precisely machining holes or grooves having a complicated structure, making the holes or grooves with a smooth inner surface, and easily adjusting the shape, size, and depth of the holes or grooves. Industrial Applicability The polishing pad, which is formed with a plurality of wave-shaped concentric grooves having the same shape while having different diameters in accordance with the present invention, is advantageous in that it can have diverse groove and hole patterns capable of optimally meeting the given polishing process conditions. The wave-shaped grooves of the polishing pad according to the present invention provides an increased area, through which a slurry passes before outwardly being discharged during a polishing process, as compared to grooves having the form of concentric circles. Accordingly, it is possible to retard the discharge rate of the slurry while uniformly distributing the slurry over the polishing surface, and effectively controlling the flow of the slurry during the polishing process, thereby maintaining a stable desired polishing rate and achieving an improved planarization. Although the preferred embodiments of the invention have been disclosed for illustrative purposes in conjunction with a polishing pad having wave-shaped grooves, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims. Claims 14 What is claimed is: A chemical mechanical polishing pad used for a chemical mechanical polishing process, wherein a plurality of wave-shaped concentric grooves of different diameters has the form of a sinusoidal loop having a number of cycles corresponding to 3 to 1,, each having a desired depth, a desired width and a desired shape are formed at a polishing surface of the pad. The chemical mechanical polishing pad according to claim 1 , wherein the wave-shaped concentric grooves are uniformly or non-uniformly spaced apart from one another. The chemical mechanical polishing pad according to claim 1 , the wave-shaped concentric grooves are non-uniformly spaced apart from one another so that the groove space defined between adjacent ones of the grooves is gradually reduced from a central portion of the pad to a peripheral portion of the pad. The chemical mechanical polishing pad according to claim 1 , wherein the pad is divided into a plurality of radial regions formed with the wave-shaped concentric grooves, the grooves of each of the radial regions having the same groove depth, the same groove width, and the same groove space while each of the radial regions being different from the remaining radial regions in terms of at least one of a groove depth, a groove width, and a groove space. The chemical mechanical polishing pad according to claim 1 , wherein a plurality of concentric circles each composed of grooves, holes or a combination thereof are further formed at the polishing surfaces. The chemical mechanical polishing pad according to claim 7 , wherein the concentric circles are uniformly or non-uniformly spaced apart from one another so that they are grouped into at least two sets having different groove spaces. The chemical mechanical polishing pad according to claim 7 , wherein the concentric circles are spaced apart from one another so that the circle space defined between adjacent ones of the concentric circles is gradually reduced from a central portion of the pad to a peripheral portion of the pad. The chemical mechanical polishing pad according to claim 1 , wherein one or more straight lines each composed of grooves, holes or a combination thereof are further formed at the polishing pad. The chemical mechanical polishing pad according to claim 10 , wherein the straight lines are grouped into a group of horizontal straight lines spaced apart from one another and a group of vertical straight lines spaced apart from one another while crossing the horizontal straight lines to form a lattice structure. The chemical mechanical polishing pad according to claim

10 , wherein the straight lines cross together at a center of the polishing surface so that they are symmetrically arranged in a diametrical direction. The chemical mechanical polishing pad according to claim 1 , wherein a plurality of concentric circles each composed of grooves, holes or a combination thereof and one or more straight lines each composed of grooves, holes or a combination thereof are further formed at the polishing surface. The chemical mechanical polishing pad according to claim 1 , wherein the wave-shaped grooves are machined by a laser. US Chemical mechanical polishing pad having wave shaped grooves Active USB2 en Priority Applications 3.