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(54) **CUTTING ELEMENTS WITH RIDGED AND INCLINED CUTTING FACE**

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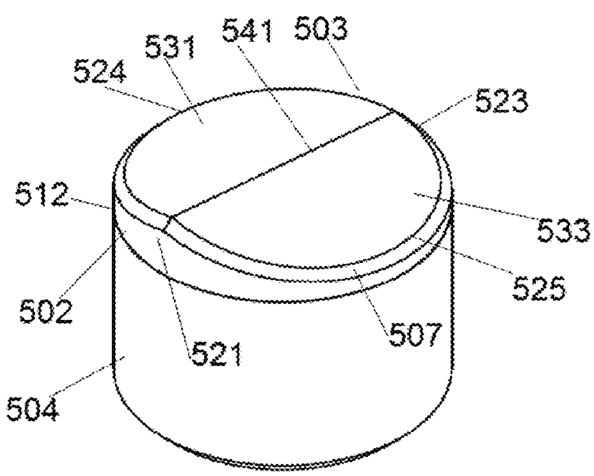
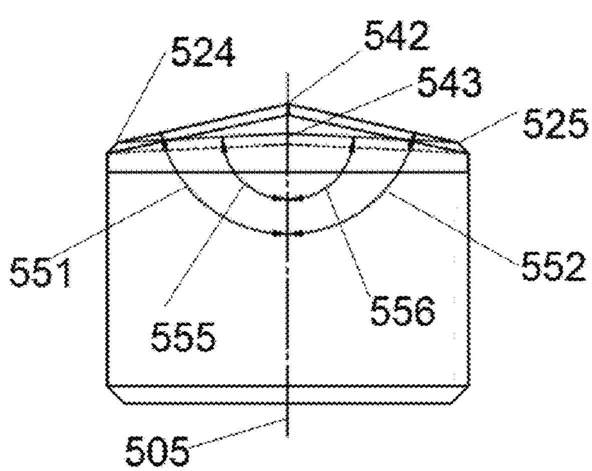
CPC ***E21B 10/5673*** (2013.01); ***E21B 10/43*** (2013.01); ***E21B 10/5676*** (2013.01)

(57) **ABSTRACT**

A drill bit for cutting formation comprises a bit body, a plurality of cutters, and a plurality of blades with pockets to accommodate the cutters, respectively. Each of the plurality of cutters has a substrate, an ultra-hard layer, an inclined surface on the top of the ultra-hard layer, wherein the inclined surface slants downward from a cutting edge to a trailing edge. The cutter can improve cutting efficiency and service life.





Prior art

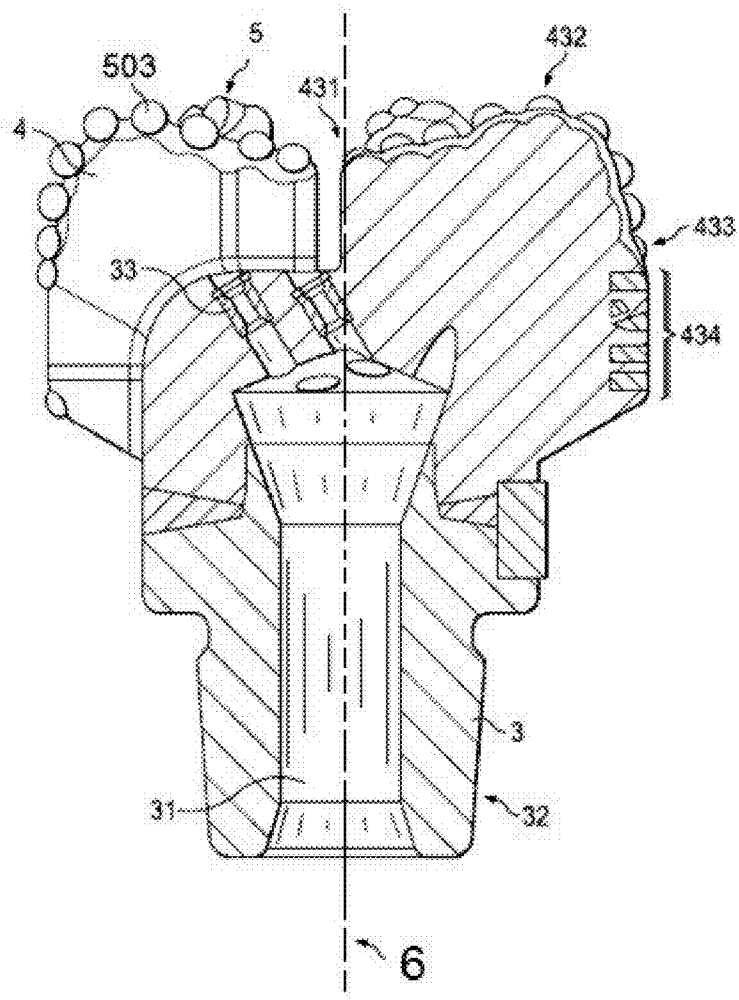


Fig. 1

Prior art

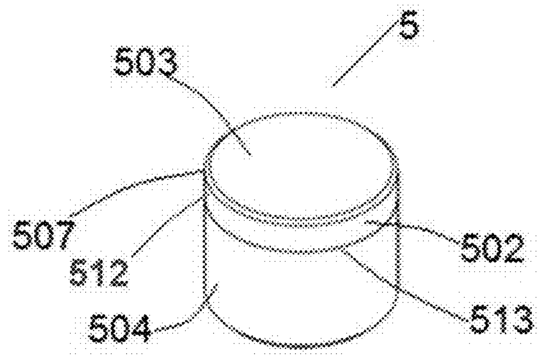


Fig. 2A

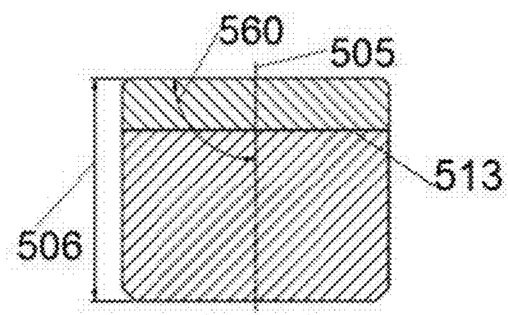


Fig. 2B

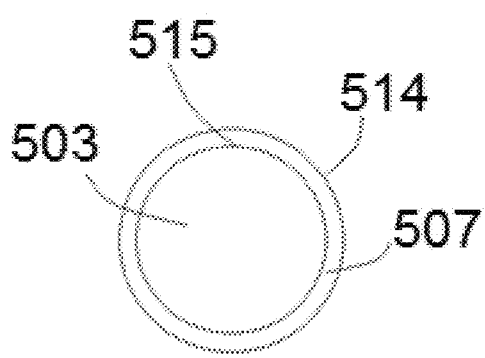


Fig. 2C

Prior art

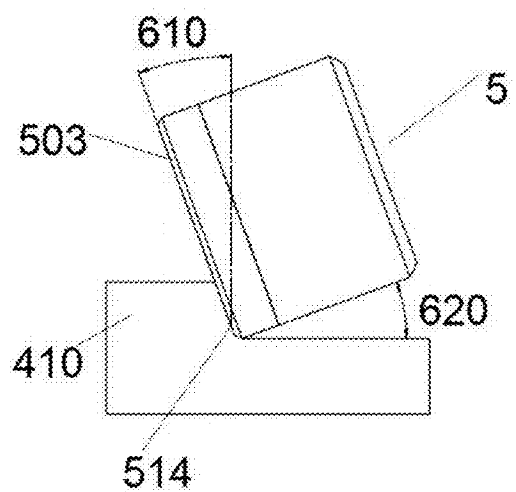


Fig. 3A

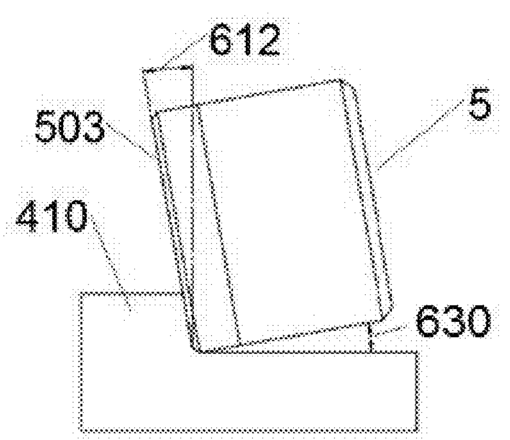


Fig. 3B

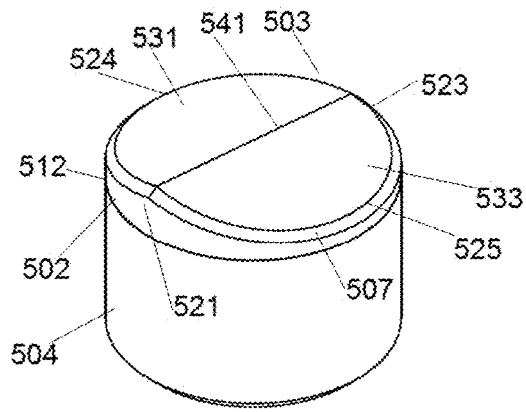


Fig. 4A

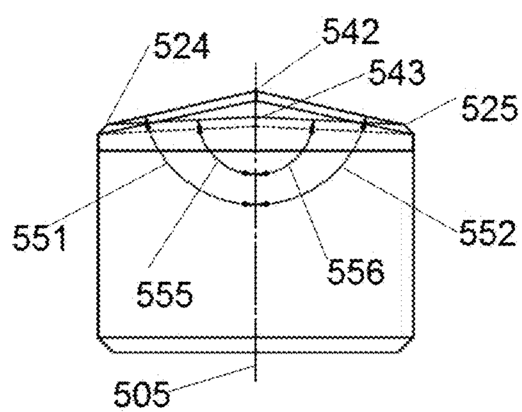


Fig. 4B

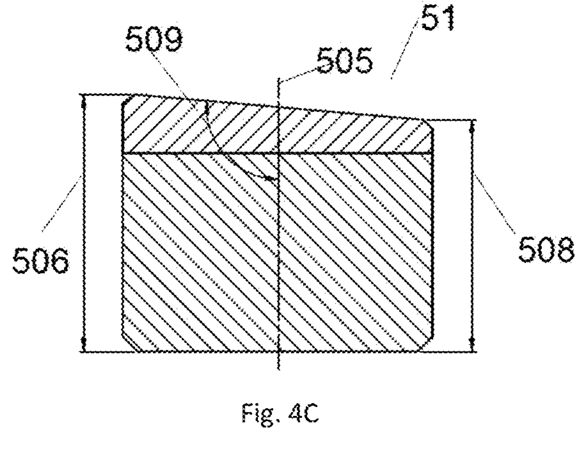


Fig. 4C

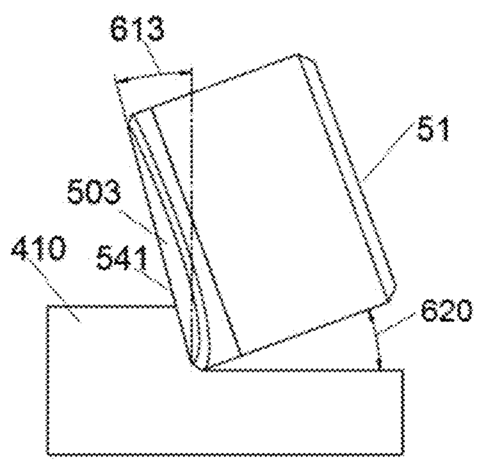


Fig. 5

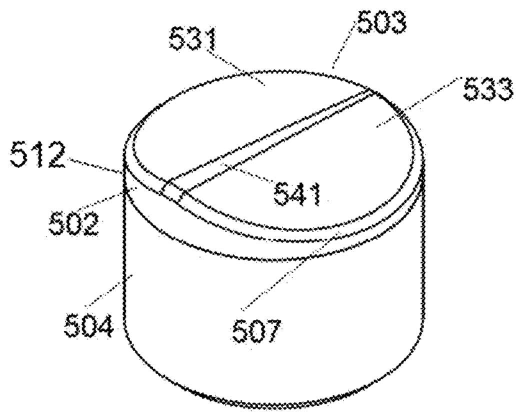


Fig. 6A

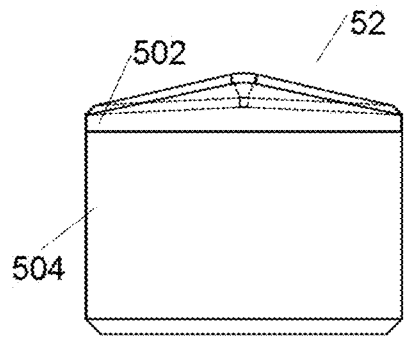


Fig. 6B

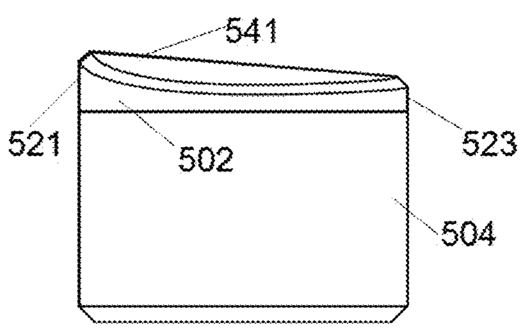


Fig. 6C

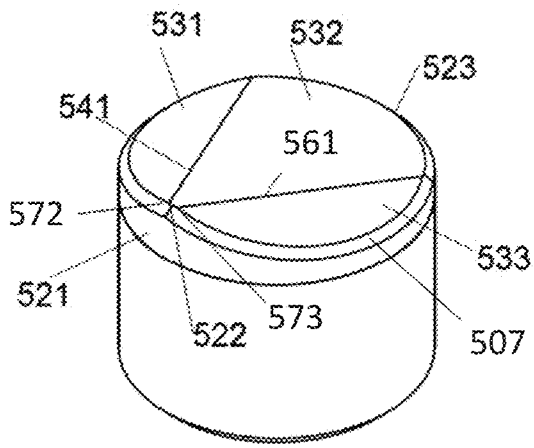


Fig. 7A

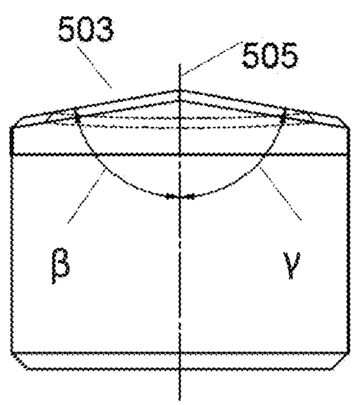


Fig. 7B

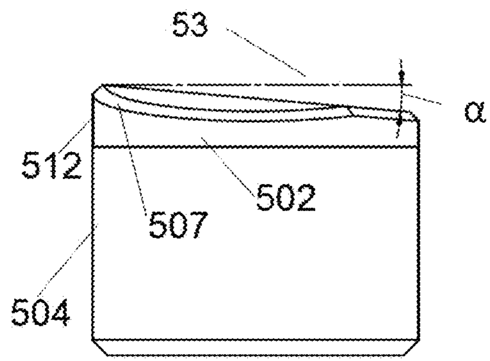


Fig. 7C

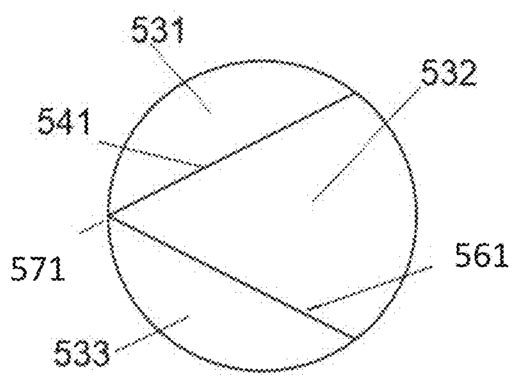


Fig. 7D

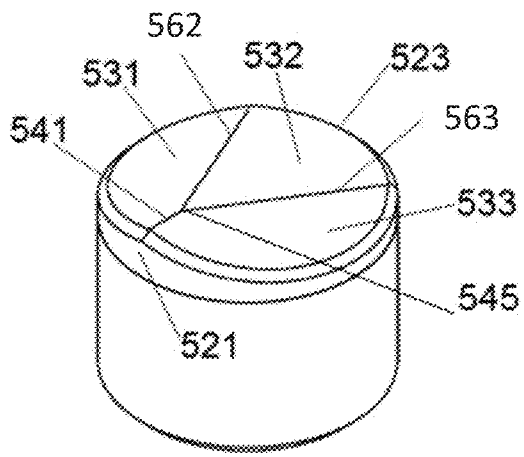


Fig. 8A

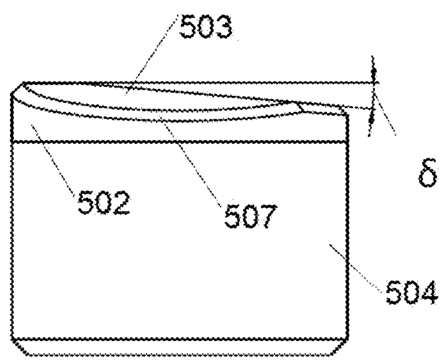


Fig. 8B

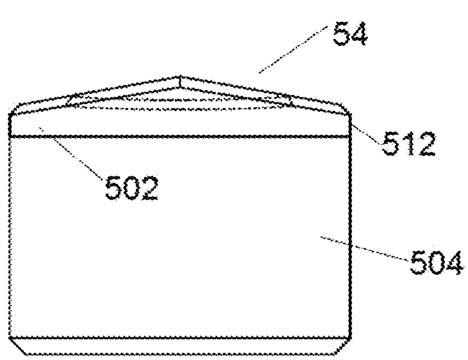


Fig. 8C

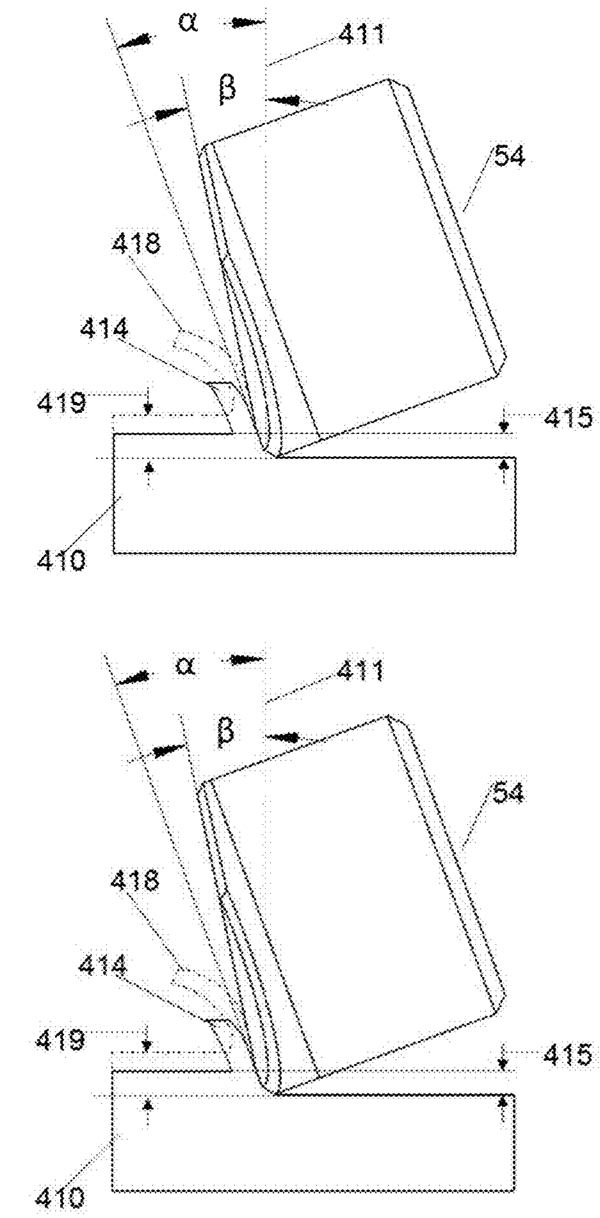


Fig. 9

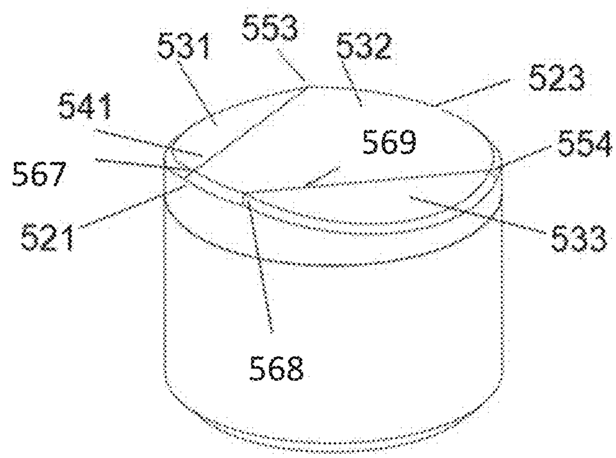


Fig. 10A

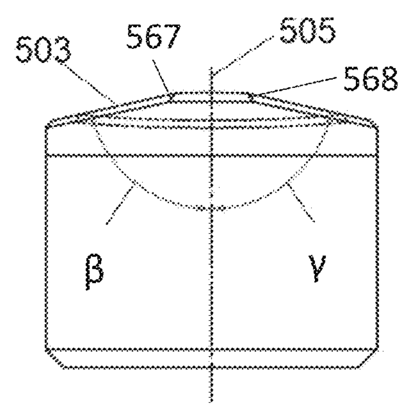


Fig. 10B

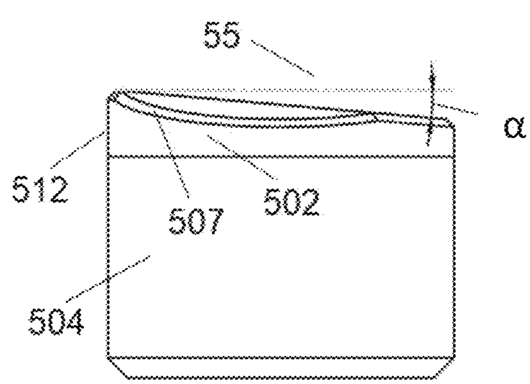


Fig. 10C

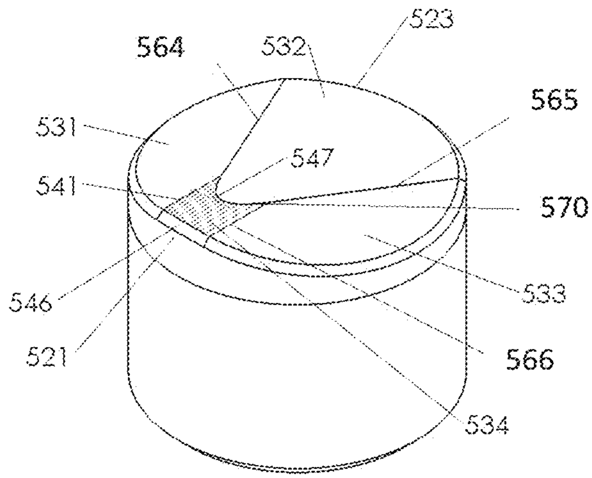


Fig. 11A

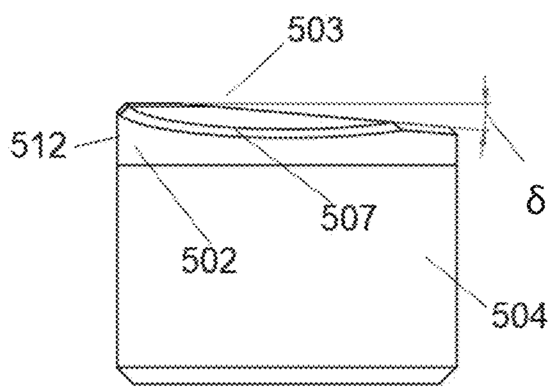


Fig. 11B

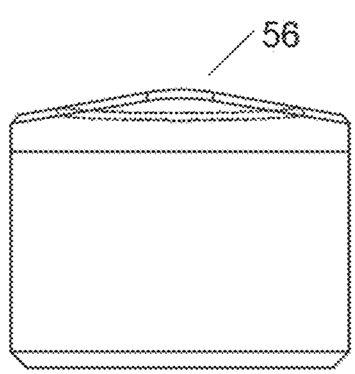


Fig. 11C

CUTTING ELEMENTS WITH RIDGED AND INCLINED CUTTING FACE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a divisional of U.S. patent application Ser. No. 17/331,353, filed May 26, 2021, and which claims the benefit of U.S. Provisional Patent Application No. 63/030,725, filed May 27, 2020; both U.S. patent application Ser. No. 17/331,353, and U.S. Provisional Patent Application No. 63/030,725 are fully incorporated by reference herein in their entireties.

FIELD

[0002] This disclosure generally relates to drill bits in oil and gas industry. The disclosure specifically relates to the cutting elements in field of the drill bits for petroleum exploration and drilling operation.

BACKGROUND

[0003] When drilling a borehole in the earth, such as for the recovery of hydrocarbons or for other applications, it is a conventional practice to connect a drill bit on the lower end of a drill string. The bit is rotated by rotating the drill string at the surface or by the actuation of downhole motors or turbines, or by both methods. The drill bit is rotated and advanced into a subterranean formation. As the drill bit rotates, cutters or abrasive structures cut, crush, shear, and/or abrade away formation material to form a borehole. A bit generally includes a bit body made from steel or matrix metal. The bit body has blades or similar structures to which are attached a plurality of cutting elements in a selected arrangement. The way in which the blades are structured, and the way in which the cutting elements are arranged on the blades depend on, among other factors, the type of earth formations to be drilled with the particular bit and the structure of a drilling assembly to which the drill bit is attached.

[0004] Referring to FIG. **1**, a conventional bit adapted for drilling through formations of rock to form a borehole is shown. The bit includes a drill bit body **3** and a plurality of blades **4** and a connection or pin **32** for connecting the bit to a drill string (not shown) which is employed to rotate the bit around a longitudinal bit axis **6** to drill the borehole. The blades **4** are separated by channels or gaps that enable drilling fluid to flow through and both clean and cool the blades **4** and cutters **5**. The cutters **5** are held in the blades **4** at predetermined angular orientations and radial locations to present a top surface **503** with a desired back rake angle against the formation to be drilled. A fluid channel **31** is formed in the drill bit body **3**, and a plurality of fluid holes **33** communicate with the fluid channel **31**. Drilling fluid can be pumped into a space between the blades **4** in selected directions and at selected rates of flow for lubricating and cooling the drill bit, the blades **4**, and the cutters **5**. The drilling fluid also cleans the bottom of the borehole and removes cuttings as the drill bit rotates and penetrates the formation.

[0005] The drill bit body **3** is substantially cylindrical. The plurality of the cutters **5** are disposed on the outer edge of the blade **4**, furthermore, the outer edge of the blade **4** comprises a cone portion **431**, a nose portion **432**, a shoulder portion **433**, and a gauge protection portion **434**. The cone portion **431** is close to the central axis of the drill bit body **3**, the gauge protection portion **434** is located on the side wall of the drill bit body **3**, and the cutters **5** are distributed across the cone portion **431**, the nose portion **432**, the shoulder portion **433** and the gauge protection portion **434** of the blades **4**.

[0006] Referring to FIGS. **2**A-**2**C, a typical cutting element (cutter) **5**, is substantially cylindrical having a cutter axis **505**, and includes a cylindrical bottom portion and a cylindrical top portion. The bottom portion, called a substrate **504**, is usually made from hard composites such as tungsten carbide, and the top portion, called an ultra-hard layer **502**, is typically made from hard and abrasive material such as polycrystalline diamond (PCD). The interface **513** between the substrate **504** and the ultra-hard layer **502** may be planar or nonplanar, according to many varying designs for interfaces known in the art. The substrate **504** and the ultra-hard layer **502** are sintered together through a high pressure, high temperature process. On the top end of the ultra-hard layer **502**, a chamfer **507** is machined to increase the durability of the cutting edge while running into the borehole and at the inception of drilling, at least along the portion which initially contacts the formation. One skilled in the art will recognize that at least a portion of the chamfer **507** may also function as a working surface that contacts the subterranean formation during drilling operations. The top surface **503** of the ultra-hard layer **502** and the surface of the chamfer **507** intersect at a top cutting edge **515**. The side wall **512** of the ultra-hard layer **502** and the surface of the chamfer **507** also intersect at a lower cutting edge **514**, which is the main formation cutting edge whose curvatures are the same as that of the outer cylindrical surface of substrate **504**.

[0007] For a typical cutter, the top surface **503** of the ultra-hard layer, also called the cutting face, is flat and parallel to the bottom surface of the substrate, i.e., perpendicular to the cutter axis **505**. The distance from any point on the cutting face to the bottom surface of the substrate is equal to cutter height **506**. It is also noted that the thickness of the ultra-hard layer is uniform if the interface **513** is planar. A non-planar interface **513** may be employed to reduce the thermal residual stress at the interface and inside the ultra-hard layer due to the mismatch of the coefficient of thermal expansion between the ultra-hard layer material and the substrate material. In this case, the thickness of the ultra-hard layer is not uniform, but the cutting face is still parallel to the bottom surface of the substrate and perpendicular to the cutter axis, i.e., the cutting face angle **560** between the cutting face and the cutter axis is 90 degrees.

[0008] Referring to FIGS. **3**A and **3**B, the cutter **5** cuts a formation **410** with the top surface **503**. In the drilling process, the drill bit (see FIG. **1**) will be positioned at the bottom of a well bore and rotated for cutting the inside surface of the cylindrical well bore. Cutters in the blades are assembled via brazing or mechanical lock at predetermined angular orientations in regard to the formation to be drilled. Drilling fluid is pumped into the inside of the bit body and exits from the nozzles. As the drill bit is rotated, the PDC cutters scrape across and shear away the underlying earth formation material and withstand great impact from the formation.

[0009] One feature of the arrangement of the cutter is known as the relief angle, which is the angle between the cutter axis and the top surface of the formation **410**. A certain relief angle is necessary to prevent the cutter from rubbing against the formation, avoiding frictional heat and extra reactive torque during drilling.

[0010] Another feature of the arrangement of the cutter is known as the back rake angle. The back rake angle is used to describe the working angle of the top surface **503**. As shown in FIG. **3**A, the back rake angle **610** is defined as the angle between the top surface **503** and a plane normal to the surface of formation **410** at the cutting edge **514**. For a cylindrical flat cutter, the back rake angle **610** is equal to the relief angle **620**. The back rake angle **610** in FIG. **3**A is greater than the back rake angle **612** in FIG. **3**B because the relief angle **620** in FIG. **3**A is greater than the relief angle **630** in FIG. **3**B. Desired back rake angle for the most efficient drilling depends on the type of formation to be drilled. Typically, a drill bit is designed so that the cutter has a relatively low back rake angle. Low back rake angle provides the drill bit with relatively high efficiency, by reducing the weight on bit (WOB) required to fail a given earth formation, meaning that the rate of penetration through earth formations is high.

[0011] However, for hard formations, such as carbonate, igneous rocks and sandstone, a relatively large back rake angle is needed, in order to increase the strength of the cutting edge and prevent the cutters from breakage or chipping resulted from the high cutting force acting on the cutters. In this case, the cutting efficiency is reduced and sometimes it is difficult for the cutter to bite into the formation, resulting in unstable drilling.

[0012] For soft formations, such as shale, claystone and mudstone, a lower cutting force is required to shear the formation and cutter damage is not significant. A relatively small back rake angle can be used to maximize the cutting efficiency without causing cutter damage. However, for the conventional cutter with a flat cutting face, the desired back rake angle might not be achievable. If the back rake angle (same as the relief angle for a planar cutter) is too small, the cutter's circumferential surface adjacent to the cutting edge will rub against the formation or extruded cuttings, increasing the frictional heat and adding extra reactive torque. The increased frictional heat will degrade cutter wear resistance and impact resistance and shorten bit life. Another disadvantage of the cutters with a planar cutting face in drilling soft formations, especially shale and claystone under high confining pressure and high bottom-hole temperature, is the continuous ribbon generated during drilling. Continuous ribbons may accumulate and compact in front of the cutter face and/or between the cutter and the rock. Cutting build-up has a major impact on cutter/rock interactions. Energy is lost in plastically deforming the cuttings rather than failing intact rock. Cutting build-up may also lead to other drilling dysfunctions such as poor cooling and even cutter balling. Due to the large size of these kinds of cuttings, they could attach to the blades and the body part of the bit to form balling, such that the work faces of the blades of the bit are clogged, restricting drilling fluid and cutting flow, eventually leading to decrease of mechanical speed, no drill footage and other issues.

[0013] Therefore, it would be advantageous to provide a cutter with reduced back rake angle while maintaining a required relief angle in order to improve cutting efficiency and service life.

SUMMARY

[0014] In one aspect, the present invention is directed to a cutter used on a drill bit for cutting formation. The cutter comprises a substrate, an ultra-hard layer, an inclined surface on the top of the ultra-hard layer, wherein the inclined surface slants downward from a cutting edge to a trailing edge. In an embodiment, the cutter further comprises a chamfer extending from the periphery of the inclined surface to the cutting edge at a side wall of the ultra-hard layer.

[0015] In some embodiments pertaining to the inclined surface, the inclined surface comprises a cutting ridge extending from the cutting edge to the trailing edge diametrically on the top of the inclined surface. Two side surfaces slant downward respectively from the cutting ridge to the periphery of the inclined surface. The profile angle at the trailing edge is larger than the profile angle at the cutting edge and the cutter height at the cutting edge is taller than the cutter height at the trailing edge. In some embodiments, the cutting ridge is rounded.

[0016] In some embodiments pertaining to the inclined surface, the inclined surface comprises two cutting ridges intersecting at a cutting point on the cutting edge and extending from the cutting point outwards at an angle towards the trailing edge. The two cutting ridges separate the inclined surface into two side flat surfaces and a central flat surface. The central flat surface slants downward from the cutting edge to the trailing edge and the two side flat surfaces slant downward from the two cutting ridges to the periphery of the inclined surface, respectively. The inclined angles of the two side flat surfaces can be equal or different.

[0017] In some embodiments pertaining to the inclined surface, the inclined surface comprises two converging cutting ridges and one central cutting ridge intersecting at a point away from the cutting edge, and the two converging cutting ridges and the central cutting ridge divide the inclined surface into two flat side surfaces and one flat central surface. The two flat side surfaces intersect at the central cutting ridge and the two flat side surfaces intersect the central surface at the two converging cutting ridges, respectively. The outer end of the central cutting ridge (close to the cutter periphery) meets the cutting edge at a cutting point. The central cutting ridge is parallel to the cutter bottom surface of the substrate. The flat central surface is sloped. In some embodiments, the central cutting ridge is rounded and forms a second central surface which is curved.

[0018] In some embodiments pertaining to the inclined surface, the inclined surface comprises two cutting ridges which do not intersect on the cutting surface and extend from the cutting edge at an angle towards the trailing edge. The two cutting ridges meet the cutting edge and form two cutting points. The two cutting ridges separate the inclined surface into two side flat surfaces and a central flat surface. The central flat surface slants downward from the cutting edge to the trailing edge and the two side flat surfaces slant downward from the two cutting ridges to the periphery of the inclined surface, respectively. The inclined angles of the two side flat surfaces can be equal or different.

[0019] In some embodiments, the ultra-hard layer is formed of PCD and the inclined surface is machined by Electrical Discharge Machining methods.

[0020] In another embodiment, the disclosure is directed to a drill bit for cutting formation. The drill bit comprises a bit body, a plurality of cutters of the present disclosure, and a plurality of blades with pockets to accommodate the cutters, respectively.

[0021] The foregoing has outlined rather broadly the features of the present disclosure in order that the detailed description that follows may be better understood. Additional features and advantages of the disclosure will be described hereinafter, which form the subject of the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] In order that the manner in which the above-recited and other enhancements and objects of the disclosure are obtained, a more particular description of the disclosure briefly described above will be rendered by reference to specific embodiments thereof which are illustrated in the appended drawings. Understanding that these drawings depict only typical embodiments of the disclosure and are therefore not to be considered limiting of its scope, the disclosure will be described with additional specificity and detail through the use of the accompanying drawings in which:

[0023] FIG. **1** is a sectional view of a prior art drill bit;

[0024] FIG. **2**A is a perspective view of a prior art cutter with planar cutting face;

[0025] FIG. **2**B is a sectional view of the cutter in FIG. **2**A;

[0026] FIG. **2**C is a top view of the cutter in FIG. **2**A;

[0027] FIG. **3**A is a schematic illustration of a planar cutter cutting formation with larger back rake angle;

[0028] FIG. **3**B is a schematic illustration of a planar cutter cutting formation with smaller back rake angle;

[0029] FIG. **4**A is a perspective view of the cutter with nonplanar cutting face, which comprises two inclined side surfaces and one inclined cutting ridge in accordance with one embodiment of the present invention;

[0030] FIG. **4**B is a front view of the cutter with nonplanar cutting face in FIG. **4**A;

[0031] FIG. **4**C is a sectional view of the cutter with nonplanar cutting face in FIG. **4**A;

[0032] FIG. **5** is a schematic illustration of the cutter in FIG. **4**A cutting formation with reduced back rake angle;

[0033] FIG. **6**A is a perspective view of the nonplanar cutter in FIG. **4**A with a round cutting ridge;

[0034] FIG. **6**B is a front view of the nonplanar cutter in FIG. **6**A;

[0035] FIG. **6**C is a side view of the nonplanar cutter in FIG. **6**A;

[0036] FIG. **7**A is a perspective view of the cutter with nonplanar cutting face, which comprises three inclined flat surfaces converging at the cutting edge in accordance with one embodiment of the present invention;

[0037] FIG. **7**B is a front view of the cutter with nonplanar cutting face in FIG. **7**A;

[0038] FIG. **7**C is a side view of the cutter with nonplanar cutting face in FIG. **7**A;

[0039] FIG. **7**D is a top view of the cutter with nonplanar cutting face in FIG. **7**A with three inclined flat surfaces converging on the cutter periphery before the chamfer is constructed;

[0040] FIG. **8**A is a perspective view of the cutter with three flat surfaces and three cutting ridges in accordance with one embodiment of the present invention;

[0041] FIG. **8**B is a front view of the cutter with nonplanar cutting face in FIG. **8**A;

[0042] FIG. **8**C is a side view of the cutter with nonplanar cutting face in FIG. **8**A;

[0043] FIG. **9** is a schematic illustration of the cutter in FIG. **8**A cutting a highly heterogeneous formation with interbedded soft and hard sections;

[0044] FIG. **10**A is a perspective view of the cutter with nonplanar cutting face, which comprises three inclined flat surfaces which do not intersect at a point on the cutting surface;

[0045] FIG. **10**B is a front view of the cutter with nonplanar cutting face in FIG. **10**A;

[0046] FIG. **10**C is a side view of the cutter with nonplanar cutting face in FIG. **10**A;

[0047] FIG. **11**A is a perspective view of the nonplanar cutter in FIG. **8**A with a round central cutting ridge;

[0048] FIG. **11**B is a front view of the cutter with nonplanar cutting face in FIG. **11**A;

[0049] FIG. **11**C is a side view of the cutter with nonplanar cutting face in FIG. **11**A.

DETAILED DESCRIPTION

[0050] The particulars shown herein are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present disclosure only and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of various embodiments of the disclosure. In this regard, no attempt is made to show structural details of the disclosure in more detail than is necessary for the fundamental understanding of the disclosure, the description taken with the drawings making apparent to those skilled in the art how the several forms of the disclosure may be embodied in practice.

[0051] The following definitions and explanations are meant and intended to be controlling in any future construction unless clearly and unambiguously modified in the following examples or when application of the meaning renders any construction meaningless or essentially meaningless. In cases where the construction of the term would render it meaningless or essentially meaningless, the definition should be taken from Webster's Dictionary 11th Edition.

[0052] FIGS. **4**A-**4**C illustrate an embodiment of a cutter **51** of the present disclosure. In accordance with the present invention, the cutter **51** has a substrate **504** and an ultra-hard layer **502** disposed thereon. The ultra-hard layer **502** can be formed of polycrystalline diamond, cubic boron nitride, silicon carbide, and the substrate **504** can be formed of tungsten carbide. The cutter **51** is substantially cylindrical and symmetrical about a longitudinal cutter axis **505**, although such symmetry is not required, and nonsymmetrical cutters are known in the art. A chamfer **507** extends from the periphery of a top surface **503** to a side wall **512** of the ultra-hard layer **502**. Chamfer **507** may extend about the entire periphery of the ultra-hard layer **502** as shown or only a portion to be located adjacent to a cutting edge **521**. Although the chamfer **507** can increase the durability of the cutting edge, it should be noted that cutters exhibiting substantially no visible chamber may be employed for certain applications in selected outer regions of a bit.

[0053] The top surface **503** of the cutter in the invention comprises two side surfaces **531**, **533** which intersect at the center of the cutter and form a cutting ridge **541**. The top surface **503** can be constructed from a typical flat cutter by removing materials with a method called loft cut. The cutting ridge **541** extends downward from the cutting edge **521** to the trailing edge **523** diametrically on the top surface **503**. The two side surfaces **531**, **533** are slanted downward respectively from the cutting ridge **541** to the periphery of the inclined top surface **503** along the perpendicular direction with respect to the cutting ridge. The intersection of the cutting ridge **541** and the cutting edge **521**, the lowest point on the side surface **531**, and the lowest point on the side surface **533** define three vertices of a cutting triangle. The projection of the cutting triangle on a plane perpendicular to the cutting ridge **541** will form a cutting triangle profile with three vertices **542**, **524**, **525**. Similarly, the intersection of the cutting ridge **541** and trailing edge **523**, the lowest point on the side surface **531**, and the lowest point on the side surface **533** define three vertices of a trailing triangle. The trailing triangle projecting onto a plane perpendicular to the cutting ridge **541** will create a trailing triangle profile with three vertices **543**, **524**, **525**.

[0054] The vertex **542** of the cutting triangle profile is higher than the vertex **543** of the trailing triangle profile. An angle between the line connecting vertices **542**, **524** and the cutter axis **505** is defined as the first cutting edge profile angle **551**, and an angle between the line connecting vertices **542**, **525** and the cutter axis **505** is defined as the second cutting edge profile angle **552**. An angle between a line connecting vertices **543**, **524** and the cutter axis **505** is defined as the first trailing edge profile angle **555**, and an angle between the line connecting vertices **543**, **525** and the cutter axis **505** is defined as the second trailing edge profile angle **556**. Using the line connecting the vertices of the triangle profiles as the guide curve, a convex surface can be formed. The slopes of the side surfaces are determined by the profile angles. The profile angles at the trailing edge are larger than the profile angles at the cutting edge to keep a reasonable diamond table thickness at the trailing edge **523**. Specially, the first trailing edge profile angle **555** is larger than the first cutting edge profile angle **551**, and the second trailing edge profile angle **556** is larger than the second cutting edge profile angle **552**. The cutting ridge **541** is typically located at the center of the top surface. The profile angles of each profile may be equal or different. The loft cut is executed by Electrical Discharge Machining (EDM), Laser Ablation, Grinding, or other material reduction methods. It can also be net shaped through sintering process.

[0055] By constructing the cutter using the aforementioned methods, the cutter height **506** at the cutting edge is taller than the cutter height **508** at the trailing edge. The cutting ridge **541** is declining from the cutting edge to the trailing edge with an angle **509** larger than 90 degrees. The cutting ridge inclination is measured between the cutting ridge **541** and the cutter axis **505**.

[0056] The advantage of the nonplanar cutter described in FIGS. **4A-4C** can be explained in FIG. **5** and FIG. **3A**. FIG. **3A** shows a planar cutter cutting formation with a back rake angle **610** and a relief angle **620**. FIG. **5** shows a cutter **51** with the inclined cutting face of FIG. **4A** cutting formation with the same relief angle. When cutting into a formation **410**, the planar cutter **5** and the non-planar cutter **51** have the same relief angle **620** in FIGS. **3A** and **5**. Because of the inclined cutting face, the back rake angle **613** of the cutter **51**, which equals to the back rake angle **610** minus the inclination angle **509** in FIG. **4C** plus 90 degrees, is smaller than the back rake angle **610** of the planar cutter **5**. The reduced back rake angle and the sharp ridge of the nonplanar cutter in FIGS. **4A-4C** requires less cutting force to fracture the formation while maintaining a reasonable relief angle.

[0057] There are some other advantages of the cutter described in FIGS. **4A-4C**. The cuttings will remain in contact with the cutting face for a shorter period of time with the reduced back rake angle, resulting in less frictional heat. The frictional heat will deteriorate the properties of the ultra-hard layer such as wear resistance and impact resistance. The nonplanar cutting face provides a favorable fluid path, allowing the drilling fluid to cool the cutter more efficiently. The cutting ridge **541** and inclined side surfaces **531**, **533** will break down the cuttings and reduce the tendency of cutting compaction in front of the cutting ridge, which might lead to other drilling dysfunctions such as poor cooling and even cutter balling.

[0058] In an embodiment of the present disclosure, the inclined cutting surface may have a round cutting ridge in the middle. FIGS. **6A-6C** illustrate a cutter **52** having inclined surface and a round cutting ridge. Specifically, the cutter **52** has a substrate **504** and an ultra-hard layer **502** disposed thereon. A chamfer **507** extends from the periphery of the top surface **503** to the side wall **512** of the ultra-hard layer **502**. The top surface **503** of the ultra-hard layer **502** is inclined. A cutting ridge **541** extends downward from a cutting edge **521** to a trailing edge **523** diametrically on the top surface **503**. The two side surfaces **531**, **533** are slanted downward respectively from the cutting ridge **541** to the periphery of the inclined top surface **503** along the perpendicular direction with respect to the cutting ridge **541**. At the same time, the two side surfaces **531**, **533** are slanted downward respectively from the cutting edge **521** to the trailing edge **523**.

[0059] As will be recognized by those skilled in the art, there are other cutter designs in accordance with the features of this invention. In a preferred embodiment. Referring to FIGS. **7A-7D**, a cutter **53** having inclined surface is illustrated. The cutter **53** has a substrate **504** and an ultra-hard layer **502** disposed thereon. A chamfer **507** extends from the periphery of a top surface **503** to the side wall **512** of the ultra-hard layer **502**. The top surface **503** of the ultra-hard layer **502** is inclined.

[0060] The top surface **503** comprises two inclined flat side surfaces **531** and **533** and an inclined flat central surface **532**. The central surface **532** has an inclination α between the central surface **532** and the bottom surface of the cutter. The inclination α, in the range of 1-45 degrees, preferred in the range of 3-15 degrees, determines the back rake angle reduction compared to a flat cutter. The side surfaces **531**, **533** have inclinations β and γ with their lower sides intersecting cutter cylindrical surface. The inclinations β and γ are measured between the side surfaces **531**, **533** and a cutter axis **505**, respectively. The three surfaces intersect at two cutting ridges **541**, **561**. Specifically, the flat side surface **531** intersects with the central surface **532** at the cutting ridge **541**, and the flat side surface **533** intersects with the central surface **532** at the cutting ridge **561**. Referring to FIG. **7D**, the cutting ridges **541**, **561** intersect the cutter periphery at the point **571** before the chamfer is constructed and extend from the point **571** to the trailing edge, such that the two cutting ridges form a substantially "V" type pattern. Referring to FIG. **7A**, after the chamfer **507** is constructed, the cutting ridges **541**, **561** intersect the cutting edge **521** at the points **572** and **573**. The two side surfaces **531** and **533** and the central surface **532** slant downward respectively from the cutting edge **521** to the trailing edge **523**, at the same time, the side surfaces **531**, **533** slant downward respectively from the two cutting ridges **541**, **561** to the cutter periphery. The side surfaces are symmetric with regard to the plane which passes through point **522** having equal distance to the points **572** and **573** and the cutter axis **505** in FIGS. **7**A-**7**B, in which case the inclinations β and γ are equal, but they can be asymmetric in other embodiments.

[0061] FIGS. **8**A-**8**C illustrate an alternative embodiment of a cutter **54** of the present disclosure. Similar to the cutter in FIGS. **7**A-**7**D, the cutting face features three inclined flat surfaces, but they intersect at a point away from the cutting edge. The cutter **54** has a substrate **504** and an ultra-hard layer **502** disposed thereon. A chamfer **507** extends from the periphery of the top surface **503** to the side wall **512** of the ultra-hard layer **502**. The central cutting ridge is parallel to the cutter bottom surface and two diverging cutting ridges extend downward to the cutter periphery at the trailing edge.

[0062] The top surface **503** of the ultra-hard layer **502** is inclined and provided with three cutting ridges **541**, **562** and **563**. The inner ends (away from the cutter periphery) of the three cutting ridges converge at a point **545** on the top surface **503**, and the outer ends (close to the cutter periphery) of the three cutting ridges extend to the outer edge of the top surface **503**. Viewed from the top of the cutter, the three cutting ridges form a substantially "Y" type pattern, and the three cutting ridges divide the top surface into two flat side surfaces **531**, **533** and one flat central surface **532**. The two flat side surfaces **531**, **533** intersect at the central cutting ridge **541**. The outer end (close to the cutter periphery) of the central cutting ridge **541** meets the cutting edge **521** at a cutting point. The two flat side surfaces **531**, **533** intersect the central surface **532** at two diverging cutting ridges **562** and **563**, respectively. In one embodiment, the central cutting ridge **541** is parallel to the cutter bottom surface and two diverging cutting ridges **562**, **563** extend downward to the cutter periphery at the trailing edge **523**. A slope is measured between the central flat surface and a plane parallel to the cutter bottom surface. In FIG. **8**B, the central surface **532** has a slope angle δ. It is worth mentioning that the central cutting ridge **541** is parallel to the cutter bottom surface in FIGS. **8**A-**8**C, but it can slant downwards from the cutting edge to the central flat surface with a slope angle which is smaller than the slope angle δ of the central surface.

[0063] The central ridge cuts the formation and its length can be optimized based the depth of cut in highly heterogeneous formation where soft and hard layers are alternating. The embodiment in FIGS. **8**A-**8**C can adapt to the formation change with a stepped back rake configuration. Referring to FIG. **9**, formation **410** is a highly heterogeneous formation with hard and soft lavers. When a bit is in a relative hard layer within the highly heterogeneous formation **410**, a larger back rake angle is preferred to maintain cutter edge strength in preventing breakage or chipping due to high cutting forces acting on the cutters. However, when the bit is cutting a relative soft layer within the highly heterogeneous formation, a smaller back rake angle is preferred to improve the cutting efficiency. Particularly, when cutting into the hard layer of the formation **410**, a cutter **54** produces a hard formation ribbon **414** with a low depth of cut **415**. In the low depth of cut, the cutting ridge **541** contact with the hard formation ribbon, and a back rake angle α is the angle between the cutting ridge **541** and the line **411** normal to the surface of formation **410**. When cutting into the soft layer of the formation **410**, the cutter produces a soft formation ribbon **418** with a high depth of cut **419**. In the high depth of cut, a back rake angle β is the angle between the central surface **532** and the line **411**. Because of the slope angle δ of the central surface **532**, the back rake angle β is smaller than the back rake angle α, which allows higher rate of penetration. Therefore, the cutter of the present invention can adjust the back rake angle in a heterogeneous formation with the same relief angle, such that the cutter can improve cutting efficiency and service life.

[0064] FIGS. **10**A-**10**C illustrate an alternative embodiment of a cutting element **55** of the present disclosure. Similar to the cutter in FIGS. **7**A-**7**D and FIGS. **8**A-**8**C, the cutting face features three inclined flat surfaces, but the three inclined flat surfaces do not interest at a point on the cutting surface.

[0065] The cutter **55** has a substrate **504** and an ultra-hard layer **502** disposed thereon. A chamfer **507** extends from the periphery of the top surface **503** to the side wall **512** of the ultra-hard layer **502**. The top surface **503** comprises two inclined flat side surfaces **531**, **533** and an inclined flat central surface **532**. The central surface **532** has an inclination α between the central surface **532** and the bottom surface of the cutter. The side surfaces **531**, **533** have inclinations β and γ with their lower sides intersecting cutter cylindrical surfaces. The inclinations β and γ are measured between the side surfaces **531**, **533** and a cutter axis **505**, respectively. The three surfaces intersect at two cutting ridges **541**, **569**. Specifically, the flat side surface **531** intersects with the central surface **532** at the cutting ridge **541**, and the flat side surface **533** intersects with the central surface **532** at the cutting ridge **569**. The cutting ridges **541**, **569** intersect the cutting edge **521** at points **567** and **568** and intersect the trailing edge **523** at points **553** and **554**. The two side surfaces **531** and **533** and central surface **532** slant downward respectively from the cutting edge **521** to the trailing edge **523**, at the same time, the side surfaces **531**, **533** slant downward respectively from the two cutting ridges **541**, **569** to the cutter periphery. It is worth mentioning that the side surfaces are symmetric with regard to the plane which passes through the point having equal distance to the points **567** and **568** and the cutter axis **505** in FIGS. **10**A-**10**B, in which case the inclinations β and γ are equal, but they can be asymmetric in other embodiments. The cutting ridge **541**, **569** in the present disclosure are sharp, but they can also be round to improve their impact resistance. FIGS. **11**A-**11**C illustrate an alternative embodiment of a cutting element **56** of the present disclosure. Similar to the cutter in FIGS. **8**A-**8**C, but the central ridge is rounded and forms a curved surface **534** where the generating lines **547** are parallel to each other. Specifically, the cutter **56** has a substrate **504** and an ultra-hard layer **502** disposed thereon. A chamfer **507** extends from the periphery of the top surface **503** to the side wall **512** of the ultra-hard layer **502**. The top surface **503** includes a central curved surface **534**, a central flat surface **532** and two flat side surfaces **531** and **533**. The two flat side surfaces **531**, **533** intersect the central curved surface **534** at the cutting ridges **541** and **566** and intersect the central flat surface **532** at the cutting ridges **564** and **565**. The central curved surface **534** intersects the central flat surface **532** at the cutting ridge **570** and intersects the side wall **512** of the ultra-hard layer **502** at the edge **546**, as part of the cutting edge **521**.

[0066] The top surface **503** of the ultra-hard layer **502** is inclined. The central surface **532** has a slope angle δ. The two side surfaces **531**, **533** are slanted downward respectively from the cutting ridges **541** and **566** to the periphery of the inclined top surface **503** along the perpendicular direction with respect to the cutting ridges **541** and **566**, respectively. At the same time, the two side surfaces **531**, **533** are slanted downward respectively from the cutting edge **521** to the trailing edge **523**. The generating lines **547** of the central curved surface **534** are parallel to the bottom surface of the cutter or have a sloped angle to the bottom surface of the cutter (not shown).

[0067] For the cutters in FIGS. **7**A-**7**D, FIGS. **8**A-**8**C, FIGS. **10**A-**10**C, and FIGS. **11**A-**11**C, the cutting faces are constructed by three flat surfaces except the additional central curved surface in FIGS. **11**A-**11**C. Other shapes of the surfaces, such as any convex or concave surfaces, shall also be included in the disclosure.

[0068] In some embodiments, the present invention also provides a drill bit, which comprises at least one cutter disclosed in this invention in any position.

[0069] All of the compositions and methods disclosed and claimed herein can be made and executed without undue experimentation in light of the present disclosure. While the compositions and methods of this disclosure have been described in terms of preferred embodiments, it will be apparent to those of skill in the art that variations may be applied to the compositions and methods and in the steps or in the sequence of steps of the methods described herein without departing from the concept, spirit, and scope of the disclosure. More specifically, it will be apparent that certain agents which are both chemically related may be substituted for the agents described herein while the same or similar results would be achieved. All such similar substitutes and modifications apparent to those skilled in the art are deemed to be within the spirit, scope and concept of the disclosure as defined by the appended claims.

What is claimed is:

1. A cutter comprising

a substrate;

an ultra-hard layer;

an inclined surface on top of the ultra-hard layer; and

wherein the inclined surface slants downward from a cutting edge to a trailing edge.

2. The cutter of claim **1**, further comprising a chamfer extending from a periphery of the inclined surface to the cutting edge at a side wall of the ultra-hard layer.

3. The cutter of claim **1**, wherein the inclined surface comprises a cutting ridge extending from the cutting edge to the trailing edge diametrically on top of the inclined surface and two side surfaces slanting downward respectively from the cutting ridge to a periphery of the inclined surface.

4. The cutter of claim **3**, wherein a profile angle at the trailing edge is larger than a profile angle at the cutting edge.

5. The cutter of claim **3**, wherein the cutting ridge is a round cutting ridge.

6. The cutter of claim **1**, wherein the cutter height at the cutting edge is taller than the cutter height at the trailing edge.

7. The cutter of claim **1**, wherein the inclined surface comprises two cutting ridges intersecting at a cutting point on the cutting edge and extending from the cutting point to the trailing edge.

8. The cutter of claim **7**, wherein the two cutting ridges separate the inclined surface into two side flat surfaces and a central flat surface; wherein the two side flat surfaces slant downward from the two cutting ridges to a periphery of the inclined surface; and wherein the central flat surface slants downward from the cutting edge to the trailing edge.

9. The cutter of claim **7**, wherein the two cutting ridges separate the inclined surface into concave or convex surfaces.

10. The cutter of claim **1**, wherein the inclined surface comprises two converging ridges and a central cutting ridge intersecting at a point away from the cutting edge, and the two converging ridges and the central cutting ridge divide the inclined surface into two side surfaces and one central surface.

11. The cutter of claim **10**, wherein the two side surfaces are flat and the one central surface is flat.

12. The cutter of claim **10**, wherein the two side surfaces intersect at the central cutting ridge and the two side surfaces intersect the central surface at the two converging ridges.

13. The cutter of claim **10**, wherein the two cutting ridges separate the inclined surface into concave or convex surfaces.

14. The cutter of claim **10**, wherein an outer end of the central cutting ridge meets the cutting edge at a cutting point; wherein the central cutting ridge is parallel to a cutter bottom surface of the substrate; and wherein the central surface has an inclination toward the trailing edge.

15. The cutter of claim **10**, wherein the central cutting ridge is a round cutting ridge and forms a curved central surface; and wherein generating lines of the curved central surface are parallel to a bottom surface of the cutter or have a sloped angle to the bottom surface of the cutter.

16. The cutter of claim **15**, wherein the curved central surface can be a concave or convex surface.

17. The cutter of claim **1**, wherein the inclined surface comprises two cutting ridges which do not intersect at a point on a cutting surface and extend from a cutting point to the trailing edge.

18. The cutter of claim **17**, wherein the two cutting ridges separate the inclined surface into two side flat surfaces and a central flat surface.

19. The cutter of claim **17**, wherein the two cutting ridges are round; wherein a central flat surface slants downward from the cutting edge to the trailing edge; and wherein two side flat surfaces slant downward from the two cutting ridges to a periphery of the inclined surface.

20. The cutter of claim **17**, wherein the two cutting ridges separate the inclined surface into concave or convex surfaces.

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