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The present invention provides antibodies that bind human programmed cell death 1 (PD-1), and may be useful for treating cancer alone and in combination with chemotherapy and other cancer therapeutics.

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PD-1 Antibodies

Technical Field

The present invention relates to the field of medicine. More particularly, the present invention relates to antibodies that bind human programmed cell death 1 (PD-1), and may be useful for treating cancer alone and in combination with chemotherapy and other cancer therapeutics.

Background

Tumor cells escape detection and elimination by the immune system through multiple mechanisms. Immune checkpoint pathways are used in self-tolerance maintenance and activated T cell control, but cancer cells can use the pathways to prevent destruction. The PD-1 / human programmed cell death 1 ligand 1 (PD-L1) pathway is one such immune checkpoint. Human PD-1 is found on T cells, and the binding of PD-L1 and human programmed cell death 1 ligand 2 (PD-L2) to PD-1 inhibits T cell proliferation and cytokine production. Tumor cell production of PD-L1 and PD-L2 can therefore allow escape from T cell surveillance.

A fully human IgG4 (S228P) antibody against human PD-1, nivolumab, has been shown to inhibit the binding of PD-1 to PD-L1 and PD-L2, and has been tested in various clinical trials. (Wang et al., Cancer Immunol Res (2014) 2(9):846). A humanized IgG4 (S228P) antibody against PD-1, pembrolizumab (formerly lambrolizumab), has been shown to inhibit the binding of PD-1 to PD-L1 and PD-L2, and has been tested in various clinical trials. (WO2008156712 and Hamid et al., N Engl J Med (2013) 369:2).

There remains a need to provide alternative antibodies that bind and neutralize human PD-1 interaction with PD-L1 and PD-L2. In particular, there remains a need to provide antibodies that bind human PD-1 with high affinity. Also, there remains a need to provide antibodies that effectively block the human PD-1 interaction with PD-L1 and PD-L2.

Summary of the Invention

The first aspect of the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), comprising a light chain (LC) and a heavy chain (HC), wherein

the light chain comprises light chain complementarity determining regions LCDR1, LCDR2, and LCDR3 consisting of the amino acid sequences RASQGISSWLA (SEQ ID NO: 10), SAASSLQS (SEQ ID NO: 11), and QQANHLPFT (SEQ ID NO: 12), respectively, and

the heavy chain comprises heavy chain complementarity determining regions HCDR1, HCDR2, and HCDR3,wherein

HCDR1 consists of the amino acid sequences as set forth by KASGGTFSSTAIS (SEQ ID NO: 2 (for HCDR1 of xd-16 A, xd-16 B, xd-16 C, xd-16 D, and/or xd-16 E));

HCDR2 consists of the amino acid sequences as set forth by

GIWPSFGTANYAQKFQG (SEQ ID NO: 3 (for HCDR2 of xd-16 A)),

GIWPSFGTASYAQKFQG (SEQ ID NO: 4 (for HCDR2 of xd-16 B)) ,

GIWPSFGTASYAQKFRG (SEQ ID NO: 5 (for HCDR2 of xd-16 C)),

GIWPSFDTANYAQKFRG (SEQ ID NO: 6 (for HCDR2 of xd-16 D)), or

GIWPSFGTANYARKFQG (SEQ ID NO: 7 (for HCDR2 of xd-16 E)); and

HCDR3 consists of the amino acid sequences as set forth by ARAEYSSTGTFDY (SEQ ID NO: 8 (for HCDR3 of xd-16 A, xd-16 C, and/or xd-16 D)), or ARAEYSSTGIFDY (SEQ ID NO: 9 (for HCDR3 of xd-16 B, and/or xd-16 E)).

Certain antibodies of the present invention bind human PD-1 with a high affinity that is greater than nivolumab and pembrolizumab under certain conditions. Furthermore, certain antibodies of the present invention mediate preferential enhanced alloreactivity compared to nivolumab and pembrolizumab in an *in vivo* model.

In an embodiment, the present invention provides an antibody, wherein LCDR1, LCDR2, and LCDR3 consist of the amino acid sequences RASQGISSWLA (SEQ ID NO: 10), SAASSLQS (SEQ ID NO: 11), and QQANHLPFT (SEQ ID NO: 12), respectively, and wherein HCDR1, HCDR2, and HCDR3 consist of the amino acid sequences KASGGTFSSTAIS (SEQ ID NO: 2), GIWPSFGTANYAQKFQG (SEQ ID NO: 3), and ARAEYSSTGTFDY (SEQ ID NO: 8), respectively.

In a further embodiment, the present invention provides an antibody, wherein LCDR1, LCDR2, and LCDR3 consist of the amino acid sequences RASQGISSWLA (SEQ ID NO: 10), SAASSLQS (SEQ ID NO: 11), and QQANHLPFT (SEQ ID NO: 12), respectively, and wherein HCDR1, HCDR2, and HCDR3 consist of the amino acid sequences KASGGTFSSTAIS (SEQ ID NO: 2), GIWPSFGTASYAQKFQG (SEQ ID NO: 4), and ARAEYSSTGIFDY (SEQ ID NO: 9), respectively.

In a further embodiment, the present invention provides an antibody, wherein LCDR1, LCDR2, and LCDR3 consist of the amino acid sequences RASQGISSWLA (SEQ ID NO: 10), SAASSLQS (SEQ ID NO: 11), and QQANHLPFT (SEQ ID NO: 12), respectively, and wherein HCDR1, HCDR2, and HCDR3 consist of the amino acid sequences KASGGTFSSTAIS (SEQ ID NO: 2), GIWPSFGTASYAQKFRG (SEQ ID NO: 5), and ARAEYSSTGTFDY (SEQ ID NO: 8), respectively.

In a further embodiment, the present invention provides an antibody, wherein

LCDR1, LCDR2, and LCDR3 consist of the amino acid sequences RASQGISSWLA (SEQ ID NO: 10), SAASSLQS (SEQ ID NO: 11), and QQANHLPFT (SEQ ID NO: 12), respectively, and wherein HCDR1, HCDR2, and HCDR3 consist of the amino acid sequences KASGGTFSSTAIS (SEQ ID NO: 2), GIWPSFDTANYAQKFRG (SEQ ID NO: 6), and ARAEYSSTGTFDY (SEQ ID NO: 8), respectively.

In a further embodiment, the present invention provides an antibody, wherein LCDR1, LCDR2, and LCDR3 consist of the amino acid sequences RASQGISSWLA (SEQ ID NO: 10), SAASSLQS (SEQ ID NO: 11), and QQANHLPFT (SEQ ID NO: 12), respectively, and wherein HCDR1, HCDR2, and HCDR3 consist of the amino acid sequences KASGGTFSSTAIS (SEQ ID NO: 2), GIWPSFGTANYARKFQG (SEQ ID NO: 7), and ARAEYSSTGIFDY (SEQ ID NO: 9), respectively.

In an embodiment, the present invention provides an antibody, comprising 1 or 2 light chain(s) (LC) and 1 or 2 heavy chain(s) (HC), wherein each of the light chain comprises a light chain variable region (LCVR) and each of the heavy chain comprises a heavy chain variable region (HCVR), wherein the LCVR has the amino acid sequence given in SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 13, SEQ ID NO: 14, SEQ ID NO: 15, SEQ ID NO: 16, or SEQ ID NO: 17.

In a further embodiment, the present invention provides an antibody, wherein the LCVR has the amino acid sequence as set forth by SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 13.

In a further embodiment, the present invention provides an antibody, wherein the LCVR has the amino acid sequence as set forth by SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 14.

In a further embodiment, the present invention provides an antibody, wherein the LCVR has the amino acid sequence as set forth by SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 15.

In a further embodiment, the present invention provides an antibody, wherein the LCVR has the amino acid sequence as set forth by SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 16.

In a further embodiment, the present invention provides an antibody, wherein the LCVR has the amino acid sequence as set forth by SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 17.

In an embodiment, the present invention provides an antibody, wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 19, SEQ ID NO: 20, SEQ ID NO: 21, SEQ ID NO: 22, or SEQ ID NO: 23.

In a further embodiment, the present invention provides an antibody, wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 19.

In a further embodiment, the present invention provides an antibody, wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 20.

In a further embodiment, the present invention provides an antibody, wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 21.

In a further embodiment, the present invention provides an antibody, wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 22.

In a further embodiment, the present invention provides an antibody, wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 23.

In an embodiment, the present invention provides an antibody, comprising two light chains and two heavy chains, wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 19, SEQ ID NO: 20, SEQ ID NO: 21, SEQ ID NO: 22, or SEQ ID NO: 23.

In a further embodiment, the present invention provides an antibody, wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 19.

In a further embodiment, the present invention provides an antibody, wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 20.

In a further embodiment, the present invention provides an antibody, wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 21.

In a further embodiment, the present invention provides an antibody, wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 22.

In a further embodiment, the present invention provides an antibody, wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 23.

In an embodiment, the present invention provides an antibody, wherein one of the heavy chains forms an inter-chain disulfide bond with one of the light chains, and the other

heavy chain forms an inter-chain disulfide bond with the other light chain, and one of the heavy chains forms two inter-chain disulfide bonds with the other heavy chain.

In an embodiment, the present invention provides an antibody, wherein the antibody is glycosylated.

In an embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), comprising a light chain (LC) and a heavy chain (HC), wherein the light chain comprises a light chain variable region (LCVR) and the heavy chain comprises a heavy chain variable region (HCVR), wherein the LCVR has the amino acid sequence as set forth by SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 13, SEQ ID NO: 14, SEQ ID NO: 15, SEQ ID NO: 16, or SEQ ID NO: 17.

In a further embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein the LCVR has the amino acid sequence as set forth by SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 13. In a further embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein the LCVR has the amino acid sequence as set forth by SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 14. In a further embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein the LCVR has the amino acid sequence as set forth by SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 15. In a further embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein the LCVR has the amino acid sequence as set forth by SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 16. In a further embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein the LCVR has the amino acid sequence as set forth by SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 17.

In an embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 19, SEQ ID NO: 20, SEQ ID NO: 21, SEQ ID NO: 22, or SEQ ID NO: 23.

In a further embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 19. In a further embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 20. In a

further embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 21. In a further embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 22. In a further embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 23.

In an embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), comprising two light chains and two heavy chains, wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 19, SEQ ID NO: 20, SEQ ID NO: 21, SEQ ID NO: 22, or SEQ ID NO: 23.

In a further embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 19. In a further embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 20. In a further embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 21. In a further embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 22. In a further embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 23. In an embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein one of the heavy chains forms an inter-chain disulfide bond with one of the light chains, and the other heavy chain forms an inter-chain disulfide bond with the other light chain, and one of the heavy chains forms two inter-chain disulfide bonds with the other heavy chain.

In an embodiment, the present invention provides an antibody that binds human PD-1 (SEQ ID NO: 1), wherein the antibody is glycosylated.

The second aspect of the present invention provides a polynucleotide encoding any one of the above antibodies of the present invention, the fragments or the derivatives thereof.

In another preferred embodiment, the polynucleotide encoding HC of xd-16 A S228P IgG4 is as set forth by SEQ ID NO: 25.

In another preferred embodiment, the polynucleotide encoding HC of xd-16 B S228P IgG4 is as set forth by SEQ ID NO: 26.

In another preferred embodiment, the polynucleotide encoding HC of xd-16 C S228P IgG4 is as set forth by SEQ ID NO: 27.

In another preferred embodiment, the polynucleotide encoding HC of xd-16 D S228P IgG4 is as set forth by SEQ ID NO: 28.

In another preferred embodiment, the polynucleotide encoding HC of xd-16 E S228P IgG4 is as set forth by SEQ ID NO: 29.

In another preferred embodiment, the polynucleotide encoding LC of xd-16 A, xd-16 B, xd-16 C, xd-16 D, and xd-16 E is as set forth by SEQ ID NO: 30.

The third aspect of the present invention provides a vector comprising the polynucleotide of the third aspect.

The forth aspect of the present invention provides a host cell comprising the vector of the third aspect or the genome of said cell is integrated with exogenous polynucleotide according to the second aspect.

In a preferred embodiment, said host cell is a mammalian cell, preferably, a CHO cell.

In an embodiment, the present invention provides a mammalian cellcomprising a DNA molecule comprising a polynucleotide sequence encoding a polypeptide having an amino acid sequence of SEQ ID NO: 24 and a polynucleotide sequence encoding a polypeptide having an amino acid sequence of SEQ ID NO: 19, wherein the cell is capable of expressing an antibody comprising a light chain having an amino acid sequence of SEQ ID NO: 24 and a heavy chain having an amino acid sequence of SEQ ID NO: 19.

In an embodiment, the present invention provides a mammalian cell, comprising a DNA molecule comprising a polynucleotide sequence encoding a polypeptide having an amino acid sequence of SEQ ID NO: 24 and a polynucleotide sequence encoding a polypeptide having an amino acid sequence of SEQ ID NO: 20, wherein the cell is capable of expressing an antibody comprising a light chain having an amino acid sequence of SEQ ID NO: 24 and a heavy chain having an amino acid sequence of SEQ ID NO: 20.

In an embodiment, the present invention provides a mammalian cell, comprising a DNA molecule comprising a polynucleotide sequence encoding a polypeptide having an

amino acid sequence of SEQ ID NO: 24 and a polynucleotide sequence encoding a polypeptide having an amino acid sequence of SEQ ID NO: 21, wherein the cell is capable of expressing an antibody comprising a light chain having an amino acid sequence of SEQ ID NO: 24 and a heavy chain having an amino acid sequence of SEQ ID NO: 21.

In an embodiment, the present invention provides a mammalian cell, comprising a DNA molecule comprising a polynucleotide sequence encoding a polypeptide having an amino acid sequence of SEQ ID NO: 24 and a polynucleotide sequence encoding a polypeptide having an amino acid sequence of SEQ ID NO: 22, wherein the cell is capable of expressing an antibody comprising a light chain having an amino acid sequence of SEQ ID NO: 24 and a heavy chain having an amino acid sequence of SEQ ID NO: 22.

In an embodiment, the present invention provides a mammalian cell, comprising a DNA molecule comprising a polynucleotide sequence encoding a polypeptide having an amino acid sequence of SEQ ID NO: 24 and a polynucleotide sequence encoding a polypeptide having an amino acid sequence of SEQ ID NO: 23, wherein the cell is capable of expressing an antibody comprising a light chain having an amino acid sequence of SEQ ID NO: 24 and a heavy chain having an amino acid sequence of SEQ ID NO: 23.

The fifth aspect of the present invention, a process is provided for producing an antibody comprising a light chain having an amino acid sequence of SEQ ID NO: 24 and a heavy chain having an amino acid sequence of SEQ ID NO: 20, comprising cultivating the host cell of the fourth aspect under conditions such that the antibody is expressed, and recovering the expressed antibody

In an embodiment, the present invention provides an antibody produced by a process of the present invention.

The sixth aspect of the present invention provides a pharmaceutical composition comprising an antibody of the present invention, and a pharmaceutical acceptable carrier.

The seventh aspect of the present invention provides a method of treating cancer comprising step of administering to a subject in need with an effective amount of an antibody of the present invention.

In a further embodiment, the method of treating cancer further comprises the step of administering to a subject in need with an effective amount of the antibody of the present invention, wherein the cancer is melanoma, lung cancer, head and neck cancer, colorectal cancer, pancreatic cancer, gastric cancer, kidney cancer, bladder cancer, prostate cancer, breast cancer, ovarian cancer, or liver cancer.

In a further embodiment, these methods comprise the administration of an effective amount of the antibody of the present invention in simultaneous, separate, or sequential combination with one or more anti-tumor agent(s), immuno-oncology agent(s), or the

combination thereof.

In a preferred embodiment, said anti-tumor agents includes, but not limited to, ramucirumab, necitumumab, olaratumab, galunisertib, abemaciclib, cisplatin, carboplatin, dacarbazine, liposomal doxorubicin, docetaxel, cyclophosphamide and doxorubicin, navelbine, eribulin, paclitaxel, paclitaxel protein-bound particles for injectable suspension, ixabepilone, capecitabine, FOLFOX (leucovorin, fluorouracil, and oxaliplatin), FOLFIRI (leucovorin, fluorouracil, and irinotecan), cetuximab, or the combination thereof.

In a further embodiment, said immuno-oncology agents includes, but not limited to, nivolumab, ipilimumab, pidilizumab, pembrolizumab, tremelimumab, urelumab, lirilumab, atezolizumab, durvalumab, or the combination thereof.

The eighth aspect of the present invention provides an antibody of the present invention for use in therapy.

The ninth aspect of the present invention provides an antibody of the present invention for use in the treatment of cancer.

In a further embodiment, the present invention provides an antibody of the present invention for use in the treatment of cancer, wherein the cancer is melanoma, lung cancer, head and neck cancer, colorectal cancer, pancreatic cancer, gastric cancer, kidney cancer, bladder cancer, prostate cancer, breast cancer, ovarian cancer, or liver cancer.

The tenth aspect of the present invention provide the antibody of any one of the aspect of the present invention in simultaneous, separate, or sequential combination with one or more anti-tumor agents, immuno-oncology agents, and combination thereof for combined use in treatment of cancer.

In a preferred embodiment, said anti-tumor agents include, but not limited to, ramucirumab, necitumumab, olaratumab, galunisertib, abemaciclib, cisplatin, carboplatin, dacarbazine, liposomal doxorubicin, docetaxel, cyclophosphamide and doxorubicin, navelbine, eribulin, paclitaxel, paclitaxel protein-bound particles for injectable suspension, ixabepilone, capecitabine, FOLFOX (leucovorin, fluorouracil, and oxaliplatin), FOLFIRI (leucovorin, fluorouracil, and irinotecan), cetuximab, or the combination thereof.

In a further embodiment, said immuno-oncology agents include, but not limited to, nivolumab, ipilimumab, pidilizumab, pembrolizumab, tremelimumab, urelumab, lirilumab, atezolizumab, durvalumab, or the combination thereof.

The eleventh aspect of the present invention provides the use of an antibody of the present invention for preparing a pharmaceutical composition for treatment of cancer.

In a further embodiment, the cancer is melanoma, lung cancer, head and neck cancer, colorectal cancer, pancreatic cancer, gastric cancer, kidney cancer, bladder cancer, prostate cancer, breast cancer, ovarian cancer, or hepatocellular carcinoma.

In a further embodiment , said pharmaceutical composition further comprises one or more of anti-tumor agents and/or immuno-oncology agents.

In a further embodiment , said pharmaceutical composition is administered to a subject in need in simultaneous, separate, or sequential combination with one or more of anti-tumor agents and/or immuno-oncology agents.

In a preferred embodiment, said anti-tumor agents include, but not limited to, ramucirumab, necitumumab, olaratumab, galunisertib, abemaciclib, cisplatin, carboplatin, dacarbazine, liposomal doxorubicin, docetaxel, cyclophosphamide and doxorubicin, navelbine, eribulin, paclitaxel, paclitaxel protein-bound particles for injectable suspension, ixabepilone, capecitabine, FOLFOX (leucovorin, fluorouracil, and oxaliplatin), FOLFIRI (leucovorin, fluorouracil, and irinotecan), cetuximab, or the combination thereof.

In a further embodiment, said immuno-oncology agents include, but not limited to, nivolumab, ipilimumab, pidilizumab, pembrolizumab, tremelimumab, urelumab, lirilumab, atezolizumab, durvalumab, or the combination thereof.

It should be understood that in the present invention, the technical features specifically described above and below (such as in the Examples) can be combined with each other, thereby constituting a new or preferred technical solution which needs not be described one by one.

Detailed Description

An antibody of the present invention is an engineered, non-naturally occurring polypeptide complex. A DNA molecule of the present invention is a non-naturally occurring DNA molecule that comprises a polynucleotide sequence encoding a polypeptide having the amino acid sequence of one of the polypeptides in an antibody of the present invention.

An antibody of the present invention is designed to have engineered CDRs and have some portions of the antibody (all or parts of the frameworks, hinge regions, and constant regions) to be of human origin that are identical with or substantially identical (substantially human) with frameworks and constant regions derived from human genomic sequences. Fully human frameworks, hinge regions, and constant regions are those human germline sequences as well as sequences with naturally-occurring somatic mutations and those with engineered mutations. An antibody of the present invention may comprise framework, hinge, or constant regions derived from a fully human framework, hinge, or constant region containing one or more amino acid substitutions, deletions, or additions therein. Further, an antibody of the present invention is preferably substantially

non-immunogenic in humans.

The antibody of the present invention is an IgG type antibody and has four amino acid chains (two "heavy" chains and two "light" chains) that are cross-linked via intra- and inter-chain disulfide bonds. Each heavy chain is comprised of an N-terminal HCVR and a heavy chain constant region ("HCCR"). Each light chain is comprised of a LCVR and a light chain constant region ("LCCR"). When expressed in certain biological systems, antibodies having native human Fc sequences are glycosylated in the Fc region. Typically, glycosylation occurs in the Fc region of the antibody at a highly conserved N-glycosylation site. N-glycans typically attach to asparagine. Antibodies may be glycosylated at other positions as well.

Optionally, the antibody of the present invention contains an Fc portion which is derived from human IgG_4 Fc region because of a reduced ability to engage Fc receptor-mediated inflammatory mechanisms or to activate complement resulting in reduced effector function.

The S228P mutation is a hinge mutation that prevents half-antibody formation (phenomenon of dynamic exchange of half-molecules in IgG_4 antibodies). The F234A and L235A mutations further reduce effector function of the already low human IgG_4 isotype.

The HCVR and LCVR regions can be further subdivided into regions of hyper-variability, termed complementarity determining regions ("CDRs"), interspersed with regions that are more conserved, termed framework regions ("FR"). Each HCVR and LCVR is composed of three CDRs and four FRs, arranged from amino-terminus to carboxy-terminus in the following order: FR1, CDR1, FR2, CDR2, FR3, CDR3, FR4. Herein, the three CDRs of the heavy chain are referred to as "HCDR1, HCDR2, and HCDR3" and the three CDRs of the light chain are referred to as "LCDR1, LCDR2 and LCDR3". The CDRs contain most of the residues which form specific interactions with the antigen. There are currently three systems of CDR assignments for antibodies that are used for sequence delineation. The Kabat CDR definition (Kabat *et al.*, "Sequences of Proteins of Immunological Interest," National Institutes of Health, Bethesda, Md. (1991)) is based upon antibody sequence variability. The Chothia CDR definition (Chothia *et al.*, "Canonical structures for the hypervariable regions of immunoglobulins", Journal of Molecular Biology, 196, 901-917 (1987); Al-Lazikani *et al.*, "Standard conformations for the canonical structures of immunoglobulins", Journal of Molecular Biology, 273, 927-948 (1997)) is based on three-dimensional structures of antibodies and topologies of the CDR loops. The Chothia CDR definitions are identical to the Kabat CDR definitions with the exception of HCDR1 and HCDR2. The North CDR definition (North *et al.*, "A New Clustering of Antibody CDR Loop Conformations", Journal of Molecular Biology, 406, 228-256 (2011)) is based on affinity

propagation clustering with a large number of crystal structures. For the purposes of the present invention, the North CDR definitions are used.

An isolated DNA encoding a HCVR region can be converted to a full-length heavy chain gene by operably linking the HCVR-encoding DNA to another DNA molecule encoding heavy chain constant regions. The sequences of human, as well as other mammalian, heavy chain constant region genes are known in the art. DNA fragments encompassing these regions can be obtained *e.g.,* by standard PCR amplification.

An isolated DNA encoding a LCVR region may be converted to a full-length light chain gene by operably linking the LCVR-encoding DNA to another DNA molecule encoding a light chain constant region. The sequences of human, as well as other mammalian, light chain constant region genes are known in the art. DNA fragments encompassing these regions can be obtained by standard PCR amplification. The light chain constant region can be a kappa or lambda constant region.

The polynucleotides of the present invention will be expressed in a host cell after the sequences have been operably linked to an expression control sequence. The expression vectors are typically replicable in the host organisms either as episomes or as an integral part of the host chromosomal DNA. Commonly, expression vectors will contain selection markers, e.g., tetracycline, neomycin, and dihydrofolate reductase, to permit detection of those cells transformed with the desired DNA sequences.

The antibody of the present invention may readily be produced in mammalian cells such as CHO, NS0, HEK293 or COS cells. The host cells are cultured using techniques well known in the art.

The vectors containing the polynucleotide sequences of interest (e.g., the polynucleotides encoding the polypeptides of the antibody and expression control sequences) can be transferred into the host cell by well-known methods, which vary depending on the type of cellular host.

Various methods of protein purification may be employed and such methods are known in the art and described, for example, in Deutscher, *Methods in Enzymology* 182: 83-89 (1990) and Scopes, *Protein Purification: Principles and Practice*, 3rd Edition, Springer, NY (1994).

In another embodiment of the present invention, the antibody, or the nucleic acids encoding the same, is provided in isolated form. As used herein, the term “isolated” refers to a protein, peptide, or nucleic acid which is free or substantially free from any other macromolecular species found in a cellular environment. “Substantially free” as used herein means the protein, peptide, or nucleic acid of interest comprises more than 80% (on a molar basis) of the macromolecular species present, preferably more than 90%, and more

preferably more than 95%.

The antibody of the present invention, or pharmaceutical compositions comprising the same, may be administered by parenteral routes (e.g., subcutaneous and intravenous). An antibody of the present invention may be administered to a patient alone with pharmaceutically acceptable carriers, diluents, or excipients in single or multiple doses. Pharmaceutical compositions of the present invention can be prepared by methods well known in the art (e.g., *Remington: The Science and Practice of Pharmacy*, 19th ed. (1995), A. Gennaro et al., Mack Publishing Co.) and comprise an antibody, as disclosed herein, and one or more pharmaceutically acceptable carriers, diluents, or excipients.

The term "treating" (or "treat" or "treatment") refers to slowing, interrupting, arresting, alleviating, stopping, reducing, or reversing the progression or severity of an existing symptom, disorder, condition, or disease.

“Binds” as used herein in reference to the affinity of an antibody for human PD-1 is intended to mean, unless indicated otherwise, a K_D of less than about 1 x10-9 M, preferably, less than about 2 x 10-10 M as determined by common methods known in the art, including by use of a surface plasmon resonance (SPR) biosensor at 37°C essentially as described herein.

For the purposes of the present disclosure, the term “high affinity” refers to a K_D of less than about 150 pM for human PD-1. The K_D values are established by binding kinetics as described in “Binding kinetics and affinity” in the Assays section.

The present invention further provides a pharmaceutical composition comprising the polypeptide of the present invention or the agonist thereof with safe and effective amounts and pharmaceutically acceptable carrier(s) or excipient(s). These carriers include (but are not limited to): saline, buffer solution, glucose, water, glycerol, ethanol, or the combination thereof. The pharmaceutical preparation should match the administration mode. The pharmaceutical composition of the present invention can be prepared into the form of injection, such as being prepared with saline or aqueous solution containing glucose or other auxiliaries by conventional methods. Pharmaceutical compositions, such as tablets and capsules can be prepared with conventional methods. Pharmaceutical compositions such as injections, solution, tablets and capsules may be preferably produced in sterile conditions. The administration amount of the active ingredients is a therapeutically effective amount, for example, about 1 μg/kg (body weight)- 5mg/kg (body weight) per day. Moreover, the polypeptide of the present invention can be further used with other therapeutical agents.

"Effective amount" means the amount of an antibody of the present invention or pharmaceutical composition comprising an antibody of the present invention that will elicit

the biological or medical response of or desired therapeutic effect on a tissue, system, animal, mammal or human that is being sought by the researcher, medical doctor, or other clinician. An effective amount of the antibody may vary according to factors such as the disease state, age, sex, and weight of the individual, and the ability of the antibody to elicit a desired response in the individual. An effective amount is also one in which any toxic or detrimental effect of the antibody is outweighed by the therapeutically beneficial effects.

The invention is further illustrated by the following examples. These examples are only intended to illustrate the invention, but not to limit the scope of the invention. For the experimental methods in the following examples the specific conditions of which are not specifically indicated, they are performed under routine conditions, e.g., those described by Sambrook. et al., in Molecular Cloning: A Laboratory Manual, New York: Cold Spring Harbor Laboratory Press, 2012, or as instructed by the manufacturers. Unless otherwise specified, the percentage and portion refer to weight percentage and weight portion.

Major advantages of the present invention:

xd-16 B, xd-16 C, xd-16 D and xd-16 E, binds human PD-1 with an affinity higher than pembrolizumab and nivolumab in both monovalent and avid binding modes. Antibody xd-16 B at each concentration increased IL-2 of IFN-γ comparable or better than to nivolumab and pembrolizumab in immune cell activation assays.

Examples

Example 1: Antibody expression and purification

The polypeptides of the variable regions of the heavy chain and light chain, the complete heavy chain and light chain amino acid sequences of Antibody A - Antibody I, and the nucleotide sequences encoding the same, are listed below in the section entitled "Amino Acid and Nucleotide Sequences." In addition, the SEQ ID NOs for the light chain, heavy chain, light chain variable region, and heavy chain variable region of Antibody A - Antibody I are shown in Table 1.

The antibodies of the present invention, including, but not limited to, Antibody A - Antibody I can be made and purified essentially as follows. An appropriate host cell, such as HEK 293 or CHO, can be either transiently or stably transfected with an expression system for secreting antibodies using an optimal predetermined HC:LC vector ratio (such as 1:3 or 1:2) or a single vector system encoding both HC and LC. Clarified media, into which the antibody has been secreted, may be purified using any of many commonly-used techniques. For example, the medium may be conveniently applied to a MabSelect column (GE Healthcare), or KappaSelect column (GE Healthcare) for Fab fragment, that has been

equilibrated with a compatible buffer, such as phosphate buffered saline (pH 7.4). The column may be washed to remove nonspecific binding components. The bound antibody may be eluted, for example, by pH gradient (such as 20 mM Tris buffer pH 7 to 10 mM sodium citrate buffer pH 3.0, or phosphate buffered saline pH 7.4 to 100 mM glycine buffer pH 3.0). Antibody fractions may be detected, such as by SDS-PAGE, and then may be pooled. Further purification is optional, depending on the intended use. The antibody may be concentrated and/or sterile filtered using common techniques. Soluble aggregate and multimers may be effectively removed by common techniques, including size exclusion, hydrophobic interaction, ion exchange, multimodal, or hydroxyapatite chromatography. The purity of the antibody after these chromatography steps is greater than 95%. The product may be immediately frozen at -70°C or may be lyophilized.

Table 1: SEQ ID NOs

	Antibody A S228P IgG4 (xd-16 A)	Antibody B S228P IgG4 (xd-16 B)	Antibody C S228P IgG4 (xd-16 C)	Antibody D S228P IgG4 (xd-16 D)	Antibody E S228P IgG4 (xd-16 E)
HCVR	13	14	15	16	17
LCVR	18	18	18	18	18
Heavy chain	19	20	21	22	23
Light chain	24	24	24	24	24

Assays

Binding kinetics and affinity

The kinetics and equilibrium dissociation constant (K_D) for human PD-1 is determined for antibodies of the present invention using MSD, surface plasmon resonance (Biacore), bio-light interferometry (ForteBio) assay methods.

As used herein, nivolumab is a human IgG4 PD-1 antibody transiently expressed in 293 HEK cells that utilizes the heavy chain and light chain sequences from Proposed INN: List 107 (CAS #946414-94-4). As used herein, pembrolizumab is a human IgG4 PD-1 antibody transiently expressed in 293 HEK cells that utilizes the heavy chain and light chain sequences from Proposed INN: List 72.

MSD assay

Equilibrium affinity measurements are performed as previously described (Estep, P., et al., MAbs, 2013. **5**(2): p. 270-8). Solution equilibrium titrations (SET) are performed in PBS + 0.1% IgG-Free BSA (PBSF) where antigen (b-PD-1 monomer) is held constant at

10-100 pM and is incubated with 3-to 5-fold serial dilutions of Fab or mAbs starting at 5-100 nM (experimental condition is sample dependent). Antibodies diluted at 20 nM in PBS are coated onto standard bind MSD-ECL plates overnight at 4°C or at room temperature for 30 min. Plates are blocked with BSA for 30 min whilst shaking at 700 rpm. Plates are then washed 3x with wash buffer (PBSF + 0.05% Tween 20). SET samples are applied and incubated on the plates for 150s with shaking at 700 rpm followed by one wash. Antigen captured on a plate is detected with 250 ng/mL sulfotag-labeled streptavidin in PBSF by incubation on the plate for 3 min. The plates are washed three times with wash buffer and are then read on the MSD Sector Imager 2400 instrument using 1x Read Buffer T with surfactant. The percent free antigen is plotted as a function of titrated antibody in Prism and fit to a quadratic equation to extract the KD. To improve throughput, liquid handling robots are used throughout MSD-SET experiments, including for SET sample preparation.

In experiments performed essentially as described in this assay, xd-16 B, xd-16 C, xd-16 D and xd-16 E, in an IgG1 format and expressed in yeast, bind human PD-1 with a K_D of 45 pM. 50 pM. 93 pM and 150 pM respectively. Pembrolizumab and nivolumab bind PD-1 with a K_D of 130 pM and 640 pM respectively. Avidity measurements for xd-16 B, xd-16 C, xd-16 D and xd-16 E, result in a K_D of approximately 0.9 pM, 2.5 pM, 1.3 pM and 0.9 pM respectively. Pembrolizumab and nivolumab bind human PD-1 with a K_D of approximately 3 pM and 5 pM respectively.

Table 2: Binding by MSD of antibodies of the invention in IgG1 format

Name	Monovalent KD (pM) against human PD-1	Avid KD (pM) against human PD-1
xd-16 B	45	~0.9
xd-16 C	50	2.5
xd-16 D	93	1.3
xd-16 E	150	~0.9
Pembrolizumab	130	~3
Nivolumab	640	~5

Bio-light interferometry

ForteBio affinity measurements were performed generally as previously described (Estep, P., et al., *High throughput solution-based measurement of antibody-antigen affinity and epitope binning.* MAbs, 2013. **5**(2): p. 270-8.). Briefly, ForteBio affinity measurements were performed by loading IgGs online onto AHQ sensors. Sensors were equilibrated off-line in assay buffer for 30 min and then monitored on-line for 60 seconds for baseline

establishment. Sensors with loaded IgGs were exposed to 100 nM antigen for 5 min, afterwards they were transferred to assay buffer for 5 min for off-rate measurement. Kinetics was analyzed using the 1:1 binding model.

In experiments performed essentially as described in this assay, xd-16 B, xd-16 C, xd-16 D and xd-16 E, in a Fab format produced from IgG1 expressed in yeast, bind human PD-1_Fc with a K_D approximately twofold to threefold lower than nivolumab and pembrolizumab when PD-1_Fc was on the sensor tip. When the antibody was on the sensor tip, xd-16 B, xd-16 C, xd-16 D and xd-16 E, in an IgG1 format and expressed in yeast, bind human PD-1_His with a K_D approximately threefold to fourfold lower than nivolumab and pembrolizumab. xd-16 B, xd-16 C, xd-16 D and xd-16 E, in a Fab format produced from IgG1 expressed in yeast, bind cynoPD-1_Fc with a similar K_D to nivolumab and pembrolizumab.

Table 3: Binding by Bio-light interferometry of antibodies of the invention in IgG1 format

	Monovalent K_D (M) Fab in solution, hPD-1_Fc on sensor tip	Monovalent K_D (M) hPD-1_HIS in solution, IgG on sensor tip	Monovalent K_D (M) Fab in solution, cynoPD-1_Fc on sensor tip
xd-16 B	6.30E-10	4.20E-10	7.80E-10
xd-16 C	5.70E-10	3.80E-10	7.30E-10
xd-16 D	9.90E-10	6.50E-10	1.20E-09
xd-16 E	8.60E-10	5.60E-10	1.00E-09
Pembrolizumab	2.00E-09	2.00E-09	4.70E-10
Nivolumab	1.70E-09	4.10E-09	1.20E-09

Binding to human PD-1 on CHO cells

The binding of an antibody of the present invention to human PD-1 may be measured in a flow cytometry assay.

CHO cells (0.2×10^6) are incubated with the experimental antibody from 200 nM titrated 19x by a factor of 2 to the lowest concentration of 3.185 pM for 30 min in PBS 1% BSA on ice. Cells are then washed 3x, and are incubated with a secondary antibody (PE-labelled, at final concentration of 5 µg/ml) in PBS 1% BSA for 30 min on ice (protected from light). Cells are washed 3x and analyzed via flow cytometry. Flow cytometry is performed on an Accuri C6 system (BD Biosciences) and MFIs are calculated on the C6 software. EC50s are calculated on Graphpad software.

In experiments performed essentially as described in this assay, xd-16 B (IgG4

S228P) binds PD-1 in a dose-dependent manner, with an EC50 value (n=1) of 1.461 nM, xd-16 D (IgG4 S228P) binds PD-1 in a dose-dependent manner, with an EC50 value (n=1) of 1.471 nM, nivolumab (IgG4 S228P) binds PD-1 in a dose-dependent manner, with an EC50 value (n=1) of 1.311 nM. In experiments performed essentially as described in this assay, xd-16 B and xd-16 D binds with a similar EC50 to human PD-1 as nivolumab under these conditions.

Table 4: Binding to human PD-1 on CHO cells

	xd-16 B IgG4	xd-16 D IgG4	Nivolumab IgG4
Binding to PD-1 (EC50 nM)	1.461	1.471	1.311

Blocking of human PD-1 to PD-L1 and PD-L2 in CHO cells.

The ability of an antibody of the present invention to block binding of human PD-1 to PD-L1 and PD-L2 may be measured by flow cytometry.

CHO cells 0.2 x 10^6 are incubated with the experimental antibody (100 nM) for 30 min in PBS 1% BSA on ice. Cells are then washed 3X, and are incubated with PD-L2 linked with NHS-FIuorescein (Promega) in PBS 1% BSA for 30 min on ice (protected from light). Cells are washed 3x and analyzed via flow cytometry. Flow cytometry is performed on an Accuri C6 system (BD Biosciences) and MFIs are calculated on the C6 software. EC50s are calculated on Graphpad software.

In experiments performed essentially as described in this assay, xd-16 B, xd-16 C, xd-16 D and xd-16 E (IgG1 format expressed in yeast) blocked human PD-L2-FITC binding, resulting in an MFI of 26,445.9, 26,524.8, 39,983.1 and 40,867.9 respectively as compared to control IgG which resulted in an MFI of 182,959.1. Pembrolizumab and nivolumab resulted in MFI's of 46,245.9 and 54,509.8 respectively.

Table 5: Blocking of human PD-1 on CHO cells

Test Sample	MFI (PD-L2-FITC)
Cells only	33,449.7
No IgG	199,716.0
IgG Control	182,959.1
Nivolumab	54,509.8
Pembrolizumab	46,245.9
xd-16 B	26,445.9
xd-16 C	26,524.8
xd-16 D	39,983.1
xd-16 E	40,867.9

Mixed Lymphocyte Reaction

The blocking of PD-1 signals by antibodies of the present invention may be evaluated by measuring the release of inhibitory signals during T cell activation.

2×10^6 PBMC are plated per well in a 6 well tissue culture plate or T25 tissue culture flask in complete T cell media. Cells are incubated for 2-3 hours, to allow for adherence of monocytes. If adherence is insufficient, serum free media is used. Unattached cells are removed by gently swirling the flask with fresh media 3X.

Immature myeloid DCs are generated by culturing monocytes (1×10^6 cells/ml) from PBMC in X-VIVO 15 media containing 1% AB serum, 10mM HEPES, 50μM β-Me, IL-4 (1000 U/ml) and GM-CSF (1000 U/ml), or 25-50 ng/ml of each. After 2 days fresh medium supplemented with IL-4 and GM-CSF is added. On Day 5, cells are either frozen or maturation is induced by adding a stimulation cocktail containing rTNFa (1000U/ml), IL-1b (5 ng/ml), IL-6 (10ng/ml) and 1 μM PGE_2 for 2 days at a cell density of 3×10^5 cells/ml.

T cell Isolation is performed as per manufacturer's instructions in the Untouched CD4+ T cell isolation kit (Invitrogen). A magnet fitted with a 1.5 ml tube rack is used to remove unwanted magnetic beads (QIAGEN).

100,000-200,000 isolated T cells are mixed with 10,000-20,000 allogeneic moDCs in a total volume of 200 μl in 96-round bottom tissue culture plates for 4-5 days at 37°C. T cells are stimulated using anti-CD3/CD28 DynaBeads at a ratio of 3:1 (cells:beads) as a positive control; beads are prepared as per the manufacturer's instructions. Test antibodies are added at the beginning of the MLR and incubated throughout the culture period.

Detection of IL-2 and IFN-γ is carried out as per manufacturer's instructions (eBioscience). OD measurements are determined on a Multiskan FC system (Thermo).

In experiments performed essentially as described in this assay, Antibody xd-16 B at each concentration increased IL-2 of IFN-γ comparable to nivolumab and pembrolizumab.

Table 6: IL-2 secretion fold change vs. IgG control

	Concentrations of IgG				
	100 nM	10 nM	1 nM	0.1 nM	0.01nM
Pembrolizumab	2.03114	2.49216	2.04189	1.47268	1.05915
Nivolumab	2.37395	2.44395	1.71526	1.26004	1.0918
xd-16 B	2.3661	2.38817	2.18347	1.45926	1.14941

Table 7: IFNg secretion fold change vs. IgG control

	Concentrations of IgG				
	100 nM	10 nM	1 nM	0.1 nM	0.01nM
Pembrolizumab	1.78083	1.771	1.75723	1.98907	1.02989
Nivolumab	1.97395	1.877	1.57676	1.52809	0.83909
xd-16 B	1.89709	2.1678	2.14839	1.58718	1.08886

All references mentioned in the present invention are incorporated herein by reference, as each of them is individually cited herein by reference. Further, it should be understood that, after reading the above contents, the skilled person can make various modifications or changes to the present invention. All these equivalents also fall into the scope defined by the appending claims of the present application.

Claims

1. An antibody that binds human PD-1 (SEQ ID NO: 1), comprising a light chain (LC) and a heavy chain (HC), wherein

the light chain comprises light chain complementarity determining regions LCDR1, LCDR2, and LCDR3 consisting of the amino acid sequences as set forth by SEQ ID NOs: 10, 11 and 12, respectively, and

the heavy chain comprises heavy chain complementarity determining regions HCDR1, HCDR2, and HCDR3, wherein

HCDR1 consists of the amino acid sequence as set forth by SEQ ID NO: 2;

HCDR2 consists of the amino acid sequences as set forth by SEQ ID NOs: 3, 4, 5, 6, or 7; and

HCDR3 consists of the amino acid sequences as set forth by SEQ ID NO: 8 or 9.

2. The antibody of Claim 1, wherein HCDR1, HCDR2, and HCDR3 consist of the amino acid sequences as set forth by SEQ ID NO: 2, SEQ ID NO: 3 and SEQ ID NO: 8, respectively.

3. The antibody of Claim 1, wherein HCDR1, HCDR2, and HCDR3 consist of the amino acid sequences as set forth by SEQ ID NO: 2, SEQ ID NO: 4, and SEQ ID NO: 9, respectively.

4. The antibody of Claim 1, wherein HCDR1, HCDR2, and HCDR3 consist of the amino acid sequences as set forth by SEQ ID NO: 2, SEQ ID NO: 5, and SEQ ID NO: 8, respectively.

5. The antibody of Claim 1, wherein HCDR1, HCDR2, and HCDR3 consist of the amino acid sequences as set forth by SEQ ID NO: 2, SEQ ID NO: 6, and SEQ ID NO: 8, respectively.

6. The antibody of Claim 1, wherein HCDR1, HCDR2, and HCDR3 consist of the amino acid sequences as set forth by SEQ ID NO: 2, SEQ ID NO: 7, and SEQ ID NO: 9, respectively.

7. An antibody, comprising 1 or 2 light chain(s) (LC) and 1 or 2 heavy chain (s)(HC), wherein each of the light chain comprises a light chain variable region (LCVR) and each of the heavy chain comprises a heavy chain variable region (HCVR), wherein the LCVR has the amino acid sequence as set forth by SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 13, SEQ ID NO: 14, SEQ ID NO: 15, SEQ ID NO: 16 or SEQ ID NO: 17.

8. The antibody of Claim 7, wherein the LCVR has the amino acid sequence as set forth by SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 13.

9. The antibody of Claim 7, wherein the LCVR has the amino acid sequence as set forth by SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 14.

10. The antibody of Claim 7, wherein the LCVR has the amino acid sequence as set forth by SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 15.

11. The antibody of Claim 7, wherein the LCVR has the amino acid sequence as set forth by SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 16.

12. The antibody of Claim 7, wherein the LCVR has the amino acid sequence as set forth by SEQ ID NO: 18, and the HCVR has the amino acid sequence as set forth by SEQ ID NO: 17.

13. The antibody of Claim 7, wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 19, SEQ ID NO: 20, SEQ ID NO: 21, SEQ ID NO: 22, or SEQ ID NO: 23.

14. The antibody of Claim 13, wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 19.

15. The antibody of Claim 13, wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 20.

16. The antibody of Claim 13, wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 21.

17. The antibody of Claim 13, wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 22.

18. The antibody of Claim 13, wherein the LC has the amino acid sequence as set forth by SEQ ID NO: 24, and the HC has the amino acid sequence as set forth by SEQ ID NO: 23.

19. The antibody of Claim 13, comprising two light chains and two heavy chains, wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and

each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 19, SEQ ID NO: 20, SEQ ID NO: 21, SEQ ID NO: 22, or SEQ ID NO: 23.

20. The antibody of Claim 19, wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 19.

21. The antibody of Claim 19, wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 20.

22. The antibody of Claim 19, wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 21.

23. The antibody of Claim 19, wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 22.

24. The antibody of Claim 19, wherein each light chain has the amino acid sequence as set forth by SEQ ID NO: 24, and each heavy chain has the amino acid sequence as set forth by SEQ ID NO: 23.

25. The antibody of any one of Claims 19-24, wherein one of the heavy chains forms an inter-chain disulfide bond with one of the light chains, and the other heavy chain forms an inter-chain disulfide bond with the other light chain, and one of the heavy chains forms two inter-chain disulfide bonds with the other heavy chain.

26. The antibody of any one of Claims 1-24, wherein the antibody is glycosylated.

27. A mammalian cell comprising a DNA molecule comprising a polynucleotide sequence encoding a polypeptide having an amino acid sequence of SEQ ID NO: 24 and a polynucleotide sequence encoding a polypeptide having an amino acid sequence of SEQ ID NO: 20, wherein the cell is capable of expressing an antibody comprising a light chain having an amino acid sequence of SEQ ID NO: 24 and a heavy chain having an amino acid sequence of SEQ ID NO: 20; preferably, said mammalian cell is a CHO cell.

28. A process for producing an antibody comprising a light chain having an amino acid sequence of SEQ ID NO: 24 and a heavy chain having an amino acid sequence of SEQ ID NO: 20, comprising cultivating the mammalian cell of Claim 27 under conditions such that the antibody is expressed, and recovering the expressed antibody.

29. An antibody produced by the process of Claim 28.

30. A pharmaceutical composition, comprising the antibody of any one of Claims 1-26, and a pharmaceutical acceptable carrier.

31. A method of treating cancer, comprising step of administering to a subject in need with an effective amount of the antibody of any one of Claims 1-26.

32. The method of Claim 31, wherein the cancer is melanoma, lung cancer, head and neck cancer, colorectal cancer, pancreatic cancer, gastric cancer, kidney cancer, bladder cancer, prostate cancer, breast cancer, ovarian cancer, or liver cancer.

33. The method of Claim 31 or 32, further comprising administering simultaneously, separately, or sequentially one or more anti-tumor agents.

34. The antibody of any one of Claims 1-26 for use in therapy.

35. The antibody of any one of Claims 1-26 for use in treatment of cancer.

36. The antibody for use of Claim 35, wherein the cancer is melanoma, lung cancer, head and neck cancer, colorectal cancer, pancreatic cancer, gastric cancer, kidney cancer, bladder cancer, prostate cancer, breast cancer, ovarian cancer, or hepatocellular carcinoma.

37. The antibody of any one of Claims 1-26 in simultaneous, separate, or sequential combination with one or more anti-tumor agents for combined use in treatment of cancer.

38. The antibody for combined use of Claim 37, wherein the cancer is melanoma, lung cancer, head and neck cancer, colorectal cancer, pancreatic cancer, gastric cancer, kidney cancer, bladder cancer, prostate cancer, breast cancer, ovarian cancer, or hepatocellular carcinoma.