Innovation, Sciences et Développement économique Canada
Office de la Propriété Intellectuelle du Canada

Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

CA 3128104 A1 2020/08/06

(21) 3 128 104

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(86) Date de dépôt PCT/PCT Filing Date: 2020/01/31
(87) Date publication PCT/PCT Publication Date: 2020/08/06
(85) Entrée phase nationale/National Entry: 2021/07/28
(86) N° demande PCT/PCT Application No.: CN 2020/074098
(87) N° publication PCT/PCT Publication No.: 2020/156509
(30) Priorités/Priorities: 2019/02/03 (CN201910108743.3); 2020/01/17 (CN202010052351.2)

(51) Cl.Int./Int.Cl. *C07K 16/28* (2006.01), *A61K 39/395* (2006.01), *A61K 48/00* (2006.01), *A61P 29/00* (2006.01), *A61P 31/00* (2006.01), *A61P 33/00* (2006.01), *A61P 35/00* (2006.01), *C12N 1/15* (2006.01), *C12N 1/19* (2006.01), *C12N 1/21* (2006.01), *C12N 15/13* (2006.01), *C12N 15/63* (2006.01), *C12N 5/10* (2006.01)

(71) Demandeurs/Applicants:
JIANGSU HENGRUI MEDICINE CO., LTD., CN;
SHANGHAI HENGRUI PHARMACEUTICAL CO., LTD., CN

(72) Inventeurs/Inventors:
GU, XIAOLING, CN; ...

(54) Titre : ANTICORPS ANTI-PD-1, FRAGMENT DE LIAISON A L'ANTIGENE DE CELUI-CI ET UTILISATION PHARMACEUTIQUE ASSOCIEE

(54) Title: ANTI-PD-1 ANTIBODY, ANTIGEN-BINDING FRAGMENT THEREOF AND PHARMACEUTICAL USE THEREOF

(57) Abrégé/Abstract:
Provided are an anti-PD-1 antibody, an antigen-binding fragment thereof, and a pharmaceutical use thereof. Specifically, provided are a humanized anti-PD-1 antibody containing a specific CDR region and an antigen-binding fragment thereof, a pharmaceutical composition containing the anti-PD-1 antibody and the antigen-binding fragment thereof, and a use thereof as medicament. In particular, provided is a use of the humanized anti-PD-1 antibody in the preparation of the medicament for treating PD-1 associated diseases or disorders.

(21) 3 128 104

(13) A1

(72) Inventeurs(suite)/Inventors(continued): YE, XIN, CN;GE, HU, CN; TAO, WEIKANG, CN

(74) Agent: BERESKIN & PARR LLP/S.E.N.C.R.L.,S.R.L.

## Abstract

Provided are an anti-PD-1 antibody, an antigen-binding fragment thereof, and a pharmaceutical use thereof. Specifically, provided are a humanized anti-PD-1 antibody containing a specific CDR region and an antigen-binding fragment thereof, a pharmaceutical composition containing the anti-PD-1 antibody and the antigen-binding fragment thereof, and a used thereof as medicament. In particular, provided is a use of the humanized anti-PD-1 antibody in the preparation of the medicament for treating PD-1 associated diseases or disorders.


Date Reçue/Date Received 2021-07-28

# ANTI-PD-1 ANTIBODY, ANTIGEN-BINDING FRAGMENT THEREOF AND PHARMACEUTICAL USE THEREOF

## FIELD OF THE INVENTION

The present disclosure belongs to the field of biotechnology. More specifically, the present disclosure relates to anti-PD-1 antibodies and applications thereof.

## BACKGROUND OF THE INVENTION

The statements herein only provide background information related to the present invention, and do not necessarily constitute prior art.

Tumor immunotherapy is a treatment method that fully utilizes and mobilizes the killer T cells in tumor patients to kill the tumor. At the same time, tumor cell evasion is a huge obstacle to tumor immunotherapy. Tumor cells use their own inhibitory effects on the immune system to promote the rapid growth of tumors. There is a very complicated relationship between the immune evasion mechanism of tumors and the immune response of the body to the tumors. In the early stage of tumor immunotherapy, tumor-specific killer T cells have their biological activity, but as the tumor grows, they lose their killing function in the later stage.

The activation of T cells in the human body adopts two signaling pathway systems. In addition to the first signal provided to T cells by the presentation of MHC-antigen peptides by antigen-presenting cells, a second signal provided by a series of co-stimulatory molecules is also required to allow T cells to produce normal immune responses. This dual-signaling pathway system plays a vital role in the balance of the immune system in the body. It strictly regulates different immune responses of the body to self and non-self antigens. If the second signal provided by the co-stimulatory molecule is absent, it will lead to a non-response or a sustained specific immune response of T cells, thus leading to tolerance. Therefore, the second signaling pathway plays a very critical regulatory role in the entire process of the immune response of the body.

Programmed death-l (PD-l) is a protein receptor expressed on the surface of T cells discovered in 1992 and is involved in the process of cell apoptosis. PD-l belongs to the CD28 family. It has 23% amino acid homology with cytotoxic T lymphocyte antigen 4 (CTLA-4),



Date Reçue/Date Received 2021-07-28

but its expression is different from that of CTLA, and it is mainly expressed on the activated T cells, B cells and myeloid cells. PD-1 has two ligands, PD-L1 and PD-L2, respectively. PD-L1 is mainly expressed on T cells, B cells, macrophages and dendritic cells (DCs), and the expression on cells can be up-regulated after being activated. The expression of PD-L2 is relatively constrained and is mainly expressed on antigen-presenting cells, such as the activated macrophages and dendritic cells.

PD-L1 inhibits the immune system by binding to PD-1 and B7-1. Many tumor cells and immune cells in the tumor tissue microenvironment express PD-L1. New research has found that high expression of PD-L1 protein was detected in breast cancer, lung cancer (for example, non-small cell lung cancer), gastric cancer, bowel cancer, kidney cancer, melanoma, colon cancer, bladder cancer, ovarian cancer, pancreatic cancer and liver cancer and other human tumor tissues, and the expression level of PD-L1 was closely related to the clinical manifestation and prognosis of patients.

Anti-PD-1 monoclonal antibody can maximize the patient's own immune system response to tumors by blocking the binding of PD-L1/PD-1, thus achieving the purpose of killing tumor cells. At present, the anti-PD-1 antibody Pembrolizumab (also known as Merck keytruda, keytruda, Merck-Pemb, Merck-keytruda, Merck-PD-1, pembrolizumab) and Novilumab (also known as BMS Opdivo, Opdivo, BMS-Nivolumab, Novilumab) has been approved by the FDA for the treatment of melanoma, Hodgkin's lymphoma patients, non-small cell lung cancer and other tumors. In addition, patent documents, such as WO200139722, WO2006121168, WO2010036959, WO2010089411, WO2011110604, WO2013173223, WO2013181634, US2014335093, US6803192B1, US8617546B2, and WO2015085847,. also disclose a variety of anti-PD-1 monoclonal antibodies.

## SUMMARY OF THE INVENTION

The present disclosure provides a new anti-PD-1 antibody, antigen-binding fragment thereof and medical use thereof.

In some alternative embodiments, the present disclosure provides an anti-PD-1 antibody or an antigen-binding fragment thereof, which is selected from any one of the following i) to iii):



Date Reçue/Date Received 2021-07-28

i) an anti-PD-1 antibody or antigen-binding fragment thereof, the heavy chain variable region of which comprises HCDR1 as shown in SEQ ID NO: 8 or having at most 3, 2 or 1 amino acid mutation thereto, HCDR2 as shown in SEQ ID NO: 9 or having at most 3, 2, or 1 amino acid mutation thereto, and HCDR3 as shown in SEQ ID NO: 10 or having at most 8, 3, 2, or 1 amino acid mutation thereto; the light chain variable region of which comprises LCDR1 as shown in SEQ ID NO: 11 or having at most 4, 3, 2 or 1 amino acid mutation thereto, LCDR2 as shown in SEQ ID NO: 12 or having at most 3, 2 or 1 amino acid mutation thereto, and LCDR3 as shown in SEQ ID NO: 13 or having at most 3, 2 or 1 amino acid mutation thereto;

ii) an anti-PD-1 antibody or antigen-binding fragment thereof, the heavy chain variable region of which comprises HCDR1 as shown in SEQ ID NO: 14 or having at most 3, 2 or 1 amino acid mutation thereto, HCDR2 as shown in SEQ ID NO: 15 or having at most 3, 2, or 1 amino acid mutation thereto, and HCDR3 as shown in SEQ ID NO: 16 or having at most 8, 3, 2, or 1 amino acid mutation thereto; the light chain variable region of which comprises LCDR1 as shown in SEQ ID NO: 17 or having at most 4, 3, 2 or 1 amino acid mutation thereto, LCDR2 as shown in SEQ ID NO: 12 or having at most 3, 2 or 1 amino acid mutation thereto, and LCDR3 as shown in SEQ ID NO: 18 or having at most 3, 2 or 1 amino acid mutation thereto; and

iii) an anti-PD-1 antibody or antigen-binding fragment thereof, the heavy chain variable region of which comprises HCDR1 as shown in SEQ ID NO: 21 or having at most 3, 2 or 1 amino acid mutation thereto, HCDR2 as shown in SEQ ID NO: 22 or having at most 3, 2, or 1 amino acid mutation thereto, and HCDR3 as shown in SEQ ID NO: 23 or having at most 3, 2, or 1 amino acid mutation thereto; the light chain variable region of which comprises LCDR1 as shown in SEQ ID NO: 24 or having at most 3, 2 or 1 amino acid mutation thereto, LCDR2 as shown in SEQ ID NO: 25 or having at most 3, 2 or 1 amino acid mutation thereto, and LCDR3 as shown in SEQ ID NO: 26 or having at most 3, 2 or 1 amino acid mutation thereto.

In some embodiments, the aforementioned anti-PD-1 antibody or antigen-binding fragment thereof of the present disclosure binds to human PD-1 with a dissociation equilibrium constant of $10^{-7}$ M or less. In some embodiments, it binds to human PD-1 with a



Date Reçue/Date Received 2021-07-28

dissociation equilibrium constant of equal to or less than $10^{-8}$ M, $10^{-9}$ M, $10^{-10}$ M or $10^{-11}$ M.

In some alternative embodiments, the present disclosure provides an anti-PD-1 antibody or antigen-binding fragment thereof, the heavy chain variable region of which comprises: HCDR1 as shown in SEQ ID NO: 65, HCDR2 as shown in SEQ ID NO: 66, and HCDR3 as shown in SEQ ID NO: 67; the light chain variable region of which comprises: LCDR1 as shown in SEQ ID NO: 68, LCDR2 as shown in SEQ ID NO: 12, and LCDR3 as shown in SEQ ID NO: 69; the sequences are shown in Table 1 below:

Table 1

| Heavy chain | | Light chain | |
|---|---|---|---|
| HCDR1 | DYE $X_1$H, $X_1$ is selected from I or M; (SEQ ID NO: 65) | LCDR1 | RSSQSX$_{13}$VHSX$_{14}$X$_{15}$X$_{16}$TY LE, wherein $X_{13}$ is selected from I or L, $X_{14}$ is selected from N, Q, L, T or D, $X_{15}$ is selected from G, A or V, and $X_{16}$ is selected from N or K; (SEQ ID NO: 68) |
| HCDR2 | LX$_2$DPETGGX$_3$VYNQKFKX$_4$, $X_2$ is selected from F or I, $X_3$ is selected from I/T and $X_4$ is selected from G or D; (SEQ ID NO: 66) | LCDR2 | KVSNRFS; (SEQ ID NO: 12) |
| HCDR3 | EX$_5$X$_6$X$_7$X$_8$YX$_9$X$_{10}$X$_{11}$X$_{12}$DWYFDV, $X_5$ is selected from G or R, $X_6$ is selected from F or absent, $X_7$ is S or absent, $X_8$ is Y or absent, $X_9$ is G or absent, $X_{10}$ is S or absent, $X_{11}$ is selected from N or T and $X_{12}$ is selected from R or S; (SEQ ID NO: 67) | LCDR3 | FQGSHVPYX$_{17}$, $X_{17}$ is selected from A or T; (SEQ ID NO: 69) |

In some alternative embodiments, in the aforementioned anti-PD-1 antibody or antigen-binding fragment thereof, the heavy chain variable region comprises HCDR1 as shown in SEQ ID NO: 8, HCDR2 as shown in SEQ ID NO: 9, and HCDR3 as shown in SEQ ID NO: 10; the light chain variable region comprises LCDR2 as shown in SEQ ID NO: 12, LCDR3 as shown in SEQ ID NO: 13, and LCDR1 as shown in the general formula RSSQSX$_{13}$VHSX$_{14}$X$_{15}$X$_{16}$TYLE (SEQ ID NO: 68), wherein $X_{13}$ is selected from L, $X_{14}$ is



Date Reçue/Date Received 2021-07-28

selected from N, Q, L, T or D, $X_{15}$ is selected from G, A or V, and $X_{16}$ is selected from N.

In some alternative embodiments, the anti-PD-1 antibody or antigen-binding fragment thereof is selected from any one of the following (a) to (e):

(a) an anti-PD-1 antibody or antigen-binding fragment thereof, which comprises HCDR1, HCDR2 and HCDR3 as shown in SEQ ID NO: 8, SEQ ID NO: 9 and SEQ ID NO: 10, respectively, and LCDR2 and LCDR3 as shown in SEQ ID NO: 12 and SEQ ID NO: 13, respectively, and LCDR1 as shown in SEQ ID NO: 11, 47, 48, 49, 50, 51 or 52;

(b) an anti-PD-1 antibody or antigen-binding fragment thereof, which comprises HCDR1, HCDR2 and HCDR3 as shown in SEQ ID NO: 14, SEQ ID NO: 15 and SEQ ID NO: 16, respectively, and LCDR1, LCDR2 and LCDR3 as shown in SEQ ID NO: 17, SEQ ID NO: 12 and SEQ ID NO: 18, respectively;

(c) an anti-PD-1 antibody or antigen-binding fragment thereof, which comprises HCDR1, HCDR2 and HCDR3 as shown in SEQ ID NO: 21, SEQ ID NO: 22 and SEQ ID NO: 23, respectively, and LCDR1, LCDR2 and LCDR3 as shown in SEQ ID NO: 24, SEQ ID NO: 25 and SEQ ID NO: 26, respectively;

(d) an anti-PD-1 antibody or antigen-binding fragment thereof, which comprises HCDR1, HCDR2 and HCDR3 as shown in SEQ ID NO: 14, SEQ ID NO: 15 and SEQ ID NO: 16, respectively, and LCDR2 and LCDR3 as shown in SEQ ID NO: 12 and SEQ ID NO: 13, respectively, and LCDR1 as shown in SEQ ID NO: 11, 47, 48, 49, 50, 51 or 52; and

(e) the heavy chain variable region comprises HCDR1, HCDR2 and HCDR3 as shown in SEQ ID NO: 8, SEQ ID NO: 9 and SEQ ID NO: 10, respectively, and the light chain variable region comprises LCDR1, LCDR2 and LCDR3 as shown in SEQ ID NO: 17, SEQ ID NO: 12 and SEQ ID NO: 18, respectively.

In some embodiments, the anti-PD-1 antibody or antigen-binding fragment thereof comprises a heavy chain variable region and a light chain variable region, wherein the heavy chain variable region comprises HCDR1, HCDR2 and HCDR3 as shown in SEQ ID NO: 8, SEQ ID NO: 9 and SEQ ID NO: 10, respectively, and the light chain variable region comprises LCDR1, LCDR2 and LCDR3 as shown in SEQ ID NO: 49, SEQ ID NO: 12 and SEQ ID NO: 13, respectively.



Date Reçue/Date Received 2021-07-28

In some embodiments, the anti-PD-1 antibody or antigen-binding fragment thereof comprises a heavy chain variable region and a light chain variable region, wherein the heavy chain variable region comprises HCDR1, HCDR2 and HCDR3 as shown in SEQ ID NO: 21, SEQ ID NO: 22 and SEQ ID NO: 23, respectively, and the light chain variable region comprises LCDR1, LCDR2 and LCDR3 as shown in SEQ ID NO: 24, SEQ ID NO: 25 and SEQ ID NO: 26, respectively.

In some alternative embodiments, the present disclosure provides an anti-PD-1 antibody or an antigen-binding fragment thereof, which is selected from any one of the following iv) to vi):

iv) an anti-PD-1 antibody or antigen-binding fragment thereof, the heavy chain variable region of which comprises HCDR1, HCDR2 and HCDR3 with the same sequences as those of the heavy chain variable region shown in sequence SEQ ID NO: 4, and the light chain variable region comprises LCDR1, LCDR2 and LCDR3 with the same sequences as those of the light chain variable region shown in sequence SEQ ID NO: 5;

v) an anti-PD-1 antibody or antigen-binding fragment thereof, the heavy chain variable region of which comprises HCDR1, HCDR2 and HCDR3 with the same sequences as those of the heavy chain variable region shown in sequence SEQ ID NO: 6, and the light chain variable region comprises LCDR1, LCDR2 and LCDR3 with the same sequences as those of the light chain variable region shown in sequence SEQ ID NO: 7; and

vi) an anti-PD-1 antibody or antigen-binding fragment thereof, the heavy chain variable region of which comprises HCDR1, HCDR2 and HCDR3 with the same sequences as those of the heavy chain variable region shown in sequence SEQ ID NO: 19, and the light chain variable region comprises LCDR1, LCDR2 and LCDR3 with the same sequences as those of the light chain variable region shown in sequence SEQ ID NO: 20.

In some embodiments of the aforementioned anti-PD-1 antibody or antigen-binding fragment thereof, the anti-PD-1 antibody or antigen-binding fragment thereof is a murine antibody or antigen-binding fragment thereof, a chimeric antibody or antigen-binding fragment thereof, a fully human antibody or antigen-binding fragment thereof, or a humanized antibody or antigen-binding fragment thereof.



Date Reçue/Date Received 2021-07-28

In some embodiments of the aforementioned anti-PD-1 antibody or antigen-binding fragment thereof, the anti-PD-1 antibody or antigen-binding fragment thereof is a humanized antibody or antigen-binding fragment thereof.

In some embodiments, the humanized antibody comprises a framework region derived from a human antibody or a framework region variant thereof.

In some embodiments, the framework region variant has at most 11 amino acid back mutations on each of the light chain framework region and/or the heavy chain framework region of a human antibody.

In some embodiments, the framework region variant comprises mutation(s) selected from any one of the following (f) to (h):

(f) 2G amino acid back mutation comprised in the light chain variable region and/or one or more amino acid back mutations selected from 27Y, 48I, 67T, 69L, 82F and 93T comprised in the heavy chain variable region;

(g) 2V amino acid back mutation comprised in the light chain variable region, and/or one or more amino acid back mutations selected from 26D, 27F, 30T, 38K, 43H, 48I, 66K, 67A, 69L, 82F and 93T comprised in the heavy chain variable region; and

(h) one or more amino acid back mutations selected from 42G, 44V and 71Y comprised in the light chain variable region, and/or 1K and/or 94S amino acid back mutations comprised in the heavy chain variable region.

In some embodiments of the aforementioned anti-PD-1 antibody or antigen-binding fragment thereof, the anti-PD-1 antibody or antigen-binding fragment thereof comprises antibody variable regions selected from the group consisting of:

(a2) a heavy chain variable region comprising HCDR1, HCDR2 and HCDR3 as shown in SEQ ID NO: 8, SEQ ID NO: 9 and SEQ ID NO: 10, respectively, and one or more amino acid back mutations of 27Y, 48I, 67T, 69L, 82F and 93T comprised in the heavy chain framework region, and

a light chain variable region comprising LCDR2 and LCDR3 as shown in SEQ ID NO: 12 and SEQ ID NO: 13, respectively, and LCDR1 as shown in SEQ ID NO: 11, 47, 48, 49, 50, 51 or 52, and 2G amino acid back mutation comprised in the light chain framework region;



Date Reçue/Date Received 2021-07-28

(b2) a heavy chain variable region comprising HCDR1, HCDR2 and HCDR3 as shown in SEQ ID NO: 14, SEQ ID NO: 15 and SEQ ID NO: 16, respectively, and one or more amino acid back mutations selected from 26D, 27F, 30T, 38K, 43H, 48I, 66K, 67A, 69L, 82F and 93T comprised in the heavy chain variable region; and

a light chain variable region comprising LCDR1, LCDR2 and LCDR3 as shown in SEQ ID NO: 17, SEQ ID NO: 12 and SEQ ID NO: 18, respectively, and 2V amino acid back mutation comprised in the light chain framework region;

(c2) a heavy chain variable region comprising HCDR1, HCDR2 and HCDR3 as shown in SEQ ID NO: 21, SEQ ID NO: 22 and SEQ ID NO: 23, respectively, and 1K and/or 94S amino acid back mutations comprised in the heavy chain framework region, and

a light chain variable region comprising LCDR1, LCDR2 and LCDR3 as shown in SEQ ID NO: 24, SEQ ID NO: 25 and SEQ ID NO: 26, respectively, and one or more amino acid back mutations selected from 42G, 44V and 71Y comprised in the light chain framework region.

In some embodiments of the aforementioned anti-PD-1 antibody or antigen-binding fragment thereof, the anti-PD-1 antibody or antigen-binding fragment thereof comprises antibody variable regions selected from any one of the following (i) to (o):

(i) a heavy chain variable region, the sequence of which is as shown in SEQ ID NO: 4 or has at least 90% sequence identity with SEQ ID NO: 4, and/or

a light chain variable region, the sequence of which is as shown in SEQ ID NO: 5 or has at least 90% sequence identity with SEQ ID NO: 5;

(j) a heavy chain variable region, the sequence of which is as shown in SEQ ID NO: 6 or has at least 90% sequence identity with SEQ ID NO: 6, and/or

a light chain variable region, the sequence of which is as shown in SEQ ID NO: 7 or has at least 90% sequence identity with SEQ ID NO: 7;

(k) a heavy chain variable region, the sequence of which is as shown in SEQ ID NO: 19 or has at least 90% sequence identity with SEQ ID NO: 19, and/or

a light chain variable region, the sequence of which is as shown in SEQ ID NO: 20 or has at least 90% sequence identity with SEQ ID NO: 20;

(l) a heavy chain variable region, the sequence of which is as shown in SEQ ID NO:



Date Reçue/Date Received 2021-07-28

27, 30, 31 or 32, or has at least 90% sequence identity with SEQ ID NO: 27, 30, 31 or 32, respectively, and/or

a light chain variable region, the sequence of which is as shown in SEQ ID NO: 28, 29, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63 or 64, or has at least 90% sequence identity with SEQ ID NO: 28, 29, 34, 35, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63 or 64, respectively;

(m) a heavy chain variable region, the sequence of which is as shown in SEQ ID NO: 33, 36, 37, 38, 39 or 40, or has at least 90% sequence identity with SEQ ID NO: 33, 36, 37, 38, 39 or 40, respectively, and/or

a light chain variable region, the sequence of which is as shown in SEQ ID NO: 34, 35, 28, 29, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63 or 64, or has at least 90% sequence identity with SEQ ID NO: 34, 35, 28, 29, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63 or 64, respectively;

(n) a heavy chain variable region, the sequence of which is as shown in SEQ ID NO: 41, 45 or 46, or has at least 90% sequence identity with SEQ ID NO: 41, 45 or 46, respectively, and/or

a light chain variable region, the sequence of which is as shown in SEQ ID NO: 42, 43 or 44, or has at least 90% sequence identity with SEQ ID NO: 42, 43 or 44, respectively;

(o) a heavy chain variable region, the sequence of which is as shown in SEQ ID NO: 70 or has at least 90% sequence identity with SEQ ID NO: 70, and/or

a light chain variable region, the sequence of which is as shown in SEQ ID NO: 71 or has at least 90% sequence identity with SEQ ID NO: 71; and

(p) a heavy chain variable region, the sequence of which is as shown in SEQ ID NO: 27, 30, 31 or 32, or has at least 90% sequence identity with SEQ ID NO: 27, 30, 31 or 32, respectively, and/or

a light chain variable region, the sequence of which is as shown in SEQ ID NO: 34 or 35, or has at least 90% sequence identity with SEQ ID NO: 34 or 35, respectively;

wherein the sequences SEQ ID NO: 70 and SEQ ID NO: 71 are represented by general formula sequences as shown in Table 2:



Date Reçue/Date Received 2021-07-28

Table 2

| | |
|---|---|
| EVQLVQSGAEVKKPGSSVKVSCKASX18X19TFX20DYEX1H WVX21QAPGX22GLEWX23GLX2DPETGGX3VYNQKFKX4X2 4X25TX26TADKSTSTAYMEX27SSLRSEDTAVYYCX28REX5X6 X7X8YX9X10X11X12DWYFDVWGQGTTVTVSS, wherein, X1 is selected from I or M, X2 is selected from F or I, X3 is selected from I/T, X4 is selected from G or D, X5 is selected from G or R, X6 is F or absent, X7 is S or absent, X8 is Y or absent, X9 is G or absent, X10 is S or absent, X11 is selected from N or T, X12 is selected from R or S, X18 is selected from G or D, X19 is selected from G, F or Y, X20 is selected from S or T, X21 is selected from R or K, X22 is selected from Q or H, X23 is selected from M or I, X24 is selected from R or K, X25 is selected from V, A or T, X26 is selected from R or K, X27 is selected from L or F and X28 is selected from A or T (SEQ ID NO: 70) | DX29VMTQTPLSLPVTPGEP ASISCRSSQSX13VHSX14X15 X16TYLEWYLQKPGQSPQL LIYKVSNRFSGVPDRFSGS GSGTDFTLKISRVEAEDVG VYYCFQGSHVPYX17FGGG TKVEIK, wherein, X13 is selected from I or L, X14 is selected from N, Q, L, T or D, X15 is selected from G, A or V, X16 is selected from N or K, X17 is selected from A or T and X29 is selected from I, V or G (SEQ ID NO: 71) |

In some embodiments, the heavy chain variable region of the anti-PD-1 antibody is as shown in SEQ ID NO: 27 or has at least 90% identity with SEQ ID NO: 27, and the light chain variable region sequence of the anti-PD-1 antibody is as shown in SEQ ID NO: 55 or has at least 90% sequence identity with SEQ ID NO: 55.

In some embodiments, the heavy chain variable region of the anti-PD-1 antibody is as shown in SEQ ID NO: 46 or has at least 90% identity with SEQ ID NO: 46, and the light chain variable region sequence of the anti-PD-1 antibody is as shown in SEQ ID NO: 43 or has at least 90% sequence identity with SEQ ID NO: 43.

The aforementioned "at least 90% identity" includes having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or 100% identity.

In some other embodiments of the aforementioned anti-PD-1 antibody or antigen-binding fragment thereof, the antibody further comprises antibody constant regions; in some other embodiments, the heavy chain constant region of the antibody constant region is selected from human IgG1, IgG2, IgG3 and IgG4 constant regions and conventional variants thereof, the light chain constant region of the antibody constant region is selected from human antibody κ and λ chain constant regions and conventional variants thereof; in some other embodiments, the antibody constant regions comprise an IgG4 heavy chain constant region into which one or more mutations of S228P, F234A and L235A are



Date Reçue/Date Received 2021-07-28

introduced, for example, comprise an IgG4 heavy chain constant region having the three amino acid mutations of S228P, F234A and L235A; in some other embodiments, the antibody comprises a heavy chain constant region as shown in SEQ ID NO: 72 or SEQ ID NO: 79, and a light chain constant region as shown in SEQ ID NO: 73.

In some embodiments of the aforementioned anti-PD-1 antibody or antigen-binding fragment thereof, the anti-PD-1antibody comprises a light chain as shown in SEQ ID NO: 78 and a heavy chain as shown in SEQ ID NO: 77 or 82; or

a light chain as shown in SEQ ID NO: 75 and a heavy chain as shown in SEQ ID NO: 74, 76, 80 or 81.

In some embodiments, the anti-PD-1 antibody comprises:

a heavy chain as shown in SEQ ID NO: 74 and a light chain as shown in SEQ ID NO: 75; or

a heavy chain as shown in SEQ ID NO: 77 and a light chain as shown in SEQ ID NO: 78.

In some embodiments, provided is an anti-PD-1 antibody or an antigen-binding fragment thereof, the antibody competitively binding to human PD-1 or binding to the same human PD-1 epitope with any one of the aforementioned anti-PD-1 antibodies or antigen-binding fragments thereof.

In some embodiments of the aforementioned anti-PD-1 antibody or antigen-binding fragment thereof, the antibody is a bispecific antibody or a multispecific antibody.

In some embodiments of the anti-PD-1 antibody or antigen-binding fragment thereof, the antigen-binding fragment is selected from the group consisting of Fab, Fab', $F(ab')_2$, single-chain antibody (scFv), dimerized V region (diabody) and disulfide bond stabilized V region (dsFv).

In some embodiments, disclosed is an isolated monoclonal antibody or antigen-binding fragment thereof, said antibody competitively binding to human PD-1 with the anti-PD-1 antibody or antigen-binding fragment thereof according to any one of the foregoing.

In some embodiments, the present disclosure also provides a pharmaceutical composition, which comprises a therapeutically effective amount of the anti-PD-1 antibody or



Date Reçue/Date Received 2021-07-28

antigen-binding fragment thereof according to any one of the foregoing, or a therapeutically effective amount of the aforementioned isolated monoclonal antibody or antigen-binding fragment thereof, and one or more pharmaceutically acceptable carriers, diluents, buffers or excipients. In some embodiments, the therapeutically effective amount refers to a unit dose of the composition containing 0.1 to 3000 mg of the aforementioned anti-PD-1 antibody or antigen-binding fragment thereof.

In some embodiments, the present disclosure also provides a nucleic acid molecule that encodes the anti-PD-1 antibody or antigen-binding fragment thereof according to any one of the foregoing, or encodes the aforementioned isolated monoclonal antibody or antigen-binding fragment thereof.

In some embodiments, the present disclosure also provides a host cell comprising the aforementioned nucleic acid molecule.

In some embodiments, the present disclosure also provides a method for immunodetection or determination of PD-1, which comprises a step of using the anti-PD-1 antibody or antigen-binding fragment thereof according to any one of the foregoing, or a step of using the aforementioned isolated monoclonal antibody or antigen-binding fragment thereof.

In some embodiments, the present disclosure also provides a kit comprising the aforementioned anti-PD-1 antibody or antigen-binding fragment thereof or the aforementioned isolated monoclonal antibody or antigen-binding fragment thereof.

In some embodiments, provided is use of the aforementioned anti-PD-1 antibody or antigen-binding fragment thereof in preparing diagnostic agents for PD-1 related diseases.

In some embodiments, the present disclosure also provides a method for treating diseases, which comprises administering to a subject a therapeutically effective amount of the anti-PD-1 antibody or antigen-binding fragment thereof according to any one of the foregoing, or the aforementioned isolated monoclonal antibody or antigen-binding fragment thereof, or the aforementioned pharmaceutical composition, or the aforementioned nucleic acid molecule.

In some embodiments, the disease is tumor.



Date Reçue/Date Received 2021-07-28

In some other embodiments, the disease is selected from: head and neck squamous cell carcinoma, head and neck cancer, brain cancer, glioma, glioblastoma multiforme, neuroblastoma, central nervous system cancer, neuroendocrine tumor, pharyngeal cancer, nasopharyngeal cancer, esophageal cancer, thyroid cancer, malignant pleural mesothelioma, lung cancer, breast cancer, liver cancer, hepatoma, hepatocellular carcinoma, hepatobiliary cancer, pancreatic cancer, gastric cancer, gastrointestinal cancer, bowel cancer, colon cancer, colorectal cancer, kidney cancer, clear cell renal cell carcinoma, ovarian cancer, endometrial cancer, cervical cancer, bladder cancer, prostate cancer, testicular cancer, skin cancer, melanoma, leukemia, lymphoma, bone cancer, chondrosarcoma, myeloma, multiple myeloma, myelodysplastic syndrome, myeloproliferative neoplasm, squamous cell carcinoma, Ewing's sarcoma, systemic light chain amyloidosis and Merkel cell carcinoma; in some of these embodiments, the lymphoma is selected from: Hodgkin's lymphoma, non-Hodgkin's lymphoma, diffuse large B-cell lymphoma, follicular lymphoma, primary mediastinal large B-cell lymphoma, mantle cell lymphoma, small lymphocytic lymphoma, T-cell/histiocyte rich large B-cell lymphoma and lymphoplasmacytic lymphoma, the lung cancer is selected from: non-small cell lung cancer and small cell lung cancer, the leukemia is selected from: chronic myeloid leukemia, acute myeloid leukemia, lymphocytic leukemia, lymphoblastic leukemia, acute lymphoblastic leukemia, chronic lymphocytic leukemia and myeloid leukemia; in some other embodiments, the disease is selected from: PD-L1 positive melanoma, lung cancer, non-small cell lung cancer, breast cancer, gastric cancer, kidney cancer, bladder cancer, bowel cancer and colon cancer.

In some embodiments, the present disclosure also provides use of the anti-PD-1 antibody or antigen-binding fragment thereof according to any one of the foregoing, or the aforementioned isolated monoclonal antibody or antigen-binding fragment thereof, or the aforementioned pharmaceutical composition, or the aforementioned nucleic acid molecule, in preparing medicaments for the treatment or prevention of diseases.

In some embodiments, the disease is tumor.

In some other embodiments, the disease is selected from: head and neck squamous cell carcinoma, head and neck cancer, brain cancer, glioma, glioblastoma multiforme, neuroblastoma, central nervous system cancer, neuroendocrine tumor, pharyngeal cancer,



Date Reçue/Date Received 2021-07-28

nasopharyngeal cancer, esophageal cancer, thyroid cancer, malignant pleural mesothelioma, lung cancer, breast cancer, liver cancer, hepatoma, hepatocellular carcinoma, hepatobiliary cancer, pancreatic cancer, gastric cancer, gastrointestinal cancer, bowel cancer, colon cancer, colorectal cancer, kidney cancer, clear cell renal cell carcinoma, ovarian cancer, endometrial cancer, cervical cancer, bladder cancer, prostate cancer, testicular cancer, skin cancer, melanoma, leukemia, lymphoma, bone cancer, chondrosarcoma, myeloma, multiple myeloma, myelodysplastic syndrome, myeloproliferative neoplasm, squamous cell carcinoma, Ewing's sarcoma, systemic light chain amyloidosis and Merkel cell carcinoma; in some of these embodiments, the lymphoma is selected from: Hodgkin's lymphoma, non-Hodgkin's lymphoma, diffuse large B-cell lymphoma, follicular lymphoma, primary mediastinal large B-cell lymphoma, mantle cell lymphoma, small lymphocytic lymphoma, T-cell/histiocyte rich large B-cell lymphoma and lymphoplasmacytic lymphoma, the lung cancer is selected from: non-small cell lung cancer and small cell lung cancer, the leukemia is selected from: chronic myeloid leukemia, acute myeloid leukemia, lymphocytic leukemia, lymphoblastic leukemia, acute lymphoblastic leukemia, chronic lymphocytic leukemia and myeloid leukemia; in some other embodiments, the disease is selected from: PD-L1 positive melanoma, lung cancer, non-small cell lung cancer, breast cancer, gastric cancer, kidney cancer, bladder cancer, bowel cancer and colon cancer.

In some embodiments, the present disclosure also provides the anti-PD-1 antibody or antigen-binding fragment thereof according to any one of the foregoing, or the aforementioned isolated monoclonal antibody or antigen-binding fragment thereof, or the aforementioned nucleic acid molecule, or the aforementioned pharmaceutical composition, for use as medicaments.

In some embodiments, the medicament is used for the treatment or prevention of PD-1 related diseases.

In some embodiments, the disease is tumor.

In some other embodiments, the disease is selected from: head and neck squamous cell carcinoma, head and neck cancer, brain cancer, glioma, glioblastoma multiforme, neuroblastoma, central nervous system cancer, neuroendocrine tumor, pharyngeal cancer, nasopharyngeal cancer, esophageal cancer, thyroid cancer, malignant pleural mesothelioma,



Date Reçue/Date Received 2021-07-28

lung cancer, breast cancer, liver cancer, hepatoma, hepatocellular carcinoma, hepatobiliary cancer, pancreatic cancer, gastric cancer, gastrointestinal cancer, bowel cancer, colon cancer, colorectal cancer, kidney cancer, clear cell renal cell carcinoma, ovarian cancer, endometrial cancer, cervical cancer, bladder cancer, prostate cancer, testicular cancer, skin cancer, melanoma, leukemia, lymphoma, bone cancer, chondrosarcoma, myeloma, multiple myeloma, myelodysplastic syndrome, myeloproliferative neoplasm, squamous cell carcinoma, Ewing's sarcoma, systemic light chain amyloidosis and Merkel cell carcinoma; in some of these embodiments, the lymphoma is selected from: Hodgkin's lymphoma, non-Hodgkin's lymphoma, diffuse large B-cell lymphoma, follicular lymphoma, primary mediastinal large B-cell lymphoma, mantle cell lymphoma, small lymphocytic lymphoma, T-cell/histiocyte rich large B-cell lymphoma and lymphoplasmacytic lymphoma, the lung cancer is selected from: non-small cell lung cancer and small cell lung cancer, the leukemia is selected from: chronic myeloid leukemia, acute myeloid leukemia, lymphocytic leukemia, lymphoblastic leukemia, acute lymphoblastic leukemia, chronic lymphocytic leukemia and myeloid leukemia; in some other embodiments, the disease is selected from: PD-L1 positive melanoma, lung cancer, non-small cell lung cancer, breast cancer, gastric cancer, kidney cancer, bladder cancer, bowel cancer and colon cancer.

## DESCRIPTION OF THE DRAWINGS

Figure 1: the test results of anti-PD-1 antibodies blocking the binding of PD-1 to its ligand;

Figure 2: the effect of anti-PD-1 antibodies on the secretion of IFNγ from PBMC cells;

Figure 3: the efficiency of anti-PD-1 antibodies on xenograft tumor of colon cancer MC38 in mice;

Figure 4: the effect of anti-PD-1 antibodies on the tumor volume of colon cancer MC38 in mice.



Date Reçue/Date Received 2021-07-28

## DETAILED DESCRIPTION OF THE INVENTION

Overview

To make the present disclosure be understood easier, certain technical and scientific terms are specifically defined below. Unless clearly defined otherwise herein, all other technical and scientific terms used herein have the meanings commonly understood by those of ordinary skill in the art to which the present disclosure belongs.

The terms "programmed death 1", "programmed cell death 1", "protein PD-1", "PD-1", "PDCD1" and "hPD-1" are used interchangeably and include human PD-1 variants, isotypes, species homologs, and analogs that have at least one epitope in common with PD-1. The complete PD-1 sequence can be found with GenBank accession number U64863.

The term "programmed death ligand-1 (PD-L1)" is one of the two cell surface glycoprotein ligands of PD-1 (the other is PD-L2), which down-regulates T cell activation and cytokine secretion when it binds to PD-1. The term "PD-L1" as used herein includes human PD-L1 (hPD-L1), hPD-L1 variants, isotypes and interspecies homologs, and 5 analogs that have at least one epitope in common with hPD-1. The complete hPD-L1 sequence can be found with GenBank accession number Q9NZQ7.

The term "cytokine" is a general term for proteins released by a population of cells and acting on other cells as intercellular mediators. Examples of such cytokines include lymphokines, monokines, chemokines and traditional polypeptide hormones. Exemplary cytokines include: human IL-2, IFN-γ, IL-6, TNFα, IL-17 and IL-5.

The three-letter codes and one-letter codes of amino acids used in the present disclosure are as described in J. biol. chem, 243, p3558 (1968).

The "antibody" described in the present disclosure refers to an immunoglobulin generally. A natural intact antibody is a tetrapeptide chain structure composed of two identical heavy chains and two identical light chains linked by interchain disulfide bonds. The amino acid compositions and sequences of the immunoglobulin heavy chain constant regions are different, so their antigenicity is also different. Thereby, immunoglobulins can be divided into five classes, or named as isotypes of immunoglobulins, namely IgM, IgD, IgG, IgA and IgE, and their corresponding heavy chains are μ chain, δ chain, γ chain, α chain and ε chain, respectively. The same class of Ig can be divided into different subclasses according to the



Date Reçue/Date Received 2021-07-28

difference in the amino acid composition of the hinge region and the number and position of heavy chain disulfide bonds. For example, IgG can be divided into IgG1, IgG2, IgG3 and IgG4. The light chain is divided into κ chain or λ chain by the difference of the constant region. Each of the five classes of Ig can have a κ chain or a λ chain. The antibodies referred to in the present disclosure include antibodies or antigen-binding fragments thereof, including antibodies or antigen-binding fragments thereof that have been modified on the basis of immunoglobulin while retaining the ability to bind antigen; including monospecific antibodies, bispecific antibodies or multispecific antibodies; also including monovalent antibodies, bivalent antibodies or multivalent antibodies. Antigen-binding fragments of antibodies, for example, can be those comprising at least one VH-CH1 and at least one VL-CL structure, in which the VH and VL structures can approach to each other based on the interchain interaction and retain antigen binding ability. In some embodiments, the antigen-binding fragment of the antibody is a monovalent Fab fragment (Fab1 fragment), bivalent Fab fragment (F(ab)2), trivalent Fab fragment (F(ab)3), multivalent (two or more) Fab fragment, and can also be other monospecific, bispecific or multispecific antigen binding fragments comprising at least one Fab fragment.

"Bispecific antibody" refers to an antibody (including antibody or antigen-binding fragment thereof, such as single-chain antibody) that can specifically bind to two different antigens or two different epitopes of the same antigen. The prior art has disclosed bispecific antibodies with various structures. According to the integrity of the IgG molecule, they can be divided into IgG-like bispecific antibodies and antibody fragment-type bispecific antibodies. According to the number and configuration of the antigen binding regions, they can be divided into bivalent, trivalent, tetravalent or more-valent bispecific antibodies. According to whether the structure is symmetric, they can be divided into symmetric structure bispecific antibodies and asymmetric structure bispecific antibodies. Among them, antibody fragment-based bispecific antibodies, for example Fab fragments lacking Fc fragment, form bispecific antibodies by binding two or more Fab fragments in one molecule. These antibodies have lower immunogenicity and smaller molecular weight and higher tumor tissue permeability. Typical antibody structures of this type are bispecific antibodies such as F(ab)2, scFv-Fab, (scFv)2-Fab, etc.; For IgG-like bispecific antibodies (for example with Fc



Date Reçue/Date Received 2021-07-28

fragment), this type of antibody has larger molecular weight. The Fc fragment helps the purification of the antibody in later stages and improves its solubility and stability. The Fc moiety may also bind to the receptor FcRn and increase the serum half-life of the antibody. Typical bispecific antibody structure models are such as KiH, CrossMAb, Triomab quadroma, FcΔAdp, ART-Ig, BiMAb, Biclonics, BEAT, DuoBody, Azymetric, XmAb, 2:1 TCBs, 1Fab-IgG TDB, FynomAb, two-in-one/DAF, scFv-Fab-IgG, DART-Fc, LP-DART, CODV-Fab-TL, HLE-BiTE, F(ab)2-CrossMAb, IgG-(scFv)2, Bs4Ab, DVD-Ig, Tetravalent-DART-Fc, (scFv)4-Fc, CODV-Ig, mAb2, F(ab)4-CrossMAb and other bispecific antibodies (see Aran F. Labrijn et al., Nature Reviews Drug Discovery volume 18, pages 585–608 (2019); Chen S1 et al., J Immunol Res. 2019 Feb 11; 2019:4516041).

The term "monovalent", "bivalent", "trivalent" or "multivalent" refers to the presence of a specified number of antigen binding sites in an antibody or polypeptide complex. For example "monovalent antibody" means that there is one antigen binding site in the antibody, "Monovalent polypeptide complex" means that there is one antigen binding site in the polypeptide complex; "Bivalent antibody" means that there are two antigen binding sites in the antibody, "Bivalent polypeptide complex" means that there are two antigen binding sites in the polypeptide complex; "Trivalent antibody" means that there are three antigen binding sites in the antibody, "Trivalent polypeptide complex" means that there are three antigen binding sites in the polypeptide complex; "Multivalent antibody" means that there are multiple (three or more) antigen binding sites in the antibody, and "Multivalent polypeptide complex" means that there are multiple (two or more) antigen binding sites in the polypeptide complex.

The term "antibody fusion protein" refers to a biologically active fusion protein formed by linking a protein of interest (polypeptide) with an immunoglobulin. The fusion protein has the biological activity both of the linked protein and of the immunoglobulin.

The sequence of about 110 amino acids near the N-terminus of the antibody heavy and light chain varies greatly and is the variable region (Fv region); the remaining amino acid sequence near the C-terminus is relatively stable and is the constant region. The variable region includes 3 hypervariable regions (HVRs) and 4 framework regions (FRs) with relatively conservative sequences. The 3 hypervariable regions which determine the



Date Reçue/Date Received 2021-07-28

specificity of the antibody are also known as complementarity determining regions (CDRs). Each of the light chain variable region (VL) and heavy chain variable region (VH) consists of 3 CDR regions and 4 FR regions. The order from the amino terminus to the carboxyl terminus is: FR1, CDR1, FR2, CDR2, FR3, CDR3, FR4. The 3 CDR regions of the light chain refer to LCDR1, LCDR2 and LCDR3; and the 3 CDR regions of the heavy chain refer to HCDR1, HCDR2 and HCDR3.

The antibodies of the present disclosure include murine antibodies, chimeric antibodies, humanized antibodies and fully human antibodies, preferably humanized antibodies.

The term "murine antibody" in the present disclosure is a monoclonal antibody against human PD-1 prepared according to the knowledge and skills in the art. During preparation, the test subject is injected with PD-1 antigen, and then hybridomas expressing antibodies with the desired sequence or functional properties are isolated. In a preferred embodiment of the present disclosure, the murine anti-PD-1 antibody or antigen-binding fragment thereof can further comprise the light chain constant region of murine κ, λ chain or variant thereof, or further comprise the heavy chain constant region of murine IgG1, IgG2, IgG3 or variant thereof.

The term "chimeric antibody" is an antibody formed by fusing the variable region of a murine antibody with the constant region of a human antibody, which can alleviate the immune response induced by murine antibody. Establishing a chimeric antibody requires first establishing a hybridoma secreting murine specific monoclonal antibodies, then cloning the variable region gene from the murine hybridoma cells, and then cloning the constant region gene of the human antibody as necessary, linking the murine variable region gene with the human constant region gene to form a chimeric gene, inserting the chimeric gene into an expression vector, and finally expressing the chimeric antibody molecule in a eukaryotic system or a prokaryotic system. In a preferred embodiment of the present disclosure, the antibody light chain of the PD-L1 chimeric antibody further comprises a light chain constant region of a human κ, λ chain or variant thereof. The antibody heavy chain of the PD-1 chimeric antibody further comprises the heavy chain constant region of human IgG1, IgG2, IgG3, IgG4 or variant thereof, preferably comprises the heavy chain constant region of human



Date Reçue/Date Received 2021-07-28

IgG1, IgG2 or IgG4, or comprises IgG1, IgG2, or IgG4 variants with amino acid mutations (for example L234A and/or L235A mutations, and/or S228P mutations).

The term "humanized antibody", also known as CDR-grafted antibody, refers to an antibody produced by grafting murine CDR sequences into the framework of human antibody variable regions, that is, refers to an antibody produced in different types of human germline antibody framework sequences. It can overcome the heterogeneous reaction induced by the chimeric antibody as it carries a large amount of murine protein components. Such framework sequences can be obtained from public DNA databases or published references that include germline antibody gene sequences. For example, the germline DNA sequences of the human heavy chain and light chain variable region genes can be found in the "VBase" human germline sequence database (available on the Internet www.mrccpe.com.ac.uk/vbase), as well as in Kabat, E. A., et al., 1991, Sequences of Proteins of Immunological Interest, 5th edition. In order to avoid the decrease in activity at the same time caused by the decrease in immunogenicity, the human antibody variable region framework sequence can be subjected to minimal reverse mutations or back mutations to maintain activity. The humanized antibodies of the present disclosure also include humanized antibodies that have been further subjected to affinity maturation of the CDRs by yeast display.

Due to the residues in contact with the antigen, CDR grafting may result in reduced affinity of the produced antibody or antigen-binding fragment thereof to the antigen due to the framework residues in contact with the antigen. Such interactions may be the result of hypermutation of somatic cells. Therefore, it may still be necessary to graft such donor framework amino acids to the framework of the humanized antibody. The amino acid residues involved in antigen binding and from non-human antibodies or antigen-binding fragments thereof can be identified by examining the sequence and structure of the animal monoclonal antibody variable region. Residues in the CDR donor framework that differ from the germline can be considered related. If the closest germline cannot be determined, the sequence can be compared with the consensus sequence of a subclass or of animal antibody sequence with a high percentage of similarity. Rare framework residues are thought to be the result of hypermutation of somatic cells and thus play an important role in binding.



Date Reçue/Date Received 2021-07-28

In an embodiment of the present disclosure, the antibody or antigen-binding fragment thereof can further comprise a light chain constant region of human or murine κ, λ chain or variant thereof, or further comprise a heavy chain constant region of human or murine IgG1, IgG2, IgG3, IgG4 or variant thereof; preferably comprise a heavy chain constant region of human IgG1, IgG2 or IgG4, or IgG1, IgG2 or IgG4 variant with amino acid mutations (for example L234A and/or L235A mutation, and/or S228P mutation).

The "conventional variant" of the human antibody heavy chain constant region and the human antibody light chain constant region described in the present disclosure refers to the variant of heavy chain constant region or light chain constant region that has been disclosed in the prior art and does not change the structure and function of the antibody variable region. Exemplary variants include IgG1, IgG2, IgG3 or IgG4 heavy chain constant region variants with site-directed modifications and amino acid substitutions of the heavy chain constant region. Specific substitutions are such as YTE mutations, L234A and/or L235A mutations, S228P mutations, and/or mutations to obtain a knob-into-hole structure (making the antibody heavy chain have a combination of knob-Fc and hole-Fc) known in the art. These mutations have been confirmed to make the antibody have new properties, but do not change the function of the antibody variable region.

"HuMAb", "human antibody", "fully human antibody" and "complete human antibody" can be used interchangeably, and can refer to antibodies derived from humans or antibodies obtained from a genetically modified organism which is "engineered" to produce specific human antibodies in response to antigen stimulation and can be produced by any method known in the art. In some technologies, the elements of human heavy and light chain loci are introduced into cell lines of organisms derived from embryonic stem cell lines, in which the endogenous heavy chain and light chain loci have been target disrupted by what targets the endogenous heavy chain and light chain loci contained in these cell lines. Transgenic organisms can synthesize human antibodies specific to human antigens, and the organisms can be used to produce human antibody-secreting hybridomas. A human antibody can also be an antibody in which the heavy and light chains are encoded by nucleotide sequences derived from one or more human DNA sources. Fully human antibodies can also be constructed by gene or chromosome transfection methods and phage display technology, or



Date Reçue/Date Received 2021-07-28

constructed from B cells activated *in vitro*, all of which are known in the art.

The terms "full-length antibody", "intact antibody", "complete antibody" and "whole antibody" are used interchangeably herein and refer to an antibody in a substantially intact form, as distinguished from the antigen-binding fragments defined below. These terms specifically refer to an antibody in which the heavy chain comprises Fc region.

The term "antigen-binding fragment" or "functional fragment" of an antibody refers to one or more fragments of the antibody that retain the ability to specifically bind to an antigen (for example, PD-1). It has been shown that fragments of full-length antibodies can be used to perform the antigen-binding function of antibodies. Examples of the binding fragment included in the term "antigen-binding fragment" of the antibody include (i) Fab fragments, monovalent fragments consist of VL, VH, CL and CH1 domains; (ii) $F(ab')_2$ fragments, including bivalent fragments of two Fab fragments linked by a disulfide bridge in the hinge region, (iii) Fd fragments consist of VH and CH1 domains; (iv) Fv fragments composed of VH and VL domains of one arm of an antibody; (V) single domains or dAb fragments (Ward et al., (1989) Nature 341:544-546), which consist of a VH domain; and (vi) isolated complementarity determining regions (CDR) or (vii) combinations of two or more isolated CDRs, optionally linked by synthetic linkers. In addition, although the two domains VL and VH of the Fv fragment are encoded by separate genes, recombination methods can be used to link them by synthetic linkers so that it can be produced as a single protein chain in which the VL and VH regions pair to form a monovalent molecule (referred to as single-chain Fv (scFv); see, for example, Bird et al. (1988) Science 242:423-426; and Huston et al. (1988) Proc. Natl. Acad. Sci USA 85: 5879-5883). Such single chain antibodies are also intended to be included in the term "antigen-binding fragment" of antibody. Such antibody fragments are obtained by using conventional techniques known to those skilled in the art, and the functions of the fragments are screened in the same manner as for those of intact antibodies. The antigen binding moiety can be produced by recombinant DNA technology or by enzymatic or chemical cleavage of the intact immunoglobulin. The antibodies may be antibodies of different isotypes, for example, IgG (for example, IgG1, IgG2, IgG3 or IgG4 subtypes), IgA1, IgA2, IgD, IgE or IgM antibodies.



Date Reçue/Date Received 2021-07-28

The antigen-binding fragments of the present disclosure include Fab, F(ab')2, Fab', single-chain antibody (scFv), dimerized V region (diabody), disulfide bond stabilized V region (dsFv), CDR-containing peptide and the like.

Fab is an antibody fragment that has a molecular weight of about 50,000 and has antigen-binding activity, and it is obtained by treating IgG antibody molecules with the protease papain (cleaves the amino acid residue at position 224 of the H chain), in which about half of the N-terminal side of the H chain and the entire L chain are joined together by disulfide bond(s).

The Fab of the present disclosure can be produced by using papain to treat the monoclonal antibody of the present disclosure which specifically recognizes human PD-1 and binds to the amino acid sequence of the extracellular region or three-dimensional structure thereof. In addition, the Fab can be produced by inserting the DNA encoding the Fab of the antibody into a prokaryotic expression vector or a eukaryotic expression vector and introducing the vector into a prokaryotic organism or eukaryotic organism to express the Fab.

F(ab')2 is an antibody fragment that has a molecular weight of about 100,000 and has antigen-binding activity and comprises two Fab regions linked at the hinge position, and it is obtained by digesting the lower part of the two disulfide bonds in the hinge region of IgG with the enzyme pepsin.

The F(ab')2 of the present disclosure can be produced by using pepsin to treat the monoclonal antibody of the present disclosure which specifically recognizes human PD-1 and binds to the amino acid sequence of the extracellular region or three-dimensional structure thereof. In addition, the F(ab')2 can be produced by linking Fab' described below with thioether bond or disulfide bond.

Fab' is an antibody fragment that has a molecular weight of about 50,000 and has antigen-binding activity obtained by cleaving the disulfide bond in the hinge region of the F(ab')2. The Fab' of the present disclosure can be produced by using reducing agents for example dithiothreitol to treat the F(ab')2 of the present disclosure which specifically recognizes PD-1 and binds to the amino acid sequence of the extracellular region or three-dimensional structure thereof.



Date Reçue/Date Received 2021-07-28

In addition, the Fab' can be produced by inserting the DNA encoding the Fab' fragment of the antibody into a prokaryotic expression vector or a eukaryotic expression vector and then introducing the vector into a prokaryotic organism or eukaryotic organism to express the Fab'.

The term "single-chain antibody", "single-chain Fv" or "scFv" refers to molecules comprising an antibody heavy chain variable domain (or region; VH) and an antibody light chain variable domain (or region; VL) linked by a linker. Such scFv molecules can have the general structure: $NH_2$-VL-linker-VH-COOH or $NH_2$-VH-linker-VL-COOH. Suitable linkers in prior art consist of repeated GGGGS amino acid sequences or variants thereof, for example a variant with 1 to 4 repeated sequences (Holliger et al. (1993), Proc. Natl. Acad. Sci. USA 90: 6444-6448). Other linkers that can be used in the present disclosure are described in Alfthan et al. (1995), Protein Eng. 8:725-731, Choi et al. (2001), Eur. J. Immunol. 31:94-106, Hu et al. (1996) , Cancer Res. 56:3055-3061, Kipriyanov et al. (1999), J. Mol. Biol. 293:41-56 and Roovers et al. (2001), Cancer Immunol.

The scFv of the present disclosure can be produced by the following steps: obtaining the cDNA encoding VH and VL of the monoclonal antibody of the present disclosure which specifically recognizes human PD-1 and binds to the amino acid sequence of the extracellular region or three-dimensional structure thereof, constructing the DNA encoding the scFv, inserting the DNA into a prokaryotic expression vector or a eukaryotic expression vector, and then introducing the expression vector into a prokaryotic organism or eukaryotic organism to express the scFv.

Diabody is a antibody fragment in which scFv is dimerized, and is a antibody fragment with bivalent antigen-binding activity. In the bivalent antigen binding activity, the two antigens can be the same or different.

The diabody of the present disclosure can be produced by the following steps: obtaining the cDNA encoding VH and VL of the monoclonal antibody of the present disclosure which specifically recognizes human PD-1 and binds to the amino acid sequence of the extracellular region or three-dimensional structure thereof, constructing the DNA encoding the scFv so that the peptide linker has 8 or less amino acid sequence residues in length, inserting the DNA into a prokaryotic expression vector or a eukaryotic expression



Date Reçue/Date Received 2021-07-28

vector, and then introducing the expression vector into a prokaryote organism or eukaryotic organism to express the diabody.

dsFv is obtained by linking polypeptides in which one amino acid residue in each of VH and VL is replaced by a cysteine residue via a disulfide bond between the cysteine residues. The amino acid residues substituted with cysteine residues can be selected according to a known method (Protein Engineering, 7, 697 (1994)) based on the prediction of the antibody three-dimensional structure.

The dsFv of the present disclosure can be produced by the following steps: obtaining the cDNA encoding VH and VL of the monoclonal antibody of the present disclosure which specifically recognizes human PD-1 and binds to the amino acid sequence of the extracellular region or three-dimensional structure thereof, constructing the DNA encoding the dsFv, inserting the DNA into a prokaryotic expression vector or a eukaryotic expression vector, and then introducing the expression vector into a prokaryotic organism or eukaryotic organism to express the dsFv.

The CDR-containing peptide is constructed by one or more regions including the CDR(s) of VH or VL. Peptides containing multiple CDR can be linked directly or via a suitable peptide linker.

The CDR-containing peptide of the present disclosure can be produced by the following steps: constructing the DNA(s) encoding the CDR(s) of VH and VL of the monoclonal antibody of the present disclosure which specifically recognizes human PD-1 and binds to the amino acid sequence of the extracellular region or three-dimensional structure thereof, inserting the DNA(s) into a prokaryotic expression vector or a eukaryotic expression vector, and then introducing the expression vector into a prokaryotic organism or eukaryotic organism to express the peptide. The CDR-containing peptide can also be produced by chemical synthesis methods for example the Fmoc method or the tBoc method.

The term "amino acid difference" or "amino acid mutation" refers to the presence of amino acid change(s) or mutation(s) in the protein or polypeptide variant compared with the original protein or polypeptide, including having 1, 2, 3 or more amino acid insertion, deletion or substitution on the basis of the original protein or polypeptide.



Date Reçue/Date Received 2021-07-28

The term "antibody framework" or "FR region" refers to a moiety of the variable domain VL or VH, which serves as a scaffold for the antigen binding loop (CDR) of the variable domain. Essentially, it is a variable domain without CDR.

The term "complementarity determining region", "CDR" or "hypervariable region" refers to one of the six hypervariable regions in the variable domain of an antibody that mainly contribute to antigen binding. Generally, there are three CDRs (HCDR1, HCDR2 and HCDR3) in each heavy chain variable region, and three CDRs (LCDR1, LCDR2 and LCDR3) in each light chain variable region. Any one of well-known schemes can be used to determine the amino acid sequence boundaries of the CDRs, including the "Kabat" numbering criteria (see Kabat et al. (1991), "Sequences of Proteins of Immunological Interest", 5th edition, Public Health Service, National Institutes of Health, Bethesda, MD), "Chothia" numbering criteria (see Al-Lazikani et al., (1997) JMB 273:927-948) and ImmunoGenTics (IMGT) numbering criteria (Lefranc M. P., Immunologist, 7, 132- 136 (1999); Lefranc, M. P., et al., Dev. Comp. Immunol., 27, 55-77 (2003)), etc. For example, for the classical format, following the Kabat Criteria, the numbering of CDR amino acid residues in the heavy chain variable domain (VH) is 31-35 (HCDR1), 50-65 (HCDR2) and 95-102 (HCDR3); the numbering of CDR amino acid residues in the light chain variable domain (VL) is 24-34 (LCDR1), 50-56 (LCDR2) and 89-97 (LCDR3). Following the Chothia criteria, the numbering of CDR amino acid residues in VH is 26-32 (HCDR1), 52-56 (HCDR2) and 95-102 (HCDR3); and the numbering of amino acid residues in VL is 26-32 (LCDR1), 50-52 (LCDR2) and 91-96 (LCDR3). According to the combination of the CDR definitions of both Kabat and Chothia, the CDRs consist of amino acid residues 26-35 (HCDR1), 50-65 (HCDR2) and 95-102 (HCDR3) in human VH and amino acid residues 24-34 (LCDR1), 50-56 (LCDR2) and 89-97 (LCDR3) in human VL. Following IMGT criteria, the numbering of CDR amino acid residues in VH is roughly 26-35 (CDR1), 51-57 (CDR2) and 93-102 (CDR3), and the numbering of CDR amino acid residues in VL is roughly 27-32 (CDR1), 50-52 (CDR2) and 89-97 (CDR3). Following IMGT criteria, the CDR regions of an antibody can be determined using the program IMGT/DomainGap Align.

The term "epitope" or "antigenic determinant" refers to a site on an antigen to which an immunoglobulin or antibody specifically binds (for example, a specific site on PD-L1



Date Reçue/Date Received 2021-07-28

molecules). Epitopes usually include at least 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 or 15 consecutive or non-consecutive amino acids in a unique spatial conformation. See, for example, Epitope Mapping Protocols in Methods in Molecular Biology, Vol. 66, G.E.Morris, Ed. (1996).

The terms "specifically binds", "selectively binds", "binds selectively" and "binds specifically" refer to the binding of an antibody to an epitope on a predetermined antigen. Generally, antibodies bind with an affinity (KD) of about less than $10^{-8}$ M, for example about less than $10^{-9}$ M, $10^{-10}$ M, $10^{-11}$ M or less.

The term "KD" or "Kd" refers to the dissociation equilibrium constant of a specific antibody-antigen interaction. Generally, the antibodies of the present disclosure bind to PD-1 with a dissociation equilibrium constant (KD) of less than about $10^{-7}$ M, for example, less than about $10^{-8}$ M or $10^{-9}$ M, for example, as measured in a BIACORE instrument using surface plasma resonance (SPR) technology.

When the term "competition" is used in the context of antigen binding proteins that compete for the same epitope (for example neutralizing antigen binding proteins or neutralizing antibodies), it refers to the competition between the antigen binding proteins, and can be determined by the following assay: in the assay, the antigen-binding protein to be tested (for example an antibody or immunologically functional fragment thereof) prevents or inhibits (for example reduces) the specific binding of a reference antigen-binding protein (for example a ligand or a reference antibody) to a common antigen (for example PD-1 or fragment thereof). Numerous types of competitive binding assays can be used to determine whether one antigen-binding protein competes with another, these assays are for example: solid phase direct or indirect radioimmunoassay (RIA), solid phase direct or indirect enzyme immunoassay (EIA), sandwich competition assay (see for example Stahli et al., 1983, Methods in Enzymology 9:242-253); solid phase direct biotin-avidin EIA (see for example Kirkland et al., 1986, J. Immunol. 137:3614-3619), solid phase direct labeling assay, solid phase direct labeling sandwich assay (see for example Harlow and Lane, 1988, Antibodies, A Laboratory Manual, Cold Spring Harbor Press); solid phase direct labeling RIA with I-125 labels (see for example Morel et al., 1988, Molec. Immunol. 25: 7-15); solid-phase direct biotin-avidin EIA (see for example Cheung et al., 1990, Virology 176: 546-552); and direct



Date Reçue/Date Received 2021-07-28

labeling RIA (Moldenhauer et al., 1990, Scand. J. Immunol. 32:77-82). Generally, the assay involves using purified antigen bound to a solid surface or cell carrying either an unlabeled antigen binding protein being tested or a labeled reference antigen binding protein. Competitive inhibition is measured by measuring the amount of label bound to the solid surface or cell in the presence of the antigen binding protein being tested. Usually the antigen binding protein being tested is present in excess. The antigen binding proteins identified by competition assays (competitive antigen binding proteins) include: antigen binding proteins that bind to the same epitope as the reference antigen binding protein; and antigen binding proteins that binds to adjacent epitopes that are sufficiently close to the binding epitope of the reference antigen binding protein, the two epitopes sterically hinder each other from binding. Additional details on the methods used to determine competitive binding are provided in the examples herein. Usually when the competitive antigen binding protein is present in excess, it will inhibit (for example reduce) the specific binding of the reference antigen binding protein to the common antigen by at least 40-45%, 45-50%, 50-55%, 55-60%, 60-65%, 65-70%, 70%-75% or 75% or more. In some cases, the binding is inhibited by at least 80-85%, 85-90%, 90-95%, 95-97%, or 97% or more.

The term "nucleic acid molecule" used herein refers to DNA molecules and RNA molecules. The nucleic acid molecule can be single-stranded or double-stranded, and is preferably double-stranded DNA or single-stranded mRNA or modified mRNA. When a nucleic acid is placed in a functional relationship with another nucleic acid sequence, the nucleic acid is "operatively linked". For example, if a promoter or enhancer affects the transcription of a coding sequence, then the promoter or enhancer is operatively linked to the coding sequence.

The term "vector" refers to a nucleic acid molecule capable of transporting another nucleic acid to which it has been linked. In one embodiment, the vector is a "plasmid", which refers to a circular double-stranded DNA loop into which additional DNA segments can be linked. In another embodiment, the vector is a viral vector in which additional DNA segments can be linked into the viral genome. The vectors disclosed herein can replicate autonomously in the host cell into which they have been introduced (for example, bacterial vector with bacterial origin of replication and episomal mammalian vector) or can be integrated into the



Date Reçue/Date Received 2021-07-28

genome of the host cell after being introduced into the host cell, so as to replicate together with the host genome (for example, non-episomal mammalian vector).

The methods for producing and purifying antibodies and antigen-binding fragments are well known in the prior art, such as Antibodies: A Laboratory Manual, Cold Spring Harbor, Chapters 5-8 and 15. For example, mice can be immunized with human PD-1 or fragments thereof, and the obtained antibodies can be renatured, purified, and amino acid sequencing can be performed by conventional methods. Antigen-binding fragments can also be prepared by conventional methods. One or more human FR regions are added to the non-human CDR regions of the antibodies or antigen-binding fragments of the invention by using genetic engineering methods. The human FR germline sequences can be obtained from the ImmunoGeneTics (IMGT) website http://imgt.cines.fr by comparing the IMGT human antibody variable region germline gene database and MOE software, or be obtained from The Immunoglobulin FactsBook, 2001ISBN012441351.

The term "host cell" refers to a cell into which an expression vector has been introduced. Host cells can include bacteria, microorganisms, plant or animal cells. Bacteria that can be easily transformed include members of the *enterobacteriaceae*, for example *Escherichia coli* or *Salmonella* strains; *Bacillaceae* for example *Bacillus subtilis*; *Pneumococcus*; *Streptococcus* and *Haemophilus influenzae*. Suitable microorganisms include *Saccharomyces cerevisiae* and *Pichia pastoris*. Suitable animal host cell lines include CHO (Chinese Hamster Ovary Cell Line) and NS0 cells.

The engineered antibodies or antigen-binding fragments of the present disclosure can be prepared and purified by conventional methods. For example, the cDNA sequences encoding the heavy and light chains can be cloned and recombined into a GS expression vector. The recombinant immunoglobulin expression vector can be stably transfected into CHO cells. As a more recommended prior art, mammalian expression systems can lead to glycosylation of antibodies, especially in the highly conserved N-terminal sites of the Fc region. Stable clones are obtained by expressing antibodies that specifically bind to human PD-1. Positive clones are expanded in the serum-free medium of the bioreactor to produce antibodies. The culture medium into which the antibodies are secreted can be purified by conventional techniques. For example, using A or G Sepharose FF column with adjusted



Date Reçue/Date Received 2021-07-28

buffer for purification. Non-specifically binding components are washed away. Then the binding antibodies are eluted by the pH gradient method, and the antibody fragments are detected by SDS-PAGE and collected. The antibodies can be filtered and concentrated by conventional methods. Soluble mixtures and polymers can also be removed by conventional methods, for example molecular sieves and ion exchange. The resulting product needs to be frozen immediately, such as -70°C, or lyophilized.

"Administering", "giving" and "treating", when applied to animals, humans, experimental subjects, cells, tissues, organs or biological fluids, refer to the contact of the exogenous medicament, therapeutic agent, diagnostic agent or composition with the animals, humans, subjects, cells, tissues, organs or biological fluids. "Administering", "giving" and "treating" can refer to for example treatment, pharmacokinetics, diagnosis, research and experimental methods. The treatment of cells includes contact of reagents with cells, and contact of reagents with fluids, in which the fluids are in contact with the cells. "Administering", "giving" and "treating" also refer to treating for example cells by reagents, diagnosis, binding compositions or by another cell *in vitro* and *ex vivo*. "Treating" when applied to human, veterinary or research subjects, refers to therapeutic treatment, preventing or preventive measures, research and diagnostic applications.

"Treatment" refers to administering an internal or external therapeutic agent, for example a composition comprising any one of the binding compounds of the present disclosure, to a patient who has one or more symptoms of a disease on which the therapeutic agent is known to have therapeutic effect. Generally, the therapeutic agent is administered in an amount effective to alleviate one or more symptoms of the disease in the treated patient or population to induce the regression of such symptoms or inhibit the development of such symptoms to any clinically measured extent. The amount of therapeutic agent that is effective to alleviate any specific disease symptom (also referred to as a "therapeutically effective amount") can vary according to a variety of factors, for example the patient's disease state, age and body weight, and the ability of the drug to produce the desired therapeutic effect in the patient. Whether the disease symptoms have been alleviated can be evaluated through any clinical testing methods commonly used by doctors or other health care professionals to evaluate the severity or progression of the symptoms. Although the embodiments of the



Date Reçue/Date Received 2021-07-28

present disclosure (for example treatment methods or products) may be ineffective in alleviating each target disease symptom, but as determined according to any statistical test methods known in the art such as Student t-test, chi-square test, Mann and Whitney's U test, Kruskal-Wallis test (H test), Jonckheere-Terpstra test and Wilcoxon test, they should reduce the target disease symptom in a statistically significant number of patients.

"Conservative modification" or "conservative replacement or substitution" refers to replacing the amino acids in a protein with other amino acids having similar characteristics (for example charge, side chain size, hydrophobicity/hydrophilicity, main chain conformation and rigidity, etc.) so that changes can be frequently made without changing the biological activity of the protein. Those skilled in the art know that, generally speaking, a single amino acid replacement in a non-essential region of a polypeptide does not substantially change the biological activity (see for example Watson et al. (1987) Molecular Biology of the Gene, The Benjamin/Cummings Pub. Co., Page 224, (4th edition)). In addition, the replacement of amino acids with similar structure or function is unlikely to disrupt the biological activity. Exemplary conservative substitutions are indicated in the table below "Exemplary amino acid conservative substitutions".

Table 3. Exemplary amino acid conservative substitutions

| Original residue | Conservative substitution |
|---|---|
| Ala(A) | Gly; Ser |
| Arg(R) | Lys; His |
| Asn(N) | Gln; His; Asp |
| Asp(D) | Glu; Asn |
| Cys(C) | Ser; Ala; Val |
| Gln(Q) | Asn; Glu |
| Glu(E) | Asp; Gln |
| Gly(G) | Ala |
| His(H) | Asn; Gln |
| Ile(I) | Leu; Val |
| Leu(L) | Ile; Val |
| Lys(K) | Arg; His |
| Met(M) | Leu; Ile; Tyr |
| Phe(F) | Tyr; Met; Leu |
| Pro(P) | Ala |
| Ser(S) | Thr |
| Thr(T) | Ser |



Date Reçue/Date Received 2021-07-28

| | |
|---|---|
| Trp(W) | Tyr; Phe |
| Tyr(Y) | Trp; Phe |
| Val(V) | Ile; Leu |

"Effective amount" or "effective dose" refers to the amount of a drug, compound or pharmaceutical composition necessary to obtain any one or more beneficial or desired therapeutic results. For preventive use, the beneficial or desired results include elimination or reduction of risk, reduction of severity or delay of the disease onset, including the biochemistry, histology and behavioral symptoms of the disease, complications thereof and intermediate pathological phenotypes that occur during the developmental process of the disease. For therapeutic applications, the beneficial or desired results include clinical results, for example reducing the incidence of various target antigen-related disorders of the present disclosure or improving one or more symptoms of the disorder, reducing the dose of other agents required to treat the disorder, enhancing the therapeutic effect of another agent, and/or delaying the progression of target antigen-related disorder of the present disclosure of the patient.

"Exogenous" refers to substances produced outside organisms, cells or human bodies according to circumstances. "Endogenous" refers to substances produced inside cells, organisms or human bodies according to circumstances.

"Homology" refers to the sequence similarity between two polynucleotide sequences or between two polypeptides. When the positions in the two sequences compared are occupied by the same base or amino acid monomer subunit, for example if each position of two DNA molecules is occupied by adenine, then the molecules are homologous at that position. The homology percentage between two sequences is a function of the number of matching or homologous positions shared by the two sequences divided by the number of positions compared × 100. For example, in the optimal sequence alignment, if there are 6 matches or homology in the 10 positions in the two sequences, then the two sequences are 60% homologous; if there are 95 matches or homology in the 100 positions in the two sequences, then the two sequences are 95% homologous. Generally, when two sequences are aligned, comparison is made to give the maximum percentage homology. For example, the comparison can be performed by the BLAST algorithm, in which the parameters of the



Date Reçue/Date Received 2021-07-28

algorithm are selected to give the maximum match between each sequence over the entire length of each reference sequence. The following references relate to the BLAST algorithm that is often used for sequence analysis: BLAST ALGORITHMS: Altschul, S. F. et al., (1990) J. Mol. Biol. 215:403-410; Gish, W. et al., (1993) Nature Genet. 3:266-272; Madden, T. L. et al., (1996) Meth. Enzymol. 266:131-141; Altschul, S. F. et al., (1997) Nucleic Acids Res. 25:3389-3402; Zhang, J. et al., (1997) Genome Res. 7:649-656. Other conventional BLAST algorithms such as provided by NCBI BLAST are also well known to those skilled in the art.

The expressions "cell", "cell line" and "cell culture" as used herein can be used interchangeably, and all such names include progeny. Therefore, the words "transformant" and "transformed cell" include primary test cells and cultures derived therefrom, regardless of the passage numbers. It should also be understood that due to deliberate or unintentional mutations, all offspring cannot be exactly the same in terms of DNA content. Mutant progeny with the same function or biological activity as screened in the original transformed cells is included. It will be clearly understood from the context when a different name is referred to.

"Polymerase chain reaction" or "PCR" as used herein refers to a procedure or technique in which a trace amount of a specific portion of nucleic acid, RNA and/or DNA is amplified as described in for example US Patent No. 4,683,195. Generally speaking, it is necessary to obtain sequence information from the end or outside of the target region so that oligonucleotide primers can be designed; these primers are the same or similar in terms of sequence to the corresponding strands of the template to be amplified. The 5' terminal nucleotides of the two primers can be identical to the ends of the material to be amplified. PCR can be used to amplify specific RNA sequences, specific DNA sequences from total genomic DNA, and cDNA, phage or plasmid sequences transcribed from total cellular RNA, etc. See generally Mullis et al. (1987) Cold Spring Harbor, Symp. Ouant. Biol. 51:263; Erlich ed., (1989) PCR TECHNOLOGY (Stockton Press, N.Y.). The PCR used herein is regarded as an example, but not the only example, of a nucleic acid polymerase reaction method for amplifying a nucleic acid test sample, and the method includes using known nucleic acids as primers and nucleic acid polymerases to amplify or produce a specific portion of the nucleic acid.



Date Reçue/Date Received 2021-07-28

"Isolated" refers to a purified state, and in this case means that the designated molecule is substantially free of other biomolecules, for example nucleic acids, proteins, lipids, carbohydrates or other materials, for example cell debris and growth medium. Generally, the term "isolated" is not intended to mean the complete absence of these materials or the absence of water, buffers or salts, unless they are present in an amount that significantly interferes with the experimental or therapeutic use of the compound as described herein.

"Optional" or "optionally" means that the event or environment described later can, but not necessarily occur, and the description includes occasions where the event or environment occurs or does not occur. For example, "optionally comprising 1 to 3 antibody heavy chain variable regions" means that the antibody heavy chain variable regions of specific sequences may but does not have to be present.

"Pharmaceutical composition" means a mixture comprising one or more of the compounds described herein, or a physiologically/pharmaceutically acceptable salt or a prodrug thereof, and other chemical components, for example physiological/pharmaceutically acceptable carriers and excipients. The purpose of the pharmaceutical composition is to promote the administration to the organism, which facilitates the absorption of the active ingredient and thereby exerts biological activity.

The term "pharmaceutically acceptable carrier" refers to any inactive substance suitable for use in a formulation for the delivery of antibodies or antigen-binding fragments. The carrier can be an anti-adhesive agent, binder, coating, disintegrant, filler or diluent, preservative (such as antioxidant, antibacterial or antifungal agent), sweetener, absorption delaying agent, wetting agent, emulsifier, buffer, etc. Examples of suitable pharmaceutically acceptable carriers include water, ethanol, polyols (for example glycerol, propanediol, polyethylene glycol, etc.) dextrose, vegetable oils (for example olive oil), saline, buffer, buffered saline, and isotonic agents for example sugars, polyols, sorbitol and sodium chloride.

In addition, the present disclosure includes agents for treating diseases related to target antigen (for example PD-1) positive cells, the agents comprising the anti-PD-1 antibody or antigen-binding fragment thereof of the present disclosure as an active ingredient.

The disease related to PD-1 in the present disclosure is not limited, as long as it is a disease related to PD-1. For example, the therapeutic response induced by the molecule of the



Date Reçue/Date Received 2021-07-28

present disclosure can be achieved by binding to human PD-1, and then inhibiting the binding of PD-1 and its ligands PD-L1 and PD-L2, or killing tumor cells overexpressing PD-1. Therefore, when in preparations and formulations suitable for therapeutic applications, the molecules of the present disclosure are very useful for people who have tumor or cancer, preferably melanoma, colon cancer, breast cancer, lung cancer, gastric cancer, bowel cancer, kidney cancer, non-small cell lung cancer, bladder cancer, etc.

In addition, the present disclosure relates to methods for immunodetection or determination of target antigens (for example PD-1), reagents for immunodetection or determination of target antigens (for example PD-1), methods for immunodetection or determination of cells expressing target antigens (for example PD-1) and diagnostic agents for diagnosing diseases related to target antigen (for example PD-1) positive cells, which includes the antibody or antibody fragment of the present disclosure, which specifically recognizes target antigen (for example human PD-1) and binds with the amino acid sequence of the extracellular region or three-dimensional structure thereof, being used as an active ingredient.

In the present disclosure, the method used for detecting or measuring the amount of the target antigen (for example PD-1) may be any known method. For example, it includes immunodetection or measurement methods.

The immunodetection or measurement methods are methods of detecting or measuring the amount of antibody or antigen using labeled antigens or antibodies. Examples of immunodetection or measurement methods include radioimmunoassay (RIA), enzyme immunoassay (EIA or ELISA), fluorescence immunoassay (FIA), luminescence immunoassay, western blotting, physicochemical methods, etc.

The aforementioned diseases related to PD-1 positive cells can be diagnosed by detecting or measuring PD-1 expressing cells using the antibodies or antibody fragments of the present disclosure.

In order to detect cells expressing the polypeptide, known immunodetection methods can be used, preferably using immunoprecipitation, fluorescent cell staining, immunohistochemical staining, etc. In addition, fluorescent antibody staining method using the FMAT8100HTS system (Applied Biosystem) can be used.



Date Reçue/Date Received 2021-07-28

In the present disclosure, there is no particular limitation on the *in vivo* sample used for detection or measurement of the target antigen (for example PD-1), as long as it has the possibility of containing cells expressing the target antigen (for example PD-1), for example histocytes, blood, plasma, serum, pancreatic juice, urine, feces, tissue fluid or culture fluid.

According to the required diagnostic method, the diagnostic agent comprising the monoclonal antibody or antibody fragment thereof of the present disclosure can also comprise reagents for performing antigen-antibody reaction or reagents for detecting the reaction. The reagents used to perform the antigen-antibody reaction include buffers, salts, etc. The reagents used for detection include reagents commonly used in immunodetection or measurement methods, for example labeled second antibodies that recognize the monoclonal antibody, antibody fragment thereof or conjugate thereof, and a substrate corresponding to the label, etc.

**Preparation of antigens**

1. Construction of antigens:

A human PD-1-IgG1Fc fusion protein is designed and synthesized, with 150 amino acids of the extracellular region of human PD-1 at the N-terminus and the Fc fragment of human IgG1 (hIgG1Fc) at the C-terminus. A recombinant PD-1-Fc protein with high-purity can be obtained after purifying with Protein A affinity column and is used to detect the binding of anti-PD-1 antibody to antigen.

Human PD-1-IgG1Fc (SEQ ID NO: 1):

<u>MEFGLSWLFLVAILKGVQC</u>PGWFLDSPDRPWNPPTFSPALLVVTEGDNATFTCSFSNT
SESFVLNWYRMSPSNQTDKLAAFPEDRSQPGQDCRFRVTQLPNGRDFHMSVVRARR
NDSGTYLCGAISLAPKAQIKESLRAELRVTERRAEVPTAHPSPSPRPAGQFQTLV*EPKSS*
*DKTHTCPPCPAPELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVD*
*GVEVHNAKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKG*
*QPREPQVYTLPPSRDELTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDG*
*SFFLYSKLTVDKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK.*

Note: The underlined part is the signal peptide, the normal part is the extracellular region of human PD-1, and the italicized part is hIgG1Fc (signal peptide + extracellular region + hIgG1Fc).



Date Reçue/Date Received 2021-07-28

Human PD-1-his (SEQ ID NO: 2):

MEFGLSWLFLVAILKGVQCPGWFLDSPDRPWNPPTFSPALLVVTEGDNATFTCSFSNT
SESFVLNWYRMSPSNQTDKLAAFPEDRSQPGQDCRFRVTQLPNGRDFHMSVVRARR
NDSGTYLCGAISLAPKAQIKESLRAELRVTERRAEVPTAHPSPSPRPAGQFQTLVGSSD
YKDDDDKHHHHHH.

PD-1 antigen encoded by nucleic acids transfected into cells (SEQ ID NO: 3):

MQIPQAPWPVVWAVLQLGWRPGWFLDSPDRPWNPPTFSPALLVVTEGDNATFTCSFS
NTSESFVLNWYRMSPSNQTDKLAAFPEDRSQPGQDCRFRVTQLPNGRDFHMSVVRA
RRNDSGTYLCGAISLAPKAQIKESLRAELRVTERRAEVPTAHPSPSPRPAGQFQTLVVG
VVGGLLGSLVLLVWVLAVICSRAARGTIGARRTGQPLKEDPSAVPVFSVDYGELDFQ
WREKTPEPPVPCVPEQTEYATIVFPSGMGTSSPARRGSADGPRSAQPLRPEDGHCSWP
L.

**Preparation of antibodies**

Anti-human PD-1 antibodies can be produced by immunizing mice, and can also be obtained from anti-human PD-1 phage mouse immunization library.

The method of preparing anti-human PD-1 antibody by immunizing mice is as follows:

1. Immunization: laboratory SJL white mice, female, 6-8 weeks old and Balb/c white mice, female, 6-8 weeks old. Housing environment: SPF level. After the mice were purchased, they were housed in a laboratory environment for 1 week under adjustment of 12/12 hours light/dark cycle, at temperature 20-25°C; humidity 40-60%. The mice adapted to the environment were immunized according to different protocols, with 6-10 mice in each group. The immune antigen could be the purified recombinant protein PD-1-IgG1Fc (see SEQ ID NO: 1), PD-1-his (see SEQ ID NO: 2), or Jurkat/CHO-PD-1 cells transfected with PD-1 as the antigen (see SEQ ID NO: 3). A single antigen combined with different immune adjuvants or different types of immunogens could be used for cross-immunization. The immunization site could be the abdominal cavity or under the skin on the back, or alternately immunized at the two sites. The immune adjuvant TiterMax® Gold Adjuvant (hereinafter referred to as Titermax, purchased from Sigma, Cat. No. T2684) and Imject Alum Adjuvant (hereinafter referred to as Alum, purchased from Pierce, Cat. No. 77161) were used for



Date Reçue/Date Received 2021-07-28

cross-immunization. The ratio of antigen to adjuvant (Titermax) was 1:1, the ratio of antigen to adjuvant (Alum) was 3:1, 25-50 μg/animal (first immunization), 50 μg/animal (booster immunization), or $1\times10^7$ Jurkat/CHO-PD-1 cells/animal. On day 0, 25-50 μg/animal emulsified antigen was intraperitoneally injected, once a week or once every two weeks after the first immunization, Titermax and Alum were alternately used, 5-8 times in total.

2. Cell fusion: mice with high antibody titers in the serum were selected for spleen cell fusion. The eyes of mice were bled 72 h after sprint immunization. The mice were sacrificed by pulling the neck and put in 75% ethanol for disinfection. Splenic lymphocytes were fused to myeloma cells Sp2/0 cells (Chinese Academy of Sciences) to obtain hybridoma cells by applying the optimized PEG-mediated fusion procedure. The fused hybridoma cells were re-suspended in HAT complete medium (RPMI-1640 medium containing 20% FBS, 1×HAT and 1×OPI), and aliquoted into 96-well cell culture plates ($1\times10^5$/150 μl/well), incubated at 37°C, 5% $CO_2$, and seeded into totally about 10-30 plates. On day 5 after fusion, HAT complete medium was added at 50 μl/well, and incubated at 37°C, 5% $CO_2$. From day 7 to day 8 after fusion, according to the cell growth density, the medium was completely changed at 200 μl/well, and incubated at 37°C, 5% $CO_2$.

3. Hybridoma cell screening: 7-9 days after fusion, according to the cell growth density, the ELISA method was carried out to detect the binding of antibody to PD-1, and the cells in positive wells were further detected with ELISA for detection of the blockade of PD-1/PDL1 binding. The medium in the positive wells were changed and the cells were expanded to 24-well plates in time according to the cell density. The cell lines transferred to 24-well plates were retested and then preserved and subcloned for the first time. Those positive in the first subcloning screening were preserved, and the second or third subcloning were performed until obtaining single-cell clones. Hybridoma cells with the effect of blocking the binding of PD-1 and PDL1 were obtained by multiple fusions.

The method of obtaining anti-human PD-1 antibodies through the anti-human PD-1 phage mouse immune library is as follows:

1. Construction of an anti-human PD-1 phage mouse immune library: the spleens of mice with high antibody titer in the serum were selected, and the tissue total RNA was extracted by using Trizol (Invitrogen Cat No. 15596-018). The cDNA were obtained by using



Date Reçue/Date Received 2021-07-28

PrimeScript™ II 1st Strand cDNA Synthesis Kit (Takara Cat No. 6210A) for reverse transcription. Primers to construct the library were designed and synthesized according to the IMGT database. Single-chain antibody fragments were obtained through three rounds of PCR reactions. The single-chain antibody fragments and the modified library construction vector pCantab5E (Amersham Biosciences/GE Cat No. 27-9400-01) were digested with Sfi1 (NEB Cat No.#R0123L), and purified and recovered with E. Z. N. A.® Gel Extraction Kit (Omega Cat No. D2500-02) after electrophoresis. Then T4 DNA ligase (NEB Cat No.#M0202L) was used for ligation at 16°C for 16-18 h, and the above kit was used for purification and recovery, and finally elution was performed with deionized water. 1 μg of ligation product was taken and mixed with 1 vial of competent TG1 (Lucigen Cat No. 60502-2) for electro-transformation, and the electro-transformation was performed with the electroporator (Bio Rad Micropulser), with parameters set to 2.5 kV, 200 Ω and 25 uF. The transformation was repeated for 10 times. The product was spread on the plates and cultured up-side-down at 37°C for 16-18 h. All the colonies were then detached and mixed together, added with glycerin at a final concentration of 15%, and stored at -80°C for use.

2. Screening of the anti-human PD-1 phage mouse immune library: the packaged anti-human PD-1 phage immune library ($1\times10^{12}$ - $1\times10^{13}$) and 100 μl streptomycin microbeads (Milenvi Biotec, Auburn, CA) were added to 1 ml phosphate buffered saline containing 2% skimmed milk (MPBS) and incubated at room temperature for 1 h, placed on a magnetic stand, and the supernatant was collected. 10 μg/ml biotinylated human PD-1-ECD-his protein (purchased from Sino Biological) was added to the supernatant and incubated for 1 h at room temperature. Then 100 μl of streptavidin-coated magnetic beads (pre-incubated with 1 ml MPBS) was added and incubated for 1 h at room temperature. And it was loaded on the magnetic stand system for sorting, and the supernatant was aspirated. 1 ml PBST (phosphate buffer containing 0.1% Tween-20) was added and turned over several times. Fresh washing solution was added after complete aspiration, repeated 11 times to remove unbound antibody fragments, and 0.5 ml elution solution (50 μl 10 mg/ml trypsin stock solution added into 450 μl PBS) was added. It was shaken for 15 min at room temperature, placed on a magnetic stand, and the supernatant was aspirated into a new EP tube. TG1 was seeded into 2YT medium and expanded until the cultured bacterium density OD600=0.4. 1.75



Date Reçue/Date Received 2021-07-28

ml of TG1 (OD600=0.4) was added to each tube, and 250 μl of eluted phage (phage) was added, incubated in a 37°C water bath for 30 min, and spread on plates with gradient dilution for testing the titer. The remaining TG1 solution was centrifuged, spread on plates and incubated overnight at 37°C.

The phage mouse immune library was screened 2-3 rounds by using the biotinylated human PD-1-ECD-his antigen, with MACS screening (streptomycin magnetic beads, Invitrogen), and monoclonal antibodies capable of binding to PD-1 and capable of blocking the binding of PD-1 to PD-L1 were finally obtained and verified by sequencing. The variable region sequences of the antibodies were obtained.

**Purification of recombinant antigen proteins/antibodies**

1. Separation and purification of hybridoma supernatant/Protein G affinity chromatography:

For the purification of mouse hybridoma supernatant, Protein G for affinity chromatography was the first choice. The cultured hybridoma was centrifuged to collect the supernatant, and 10-15% volume of 1 M Tris-HCl (pH 8.0-8.5) was added according to the volume of the supernatant to adjust the pH of the supernatant. For the Protein G column, 6 M guanidine hydrochloride was used to wash 3-5 times the column volume, and then pure water was used to wash 3-5 times the column volume; a buffer system such as 1×PBS (pH 7.4) as an equilibration buffer was used to equilibrate the column for 3-5 times the column volume; The cell supernatant was loaded and bound by using a low flow rate, which was controlled so that the retention time was about 1 min or longer; 1×PBS (pH 7.4) was used to wash the chromatographic column 3-5 times the column volume until the UV absorption dropped to baseline: 0.1M acetic acid/sodium acetate (pH 3.0) buffer was used for sample elution, the elution peaks were collected according to UV detection, and 1 M Tris-HCl (pH 8.0) was used to quickly adjust the pH of the eluted product to 5-6 for temporary storage. For the eluted product, solution replacement could be performed by methods well known to those skilled in the art, such as using ultrafiltration tubes for ultrafiltration and concentration and replacing the solution to the required buffer system, or using molecular exclusion such as G-25 to desalt and replace to the required buffer system, or using high-resolution molecular exclusion columns such as Superdex 200 to remove the components aggregated in the eluted product



Date Reçue/Date Received 2021-07-28

to improve sample purity.

2. Protein A affinity chromatography purification of proteins or antibodies:

First, the supernatant of the cell culture expressing the antigen protein or antibody was centrifuged at a high speed to collect the supernatant. For the Protein A affinity column, 6 M guanidine hydrochloride was used to wash 3-5 times the column volume, and then pure water was used to wash 3-5 times the column volume. A buffer system such as 1×PBS (pH 7.4) was used as an equilibration buffer to equilibrate the chromatography column for 3-5 times the column volume. The cell supernatant was loaded and bound by using a low flow rate, which was controlled so that the retention time was about 1 min or longer. After the binding was completed, 1×PBS (pH 7.4) was used to wash the chromatographic column 3-5 times the column volume until the UV absorption dropped to baseline. 0.1M acetic acid/sodium acetate (pH 3.0-3.5) buffer was used for sample elution, the elution peaks were collected according to UV detection, and 1 M Tris-HCl (pH 8.0) was used to quickly adjust the pH of the eluted product to 5-6 for temporary storage. For the eluted product, solution replacement could be performed by methods well known to those skilled in the art, such as using ultrafiltration tubes for ultrafiltration and concentration and replacing the solution to the required buffer system, or using molecular exclusion such as G-25 to desalt and replace to the required buffer system, or using high-resolution molecular exclusion columns such as Superdex 200 to remove the components aggregated in the eluted product to improve sample purity.

**EXAMPLES**

The present disclosure is further described below in combination with the examples, but these examples do not limit the scope of the present disclosure. The experimental methods for which the conditions are not specifically indicated in the examples of the present disclosure usually follow conventional conditions, such as Antibodies: A Laboratory Manual and Molecular Cloning: A Laboratory Manual, Cold Spring Harbor; or according to the conditions recommended by the raw material or product manufacturer. The reagents for which the sources are not specifically indicated are the conventional reagents available from the market.



Date Reçue/Date Received 2021-07-28

**Example 1. Obtaining anti-human PD-1 murine antibodies**

The anti-human PD-1 murine antibodies obtained by the aforementioned method were subjected to antigen binding experiments and screened to obtain multiple strains of antibodies with good activity: wherein M23, M32 and M33 were included. The single cell clones were expanded and cultured, the RNA was extracted, and degenerate primers of mouse-Ig were used to perform reverse transcription amplification (RT-PCR) to obtain the variable region sequence of the antibody. The murine antibody variable region sequence was linked with the human antibody constant region sequence. The chimeric antibody of the murine monoclonal antibody was cloned and expressed recombinantly, and *in vitro* activity experiments were performed to confirm that the obtained monoclonal antibody variable region sequence was correct.

The variable region sequences of murine antibodies M23, M32 and M33 are determined as follows:

The heavy chain variable region of murine antibody M23 (SEQ ID NO: 4):

QVQLQQSGAELVRPGASVTLSCKASGYTFTDYEMHWVKQTPIHGLEWIGLIDPETGG TVYNQKFKDKTILTADKSSSTAYMEFRSLTSEDSAVYHCTRERFSYYGSTSDWYFDV WGTGTTVTVSS.

The light chain variable region of murine antibody M23 (SEQ ID NO: 5):

DGLMTQTPLSLPVSLGDHASISCRSSQSLVHSNGNTYLEWYLQKPGQSPKLLIYKVSN RFSGVPDRFSGSGSGTDFTLKISRVEAEDLGIYYCFQGSHVPYTFGGGTKLEIK.

The heavy chain variable region of murine antibody M32 (SEQ ID NO: 6):

QVQLQQSGAELVRPGASVTLSCKASDFTFTDYEIHWVKQTPVHGLEWIGLFDPETGGI VYNQKFKGKAILTADKSSNTAYMEFRSLTSEDSAVYYCTREGYNRDWYFDVWGTGT TVTVSS.

The light chain variable region of murine antibody M32 (SEQ ID NO: 7):

DVLMTQTPLSLPVSLGDQASISCRSSQSIVHSNGNTYLEWYLQKPGQSPKLLIYKVSN RFSGVPDRFSGSGSGTDFTLKISRVEAEDLGIYYCFQGSHVPYAFGGGTKLEIK.

The heavy chain variable region of murine antibody M33 (SEQ ID NO: 19):

KVMLVESGGGLVKPGGSLKLSCAASGFTFSSYAMSWVRQTPEKRLEWVATISGGGVD TYYQDNVQGRFTISRDNAKNTLYLQMSSLRSEDTALYYCASPYGHGYFDVWGTGTT



Date Reçue/Date Received 2021-07-28

VTVSS.

The light chain variable region of murine antibody M33 (SEQ ID NO: 20):

DIQMTQTTSSLSASLGDRVTISCRASQDINNFLNWYQQKPDGTVKLLIYYTSSLHSGV PSRFSGSGSGTDYSLTISNLEQEDIATYFCQQGNTLPWTFGGGTKLEIK.

Note: in the heavy chain variable region and light chain variable region sequences of the above antibodies, underlined are the CDR sequences determined by the Kabat numbering system, in the order as follows: FR1-CDR1-FR2-CDR2-FR3-CDR3-FR4.

Table 4. Murine antibody M23, M32 and M33 heavy chain and light chain CDR region sequences

| Name of antibody | Heavy chain | | Light chain | |
|---|---|---|---|---|
| M23 | HCDR1 | DYEMH (SEQ ID NO: 8) | LCDR1 | RSSQSLVHSNGNTYLE (SEQ ID NO: 11) |
| | HCDR2 | LIDPETGGTVYNQKFKD (SEQ ID NO: 9) | LCDR2 | KVSNRFS (SEQ ID NO: 12) |
| | HCDR3 | ERFSYYGSTSDWYFDV (SEQ ID NO: 10) | LCDR3 | FQGSHVPYT (SEQ ID NO: 13) |
| M32 | HCDR1 | DYEIH (SEQ ID NO: 14) | LCDR1 | RSSQSIVHSNGNTYLE (SEQ ID NO: 17) |
| | HCDR2 | LFDPETGGIVYNQKFKG (SEQ ID NO: 15) | LCDR2 | KVSNRFS (SEQ ID NO: 12) |
| | HCDR3 | EGYNRDWYFDV (SEQ ID NO: 16) | LCDR3 | FQGSHVPYA (SEQ ID NO: 18) |
| M33 | HCDR1 | SYAMS (SEQ ID NO: 21) | LCDR1 | RASQDINNFLN (SEQ ID NO: 24) |
| | HCDR2 | TISGGGVDTYYQDNVQG (SEQ ID NO: 22) | LCDR2 | YTSSLHS (SEQ ID NO: 25) |
| | HCDR3 | PYGHGYFDV (SEQ ID NO: 23) | LCDR3 | QQGNTLPWT (SEQ ID NO: 26) |

Note: the antibody CDR sequences in the table are determined according to the Kabat numbering system.

**Example 2. Humanization of anti-human PD-1 monoclonal antibodies**

By aligning against the IMGT human antibody heavy and light chain variable region germline gene database and MOE software analysis, the human germline heavy and light chain variable region germline genes with high identity with M23, M32 and M33 light and



Date Reçue/Date Received 2021-07-28

heavy chain sequences were selected as templates. The CDR of these 3 murine antibodies were grafted into the corresponding human antibody templates to construct their corresponding humanized antibodies, respectively.

1. Humanization of murine antibody M23

1.1 Selection of humanization framework of murine antibody M23

The humanization light chain templates of the murine antibody M23 are IGKV2-40*01 and IGKJ4*01, and the humanization heavy chain templates are IGHV1-69*02 and IGHJ6*01. The sequences of the variable regions after humanization are as follows (underlined are the CDR sequences):

Hu23VH-CDR grafted: (SEQ ID NO: 27)

EVQLVQSGAEVKKPGSSVKVSCKASGGTFSDYEMHWVRQAPGQGLEWMGLIDPET GGTVYNQKFKDRVTITADKSTSTAYMELSSLRSEDTAVYYCARERFSYYGSTSDWYF DVWGQGTTVTVSS.

Hu23VL-CDR grafted: (SEQ ID NO: 28)

DIVMTQTPLSLPVTPGEPASISCRSSQSLVHSNGNTYLEWYLQKPGQSPQLLIYKVSNR FSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIK.

1.2 Humanization template selection and back mutation design of murine antibody M23

Table 5. Back mutations of murine antibody M23 humanized antibodies

| VL | | VH | |
|---|---|---|---|
| Hu23VL1 | Grafted | Hu23VH1 | Grafted |
| Hu23VL2 | I2G | Hu23VH2 | G27Y I69L |
| | | Hu23VH3 | G27Y M48I V67T I69L L82F |
| | | Hu23VH4 | G27Y M48I V67T I69L L82F A93T |

Note: grafted means that the murine antibody CDRs are implanted into the human germline FR region sequences. The amino acid residues are determined and annotated by the Kabat numbering system, for example I2G means that the I at position 2 of Kabat numbering is mutated back to G according to the Kabat numbering system.



Date Reçue/Date Received 2021-07-28

The light/heavy chain variable region sequences of the humanized antibodies of M23 are as follows:

> Hu23VL1 (same as Hu23VL-CDR grafted): (SEQ ID NO: 28)

DIVMTQTPLSLPVTPGEPASISCRSSQSLVHSNGNTYLEWYLQKPGQSPQLLIYKVSNR FSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIK.

> Hu23VL2 (SEQ ID NO: 29)

DGVMTQTPLSLPVTPGEPASISCRSSQSLVHSNGNTYLEWYLQKPGQSPQLLIYKVSN RFSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIK.

> Hu23VH1 (same as Hu23VH-CDR grafted): (SEQ ID NO: 27)

EVQLVQSGAEVKKPGSSVKVSCKASGGTFSDYEMHWVRQAPGQGLEWMGLIDPET GGTVYNQKFKDRVTITADKSTSTAYMELSSLRSEDTAVYYCARERFSYYGSTSDWYF DVWGQGTTVTVSS.

> Hu23VH2 (SEQ ID NO: 30)

EVQLVQSGAEVKKPGSSVKVSCKASGYTFSDYEMHWVRQAPGQGLEWMGLIDPET GGTVYNQKFKDRVTLTADKSTSTAYMELSSLRSEDTAVYYCARERFSYYGSTSDWYF DVWGQGTTVTVSS.

> Hu23VH3 (SEQ ID NO: 31)

EVQLVQSGAEVKKPGSSVKVSCKASGYTFSDYEMHWVRQAPGQGLEWIGLIDPETG GTVYNQKFKDRTTLTADKSTSTAYMEFSSLRSEDTAVYYCARERFSYYGSTSDWYFD VWGQGTTVTVSS.

> Hu23VH4 (SEQ ID NO: 32)

EVQLVQSGAEVKKPGSSVKVSCKASGYTFSDYEMHWVRQAPGQGLEWIGLIDPETG GTVYNQKFKDRTTLTADKSTSTAYMEFSSLRSEDTAVYYCTRERFSYYGSTSDWYFD VWGQGTTVTVSS.

1.3 Humanized sequence combination of murine antibody M23

The antibodies and variable region combinations thereof obtained by humanization of the murine antibody M23 are shown in the table below.



Date Reçue/Date Received 2021-07-28

Table 6. Combinations of humanized Hu23 antibody variable regions

| VL / VH | Hu23VL1 | Hu23VL2 |
|---|---|---|
| Hu23VH1 | Hu23-1 | Hu23-5 |
| Hu23VH2 | Hu23-2 | Hu23-6 |
| Hu23VH3 | Hu23-3 | Hu23-7 |
| Hu23VH4 | Hu23-4 | Hu23-8 |

Note: "Hu23-1" refers to an antibody wherein the light chain variable region is Hu23VL1 and heavy chain variable region is Hu23VH1, and so on.

Combinations of the antibody light/heavy chain variable regions (for example Hu23-1) referred to in the above table can be linked with the antibody light/heavy chain constant regions to form full-length antibodies, respectively; unless otherwise specified in the present disclosure, when forming a full-length antibody, the light chain variable region is linked to the Kappa chain constant region shown in SEQ ID NO: 73 to form the antibody light chain, and the heavy chain variable region is linked to the IgG4-AA heavy chain constant region shown in SEQ ID NO: 72 or to the IgG4-P heavy chain constant region shown in ID NO: 79 to form the antibody heavy chain, and the name in the table referring to the combination of the antibody light/heavy chain variable regions (for example Hu23-1) plus the suffix ". IgG4AA" means the full-length antibody formed by ligation with the IgG4-AA heavy chain constant region, plus the suffix ". IgG4P" means the full-length antibody formed by ligation with the IgG4-P heavy chain constant region, for example, "Hu23-1.IgG4AA" means the full-length antibody formed by linking the heavy chain, formed by linking Hu23VH1 heavy chain variable region and IgG4-AA heavy chain constant region as shown in SEQ ID NO: 72, and the light chain, formed by linking the Hu23VL1 light chain variable region and the Kappa chain constant region as shown in SEQ ID NO: 73. "Hu23-1.IgG4P" means the full-length antibody formed by linking the heavy chain, formed by linking Hu23VH1 heavy chain variable region and IgG4-P heavy chain constant region as shown in SEQ ID NO: 79, and the light chain, formed by linking the Hu23VL1 light chain variable region and the Kappa chain constant region as shown in SEQ ID NO: 73.



Date Reçue/Date Received 2021-07-28

2. Humanization of murine antibody M32

2.1 Selection of humanization framework of murine antibody M32

The humanization light chain templates of the murine antibody M32 are IGKV2-40*01 and IGKJ4*01, and the humanization heavy chain templates are IGHV1-69*02 and IGHJ6*01. The sequences of the humanized variable regions are as follows (underlined are the CDR sequences):

Hu32VH-CDR grafted: (SEQ ID NO: 33) IGHV1-69*02 and IGHJ6*01

EVQLVQSGAEVKKPGSSVKVSCKASGGTFSDYEIHWVRQAPGQGLEWMGLFDPETG GIVYNQKFKGRVTITADKSTSTAYMELSSLRSEDTAVYYCAREGYNRDWYFDVWGQ GTTVTVSS.

Hu32VL-CDR grafted: (SEQ ID NO: 34)

DIVMTQTPLSLPVTPGEPASISCRSSQSIVHSNGNTYLEWYLQKPGQSPQLLIYKVSNR FSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYAFGGGTKVEIK.

2.2 Humanization template selection and back mutation design of murine antibody M32

Table 7. Back mutations of murine antibody M32 humanized antibodies

| **VL** | | **VH** | |
|---|---|---|---|
| Hu32VL1 | Grafted | Hu32VH1 | Grafted |
| Hu32VL2 | I2V | Hu32VH2 | G27F, I69L, A93T |
| | | Hu32VH3 | G26D, G27F, I69L, A93T |
| | | Hu32VH4 | G27F, M48I, V67A, I69L, L82F, A93T |
| | | Hu32VH5 | G26D, G27F, S30T, M48I, V67A, I69L, L82F, A93T |
| | | Hu32VH6 | G26D, G27F, S30T, R38K, Q43H, M48I, R66K, V67A, I69L, L82F, A93T |

Note: grafted means that the murine antibody CDRs are implanted into the human germline FR region sequences. The amino acid residues are determined and annotated by the



Date Reçue/Date Received 2021-07-28

Kabat numbering system, for example I2V means that the I at position 2 of Kabat numbering is mutated back to V according to the Kabat numbering system.

The light and heavy chain variable region sequences of the humanized antibodies of murine antibody M32 are as follows:

> Hu32VL1 (same as Hu32VL-CDR grafted): (SEQ ID NO: 34)

DIVMTQTPLSLPVTPGEPASISCRSSQSIVHSNGNTYLEWYLQKPGQSPQLLIYKVSNR FSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYAFGGGTKVEIK.

> Hu32VL2 (SEQ ID NO: 35)

DVVMTQTPLSLPVTPGEPASISCRSSQSIVHSNGNTYLEWYLQKPGQSPQLLIYKVSNR FSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYAFGGGTKVEIK.

> Hu32VH1 (same as Hu23VH-CDR grafted): (SEQ ID NO: 33)

EVQLVQSGAEVKKPGSSVKVSCKASGGTFSDYEIHWVRQAPGQGLEWMGLFDPETG GIVYNQKFKGRVTITADKSTSTAYMELSSLRSEDTAVYYCAREGYNRDWYFDVWGQ GTTVTVSS.

> Hu32VH2 (SEQ ID NO: 36)

EVQLVQSGAEVKKPGSSVKVSCKASGFTFSDYEIHWVRQAPGQGLEWMGLFDPETG GIVYNQKFKGRVTLTADKSTSTAYMELSSLRSEDTAVYYCTREGYNRDWYFDVWGQ GTTVTVSS.

> Hu32VH3 (SEQ ID NO: 37)

EVQLVQSGAEVKKPGSSVKVSCKASDFTFSDYEIHWVRQAPGQGLEWMGLFDPETG GIVYNQKFKGRVTLTADKSTSTAYMELSSLRSEDTAVYYCTREGYNRDWYFDVWGQ GTTVTVSS.

> Hu32VH4 (SEQ ID NO: 38)

EVQLVQSGAEVKKPGSSVKVSCKASGFTFSDYEIHWVRQAPGQGLEWIGLFDPETGG IVYNQKFKGRATLTADKSTSTAYMEFSSLRSEDTAVYYCTREGYNRDWYFDVWGQGT TVTVSS.

> Hu32VH5 (SEQ ID NO: 39)

EVQLVQSGAEVKKPGSSVKVSCKASDFTFTDYEIHWVRQAPGQGLEWIGLFDPETGG IVYNQKFKGRATLTADKSTSTAYMEFSSLRSEDTAVYYCTREGYNRDWYFDVWGQGT TVTVSS.



Date Reçue/Date Received 2021-07-28

> Hu32VH6 (SEQ ID NO: 40)

EVQLVQSGAEVKKPGSSVKVSCKASDFTFTDYEIHWVKQAPGHGLEWIGLFDPETGG IVYNQKFKGKATLTADKSTSTAYMEFSSLRSEDTAVYYCTREGYNRDWYFDVWGQG TTVTVSS.

2.3 Humanized sequence combination of murine antibody M32

The antibodies and variable region combinations thereof obtained by humanization of the murine antibody M32.

Table 8. Combinations of the light/heavy chain variable regions of the humanized antibody Hu32

| VH \ VL | Hu32VL1 | Hu32VL2 |
|---|---|---|
| Hu32VH1 | Hu32-1 | Hu32-7 |
| Hu32VH2 | Hu32-2 | Hu32-8 |
| Hu32VH3 | Hu32-3 | Hu32-9 |
| Hu32VH4 | Hu32-4 | Hu32-10 |
| Hu32VH5 | Hu32-5 | Hu32-11 |
| Hu32VH6 | Hu32-6 | Hu32-12 |

Note: in the table for example, "Hu32-1" refers to an antibody with the combination of antibody light chain variable region of Hu32VL1 and heavy chain variable region of Hu32VH1, and so on.

Combinations of the antibody light/heavy chain variable regions (for example Hu32-1) referred to in the above table can be linked with the antibody light/heavy chain constant regions to form full-length antibodies, respectively; unless otherwise specified in the present disclosure, when forming a full-length antibody, the light chain variable region is linked to the Kappa chain constant region shown in SEQ ID NO: 73 to form the antibody light chain, and the heavy chain variable region is linked to the IgG4-AA heavy chain constant region shown in SEQ ID NO: 72 or to the IgG4-P heavy chain constant region shown in ID NO: 79 to form the antibody heavy chain, and the name in the table referring to the combination of the antibody light/heavy chain variable regions (for example Hu32-1) plus the suffix ". IgG4AA" means the full-length antibody formed by ligation with the IgG4-AA heavy chain constant region, plus the suffix ". IgG4P" means the full-length antibody formed by ligation with the



Date Reçue/Date Received 2021-07-28

IgG4-P heavy chain constant region, for example, "Hu32-1.IgG4AA" means the full-length antibody formed by linking the heavy chain, formed by linking Hu32VH1 heavy chain variable region and IgG4-AA heavy chain constant region as shown in SEQ ID NO: 72, and the light chain, formed by linking the Hu32VL1 light chain variable region and the Kappa chain constant region as shown in SEQ ID NO: 73. "Hu32-1.IgG4P" means the full-length antibody formed by linking the heavy chain, formed by linking Hu32VH1 heavy chain variable region and IgG4-P heavy chain constant region as shown in SEQ ID NO: 79, and the light chain, formed by linking the Hu32VL1 light chain variable region and the Kappa chain constant region as shown in SEQ ID NO: 73.

3. Humanization of murine antibody M33

3.1 Selection of humanization framework of murine antibody M33

The humanization light chain templates of the murine antibody M33 are IGKV1-39*01 and IGKJ4*01, and the humanization heavy chain templates are IGHV3-7 and IGHJ6*01. The sequences of the humanized variable regions are as follows (underlined are the CDR sequences):

Hu33VH-CDR grafted (SEQ ID NO: 41):

EVQLVESGGGLVQPGGSLRLSCAASGFTFSSYAMSWVRQAPGKGLEWVATISGGGVD TYYQDNVQGRFTISRDNAKNSLYLQMNSLRAEDTAVYYCARPYGHGYFDVWGQGT TVTVSS.

Hu33VL-CDR grafted (SEQ ID NO: 42):

DIQMTQSPSSLSASVGDRVTITCRASQDINNFLNWYQQKPGKAPKLLIYYTSSLHSGV PSRFSGSGSGTDFTLTISSLQPEDFATYYCQQGNTLPWTFGGGTKVEIK.

3.2 Humanization template selection and back mutation design of murine antibody M33

Table 9. Back mutations of murine antibody M33 humanized antibodies

| **VL** | | **VH** | |
|---|---|---|---|
| Hu33VL1 | **Grafted** | Hu33VH1 | **Grafted** |
| Hu33VL2 | F71Y | Hu33VH2 | R94S |
| Hu33VL3 | K42G P44V F71Y | Hu33VH3 | E1K R94S |

Note: grafted means that the murine antibody CDRs are implanted into the human



Date Reçue/Date Received 2021-07-28

germline FR region sequences. The amino acid residues are determined and annotated by the Kabat numbering system, for example F71Y means that F at position 71 of Kabat numbering is mutated back to Y according to the Kabat numbering system.

The light chain variable region and heavy chain variable region sequences of the humanized antibodies of murine antibody M33 are as follows:

> Hu33VL1 (same as Hu33VL-CDR grafted): (SEQ ID NO: 42)

DIQMTQSPSSLSASVGDRVTITCRASQDINNFLNWYQQKPGKAPKLLIYYTSSLHSGV PSRFSGSGSGTDFTLTISSLQPEDFATYYCQQGNTLPWTFGGGTKVEIK.

> Hu33VL2 (SEQ ID NO: 43)

DIQMTQSPSSLSASVGDRVTITCRASQDINNFLNWYQQKPGKAPKLLIYYTSSLHSGV PSRFSGSGSGTDYTLTISSLQPEDFATYYCQQGNTLPWTFGGGTKVEIK.

> Hu33VL3 (SEQ ID NO: 44)

DIQMTQSPSSLSASVGDRVTITCRASQDINNFLNWYQQKPGGAVKLLIYYTSSLHSGV PSRFSGSGSGTDYTLTISSLQPEDFATYYCQQGNTLPWTFGGGTKVEIK.

> Hu33VH1 (same as Hu33VH-CDR grafted): (SEQ ID NO: 41)

EVQLVESGGGLVQPGGSLRLSCAASGFTFSSYAMSWVRQAPGKGLEWVATISGGGVD TYYQDNVQGRFTISRDNAKNSLYLQMNSLRAEDTAVYYCARPYGHGYFDVWGQGT TVTVSS.

> Hu33VH2 (SEQ ID NO: 45)

EVQLVESGGGLVQPGGSLRLSCAASGFTFSSYAMSWVRQAPGKGLEWVATISGGGVD TYYQDNVQGRFTISRDNAKNSLYLQMNSLRAEDTAVYYCASPYGHGYFDVWGQGTT VTVSS.

> Hu33VH3 (SEQ ID NO: 46)

KVQLVESGGGLVQPGGSLRLSCAASGFTFSSYAMSWVRQAPGKGLEWVATISGGGVD TYYQDNVQGRFTISRDNAKNSLYLQMNSLRAEDTAVYYCASPYGHGYFDVWGQGTT VTVSS.

3.3 Humanized sequence combination of murine antibody M33

Table 10. Combinations of the light and heavy chain variable regions of the humanized antibody



Date Reçue/Date Received 2021-07-28

| VL / VH | Hu33VL1 | Hu33VL2 | Hu33VL3 |
|---|---|---|---|
| Hu33VH1 | Hu33-1 | Hu33-4 | Hu33-7 |
| Hu33VH2 | Hu33-2 | Hu33-5 | Hu33-8 |
| Hu33VH3 | Hu33-3 | Hu33-6 | Hu33-9 |

Note: in the table for example, "Hu33-6" refers to an antibody with the combination of the antibody light chain variable region of Hu33VL2 and the heavy chain variable region of Hu33VH3, and so on.

Combinations of the antibody light/heavy chain variable regions (for example Hu33-6) referred to in the above table can be linked with the antibody light/heavy chain constant regions to form full-length antibodies, respectively; unless otherwise specified in the present disclosure, when forming a full-length antibody, the light chain variable region is linked to the Kappa chain constant region shown in SEQ ID NO: 73 to form the antibody light chain, and the heavy chain variable region is linked to the IgG4-AA heavy chain constant region shown in SEQ ID NO: 72 or the IgG4-P heavy chain constant region shown in ID NO: 79 to form the antibody heavy chain, and the name in the table referring to the combination of the antibody light/heavy chain variable regions (for example Hu33-6) plus the suffix ". IgG4AA" means the full-length antibody formed by ligation with the IgG4-AA heavy chain constant region, plus the suffix ". IgG4P" means the full-length antibody formed by ligation with the IgG4-P heavy chain constant region, for example, "Hu32-6.IgG4AA" means the full-length antibody formed by linking the heavy chain, formed by linking Hu33VH3 heavy chain variable region and IgG4-AA heavy chain constant region as shown in SEQ ID NO: 72, and the light chain, formed by linking the Hu33VL2 light chain variable region and the Kappa chain constant region as shown in SEQ ID NO: 73. "Hu33-6.IgG4P" means the full-length antibody formed by linking the heavy chain, formed by linking Hu33VH3 heavy chain variable region and IgG4-P heavy chain constant region as shown in SEQ ID NO: 79, and the light chain, formed by linking the Hu33VL2 light chain variable region and the Kappa chain constant region as shown in SEQ ID NO: 73.

4. Mutants of humanized antibodies

4.1 Mutant antibodies of Hu23 humanized antibody

Through computer simulation, amino acids at specific sites of the light chain LCDR1



Date Reçue/Date Received 2021-07-28

(SEQ ID NO: 11) of the Hu23 humanized antibody were subjected to site-directed mutations, and the specific mutations are shown in Table 11:

Table 11. Mutant sequences of Hu23 light chain LCDR1:

| Name | Sequence (SEQ ID NO) |
|---|---|
| Hu23LCDR1(N28Q) | RSSQSLVHSQGNTYLE (SEQ ID NO: 47) |
| Hu23LCDR1(N28L) | RSSQSLVHSLGNTYLE (SEQ ID NO: 48) |
| Hu23LCDR1(N28T) | RSSQSLVHSTGNTYLE (SEQ ID NO: 49) |
| Hu23LCDR1(N28D) | RSSQSLVHSDGNTYLE (SEQ ID NO: 50) |
| Hu23LCDR1(G29A) | RSSQSLVHSNANTYLE (SEQ ID NO: 51) |
| Hu23LCDR1(G29V) | RSSQSLVHSNVNTYLE (SEQ ID NO: 52) |

Note: Hu23LCDR1 (N28Q) means the LCDR1 mutation sequence in which N at position 28 according to the Kabat numbering criteria of the Hu23 humanized antibody light chain variable region Hu23VL1 or Hu23VL2 is mutated to Q, Hu23LCDR1 (G29A) means the LCDR1 mutation sequence in which G at position 29 according to the Kabat numbering criteria of the Hu23 humanized antibody light chain variable region Hu23VL1 or Hu23VL2 is mutated to A (the CDRs are determined by the Kabat numbering system).

The sequences of the Hu23 humanized antibody light chain variable region after LCDR1 mutation are as follows:

> Hu23VL1(N28Q) sequence is:

DIVMTQTPLSLPVTPGEPASISCRSSQSLVHSQGNTYLEWYLQKPGQSPQLLIYKVSNR FSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIK (SEQ ID NO: 53)

> Hu23VL1(N28L) sequence is:

DIVMTQTPLSLPVTPGEPASISCRSSQSLVHSLGNTYLEWYLQKPGQSPQLLIYKVSNR FSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIK (SEQ ID NO: 54)

> Hu23VL1(N28T) sequence is:

DIVMTQTPLSLPVTPGEPASISCRSSQSLVHSTGNTYLEWYLQKPGQSPQLLIYKVSNR



Date Reçue/Date Received 2021-07-28

FSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIK
(SEQ ID NO: 55)

> Hu23VL1(N28D) sequence is:

DIVMTQTPLSLPVTPGEPASISCRSSQSLVHSDGNTYLEWYLQKPGQSPQLLIYKVSNR
FSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIK
(SEQ ID NO: 56)

> Hu23VL1(G29A) sequence is:

DIVMTQTPLSLPVTPGEPASISCRSSQSLVHSNANTYLEWYLQKPGQSPQLLIYKVSNR
FSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIK
(SEQ ID NO: 57)

> Hu23VL1(G29V) sequence is:

DIVMTQTPLSLPVTPGEPASISCRSSQSLVHSNVNTYLEWYLQKPGQSPQLLIYKVSNR
FSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIK
(SEQ ID NO: 58)

> Hu23VL2(N28Q) sequence is:

DGVMTQTPLSLPVTPGEPASISCRSSQSLVHSQGNTYLEWYLQKPGQSPQLLIYKVSN
RFSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIK
(SEQ ID NO: 59)

> Hu23VL2(N28L) sequence is:

DGVMTQTPLSLPVTPGEPASISCRSSQSLVHSLGNTYLEWYLQKPGQSPQLLIYKVSN
RFSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIK
(SEQ ID NO: 60)

> Hu23VL2(N28T) sequence is:

DGVMTQTPLSLPVTPGEPASISCRSSQSLVHSTGNTYLEWYLQKPGQSPQLLIYKVSN
RFSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIK
(SEQ ID NO: 61)

> Hu23VL2(N28D) sequence is:

DGVMTQTPLSLPVTPGEPASISCRSSQSLVHSDGNTYLEWYLQKPGQSPQLLIYKVSN
RFSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIK
(SEQ ID NO: 62)



Date Reçue/Date Received 2021-07-28

> Hu23VL2(G29A) sequence is:

DGVMTQTPLSLPVTPGEPASISCRSSQSLVHSNANTYLEWYLQKPGQSPQLLIYKVSN RFSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIK (SEQ ID NO: 63)

> Hu23VL2(G29V) sequence is:

DGVMTQTPLSLPVTPGEPASISCRSSQSLVHSNVNTYLEWYLQKPGQSPQLLIYKVSN RFSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIK (SEQ ID NO: 64)

Table 12. Combinations of the light and heavy chain variable regions of the Hu23 humanized antibody

| VH / VL | Hu23VH1 | Hu23VH2 | Hu23VH3 | Hu23VH4 |
|---|---|---|---|---|
| Hu23VL1(N28Q) | Hu23-9 | Hu23-21 | Hu23-33 | Hu23-45 |
| Hu23VL1(N28L) | Hu23-10 | Hu23-22 | Hu23-34 | Hu23-46 |
| Hu23VL1(N28T) | Hu23-11 | Hu23-23 | Hu23-35 | Hu23-47 |
| Hu23VL1(N28D) | Hu23-12 | Hu23-24 | Hu23-36 | Hu23-48 |
| Hu23VL1(G29A) | Hu23-13 | Hu23-25 | Hu23-37 | Hu23-49 |
| Hu23VL1(G29V) | Hu23-14 | Hu23-26 | Hu23-38 | Hu23-50 |
| Hu23VL2(N28Q) | Hu23-15 | Hu23-27 | Hu23-39 | Hu23-51 |
| Hu23VL2(N28L) | Hu23-16 | Hu23-28 | Hu23-40 | Hu23-52 |
| Hu23VL2(N28T) | Hu23-17 | Hu23-29 | Hu23-41 | Hu23-53 |
| Hu23VL2(N28D) | Hu23-18 | Hu23-30 | Hu23-42 | Hu23-54 |
| Hu23VL2(G29A) | Hu23-19 | Hu23-31 | Hu23-43 | Hu23-55 |
| Hu23VL2(G29V) | Hu23-20 | Hu23-32 | Hu23-44 | Hu23-56 |

Note: in the table for example, "Hu23-11" refers to an antibody with the combination of the antibody light chain variable region of Hu23VL1(N28T) and heavy chain variable region of Hu23VH1, and so on.

Combinations of the antibody light/heavy chain variable regions (for example Hu23-11) referred to in the above table can be linked with the antibody light/heavy chain constant regions to form full-length antibodies, respectively; unless otherwise specified in the present disclosure, when forming a full-length antibody, the light chain variable region is linked to the Kappa chain constant region shown in SEQ ID NO: 73 to form the antibody light chain, and the heavy chain variable region is linked to the IgG4-AA heavy chain constant region shown in SEQ ID NO: 72 or the IgG4-P heavy chain constant region shown in ID NO:



Date Reçue/Date Received 2021-07-28

79 to form the antibody heavy chain, and the name in the table referring to the combination of the antibody light/heavy chain variable regions (for example Hu23-11) plus the suffix ". IgG4AA" means the full-length antibody formed by ligation with the IgG4-AA heavy chain constant region, plus the suffix ". IgG4P" means the full-length antibody formed by ligation with the IgG4-P heavy chain constant region, for example, "Hu23-11.IgG4AA" means the full-length antibody formed by linking the heavy chain, formed by linking Hu23VH1 heavy chain variable region and IgG4-AA heavy chain constant region as shown in SEQ ID NO: 72, and the light chain, formed by linking the Hu23VL1(N28T) light chain variable region and the Kappa chain constant region as shown in SEQ ID NO: 73. "Hu23-11.IgG4P" means the full-length antibody formed by linking the heavy chain, formed by linking Hu23VH1 heavy chain variable region and IgG4-P heavy chain constant region as shown in SEQ ID NO: 79, and the light chain, formed by linking the Hu23VL1(N28T) light chain variable region and the Kappa chain constant region as shown in SEQ ID NO: 73.

The experimental results showed that after site mutations, the humanized antibodies Hu23LCDR1 (N28Q), Hu23LCDR1 (N28L), Hu23LCDR1 (N28T), Hu23LCDR1 (N28D), Hu23LCDR1 (G29A) and Hu23LCDR1 (G29V) all maintained the ability of binding to PD-1 (Table 16).

4.2 Mutant antibodies of Hu32 humanized antibody

The series of humanized antibodies Hu23 derived from M23 and the series of humanized antibodies Hu32 derived from M32 had high sequence identity by sequence analysis. The Hu23 light chain variable region and the Hu32 heavy chain variable region were combined into new light and heavy chain variable region combinations. The experimental results showed that the humanized antibodies comprising the new light and heavy chain variable region combinations maintain the ability of binding to the PD-1 antigen (Table 16).

Table 13. General formulas of Hu32 and Hu23 antibody variable region consensus sequences

| Heavy chain | | Light chain | |
|---|---|---|---|
| HCDR1 | DYEX$_1$H, wherein X$_1$ is selected from I or M;<br>(SEQ ID NO: 65) | LCDR1 | RSSQSX$_{13}$VHSX$_{14}$X$_{15}$X$_{16}$TY LE, wherein, X$_{13}$ is selected from I or L, X$_{14}$ is selected from N, Q, L, T or D, X$_{15}$ is |



Date Reçue/Date Received 2021-07-28

| | | | |
|---|---|---|---|
| | | | selected from G, A or V, and $X_{16}$ is selected from N or K; (SEQ ID NO: 68) |
| HCDR2 | $LX_2DPETGGX_3VYNQKFKX_4$, wherein $X_2$ is selected from F or I, $X_3$ is selected from I/T and wherein $X_4$ is selected from G or D; (SEQ ID NO: 66) | LCDR2 | KVSNRFS; (SEQ ID NO: 12) |
| HCDR3 | $EX_5X_6X_7X_8YX_9X_{10}X_{11}X_{12}DWYFDV$, wherein $X_5$ is selected from G or R, $X_6$ is F or absent, $X_7$ is S or absent, $X_8$ is Y or absent, $X_9$ is G or absent, $X_{10}$ is S or absent, $X_{11}$ is selected from N or T and $X_{12}$ is selected from R or S; (SEQ ID NO: 67) | LCDR3 | $FQGSHVPYX_{17}$, wherein $X_{17}$ is selected from A or T; (SEQ ID NO: 69) |
| VH | EVQLVQSGAEVKKPGSSVKVSCKA $SX_{18}X_{19}TFX_{20}$DYEX$_1$HWV$X_{21}$QAPGX $_{22}$GLEW$X_{23}$GL$X_2$DPETGG$X_3$VYNQKF KX$_4X_{24}X_{25}TX_{26}$TADKSTSTAYMEX$_{27}$S SLRSEDTAVYYCX$_{28}$REX$_5X_6X_7X_8YX_9$ $X_{10}X_{11}X_{12}$DWYFDVWGQGTTVTVSS, wherein, $X_1$ is selected from I or M, $X_2$ is selected from F or I, $X_3$ is selected from I/T, $X_4$ is selected from G or D, $X_5$ is selected from G or R, $X_6$ is F or absent, $X_7$ is S or absent, $X_8$ is Y or absent, $X_9$ is G or absent, $X_{10}$ is S or absent, $X_{11}$ is selected from N or T, $X_{12}$ is selected from R or S, $X_{18}$ is selected from G or D, $X_{19}$ is selected from G, F or Y, $X_{20}$ is selected from S or T, $X_{21}$ is selected from R or K, $X_{22}$ is selected from Q or H, $X_{23}$ is selected from M or I, $X_{24}$ is selected from R or K, $X_{25}$ is selected from V, A or T, $X_{26}$ is selected from R or K, $X_{27}$ is selected from L or F and $X_{28}$ is selected from A or T (SEQ ID NO: 70) | VL | $DX_{29}$VMTQTPLSLPVTPGEP ASISCRSSQS$X_{13}$VHS$X_{14}X_{15}$ $X_{16}$TYLEWYLQKPGQSPQL LIYKVSNRFSGVPDRFSGS GSGTDFTLKISRVEAEDVG VYYCFQGSHVPY$X_{17}$FGGG TKVEIK, wherein, $X_{13}$ is selected from I or L, $X_{14}$ is selected from N, Q, L, T or D, $X_{15}$ is selected from G, A or V, $X_{16}$ is selected from N or K, $X_{17}$ is selected from A or T and $X_{29}$ is selected from I, V or G. (SEQ ID NO: 71) |



Date Reçue/Date Received 2021-07-28

Table 14. Combinations of Hu32 heavy chain variable regions and Hu23 light chain variable regions

| VH / VL | Hu32VH1 | Hu32VH2 | Hu32VH3 | Hu32VH4 | Hu32VH5 | Hu32VH6 |
|---|---|---|---|---|---|---|
| Hu23VL1(N28Q) | Hu32a-13 | Hu32a-27 | Hu32a-41 | Hu32a-55 | Hu32a-69 | Hu32a-83 |
| Hu23VL1(N28L) | Hu32a-14 | Hu32a-28 | Hu32a-42 | Hu32a-56 | Hu32a-70 | Hu32a-84 |
| Hu23VL1(N28T) | Hu32a-15 | Hu32a-29 | Hu32a-43 | Hu32a-57 | Hu32a-71 | Hu32a-85 |
| Hu23VL1(N28D) | Hu32a-16 | Hu32a-30 | Hu32a-44 | Hu32a-58 | Hu32a-72 | Hu32a-86 |
| Hu23VL1(G29A) | Hu32a-17 | Hu32a-31 | Hu32a-45 | Hu32a-59 | Hu32a-73 | Hu32a-87 |
| Hu23VL1(G29V) | Hu32a-18 | Hu32a-32 | Hu32a-46 | Hu32a-60 | Hu32a-74 | Hu32a-88 |
| Hu23VL2(N28Q) | Hu32a-19 | Hu32a-33 | Hu32a-47 | Hu32a-61 | Hu32a-75 | Hu32a-89 |
| Hu23VL2(N28L) | Hu32a-20 | Hu32a-34 | Hu32a-48 | Hu32a-62 | Hu32a-76 | Hu32a-90 |
| Hu23VL2(N28T) | Hu32a-21 | Hu32a-35 | Hu32a-49 | Hu32a-63 | Hu32a-77 | Hu32a-91 |
| Hu23VL2(N28D) | Hu32a-22 | Hu32a-36 | Hu32a-50 | Hu32a-64 | Hu32a-78 | Hu32a-92 |
| Hu23VL2(G29A) | Hu32a-23 | Hu32a-37 | Hu32a-51 | Hu32a-65 | Hu32a-79 | Hu32a-93 |
| Hu23VL2(G29V) | Hu32a-24 | Hu32a-38 | Hu32a-52 | Hu32a-66 | Hu32a-80 | Hu32a-94 |
| Hu23VL1 | Hu32a-25 | Hu32a-39 | Hu32a-53 | Hu32a-67 | Hu32a-81 | Hu32a-95 |
| Hu23VL2 | Hu32a-26 | Hu32a-40 | Hu32a-54 | Hu32a-68 | Hu32a-82 | Hu32a-96 |

Note: in the table for example, "Hu32a-85" refers to an antibody with antibody light chain variable region of Hu23VL1(N28T) and heavy chain variable region of Hu32VH6, and so on.

Combinations of the antibody light/heavy chain variable regions (for example Hu32a-85) referred to in the above table can be linked with the antibody light/heavy chain constant regions to form full-length antibodies, respectively; unless otherwise specified in the present disclosure, when forming a full-length antibody, the light chain variable region is linked to the Kappa chain constant region shown in SEQ ID NO: 73 to form the antibody light chain, and the heavy chain variable region is linked to the IgG4-AA heavy chain constant region shown in SEQ ID NO: 72 or the IgG4-P heavy chain constant region shown in ID NO: 79 to form the antibody heavy chain, and the name in the table referring to the combination of the antibody light/heavy chain variable regions (for example Hu32a-85) plus the suffix ". IgG4AA" means the full-length antibody formed by ligation with the IgG4-AA heavy chain constant region, plus the suffix ". IgG4P" means the full-length antibody formed by ligation with the IgG4-P heavy chain constant region, for example, "Hu32a-85.IgG4AA" means the full-length antibody formed by linking the heavy chain, formed by linking Hu32VH6 heavy



Date Reçue/Date Received 2021-07-28

chain variable region and IgG4-AA heavy chain constant region as shown in SEQ ID NO: 72, and the light chain, formed by linking the Hu23VL1(N28T) light chain variable region and the Kappa chain constant region as shown in SEQ ID NO: 73. "Hu32a-85.IgG4P" means the full-length antibody formed by linking the heavy chain, formed by linking Hu32VH6 heavy chain variable region and IgG4-P heavy chain constant region as shown in SEQ ID NO: 79, and the light chain, formed by linking the Hu23VL1(N28T) light chain variable region and the Kappa chain constant region as shown in SEQ ID NO: 73.

Table 15. Combinations of Hu23 heavy chain variable regions and Hu32 light chain variable regions

| VH / VL | Hu23VH1 | Hu23VH2 | Hu23VH3 |
|---|---|---|---|
| Hu32VL1 | Hu23a-57 | Hu23a-59 | Hu23a-61 |
| Hu32VL2 | Hu23a-58 | Hu23a-60 | Hu23a-62 |

Note: in the table for example, "Hu23a-57" refers to an antibody with the combination of the antibody light chain variable region of Hu32VL1 and the heavy chain variable region of Hu23VH1, and so on.

Combinations of the antibody light/heavy chain variable regions (for example Hu23a-57) referred to in the above table can be linked with the antibody light/heavy chain constant regions to form full-length antibodies, respectively; unless otherwise specified in the present disclosure, when forming a full-length antibody, the light chain variable region is linked to the Kappa chain constant region shown in SEQ ID NO: 73 to form the antibody light chain, and the heavy chain variable region is linked to the IgG4-AA heavy chain constant region shown in SEQ ID NO: 72 or the IgG4-P heavy chain constant region shown in ID NO: 79 to form the antibody heavy chain, and the name in the table referring to the combination of the antibody light/heavy chain variable regions (for example Hu32a-85) plus the suffix ". IgG4AA" means the full-length antibody formed by ligation with the IgG4-AA heavy chain constant region, plus the suffix ". IgG4P" means the full-length antibody formed by ligation with the IgG4-P heavy chain constant region, for example, "Hu23a-57.IgG4AA" means the full-length antibody formed by linking the heavy chain, formed by linking Hu23VH1 heavy chain variable region and IgG4-AA heavy chain constant region as shown in SEQ ID NO: 72, and the light chain, formed by linking the Hu32VL1 light chain variable region and the Kappa



Date Reçue/Date Received 2021-07-28

chain constant region as shown in SEQ ID NO: 73. "Hu23a-57.IgG4P" means the full-length antibody formed by linking the heavy chain, formed by linking Hu23VH1 heavy chain variable region and IgG4-P heavy chain constant region as shown in SEQ ID NO: 79, and the light chain, formed by linking the Hu32VL1 light chain variable region and the Kappa chain constant region as shown in SEQ ID NO: 73.

5. Screening of humanized antibodies

The affinity detection of different humanized antibodies was carried out by Biacore (see Test Example 3 for the method) and the results are shown in Table 16. The results showed that different humanized antibodies maintain the ability of binding to PD-1, and some humanized antibodies have affinity even substantially close to those of murine antibodies thereof.

Table 16. Affinity of Hu23 humanized antibody to human PD-1

| Antibody | ka (1/Ms) | kd (1/s) | KD (M) |
|---|---|---|---|
| M23 | 4.57E+04 | 1.32E-04 | 2.89E-09 |
| Hu23-1.IgG4AA | 3.43E+04 | 1.10E-04 | 3.20E-09 |
| Hu23-5.IgG4AA | 2.99E+04 | 1.14E-04 | 3.82E-09 |
| Hu23-2.IgG4AA | 2.74E+04 | 1.61E-04 | 5.86E-09 |
| Hu23-6.IgG4AA | 2.79E+04 | 1.55E-04 | 5.57E-09 |
| Hu23-3.IgG4AA | 2.93E+04 | 1.60E-04 | 5.46E-09 |
| Hu23-7.IgG4AA | 2.77E+04 | 1.66E-04 | 5.97E-09 |
| Hu23-4.IgG4AA | 4.24E+04 | 1.44E-04 | 3.39E-09 |
| Hu23-8.IgG4AA | 4.11E+04 | 1.47E-04 | 3.56E-09 |
| Hu23-9.IgG4AA | 6.16E+04 | 1.32E-04 | 2.15E-09 |
| Hu23-10.IgG4AA | 5.51E+04 | 1.53E-04 | 2.77E-09 |
| Hu23-11.IgG4AA | 4.22E+04 | 1.14E-04 | 2.71E-09 |
| Hu23-12.IgG4AA | 5.45E+04 | 1.10E-04 | 2.02E-09 |
| Hu23-13.IgG4AA | 4.24E+04 | 1.22E-04 | 2.88E-09 |
| Hu23-14.IgG4AA | 7.23E+04 | 1.61E-04 | 2.22E-09 |
| M32 | 7.83E+04 | 4.15E-04 | 5.3E-09 |
| Hu32a-15.IgG4AA | 4.89E+04 | 2.52E-03 | 5.14E-08 |
| Hu32a-29.IgG4AA | 7.89E+04 | 6.20E-04 | 7.86E-09 |
| Hu32a-43.IgG4AA | 8.39E+04 | 6.85E-04 | 8.16E-09 |
| Hu32a-57.IgG4AA | 7.94E+04 | 6.24E-04 | 7.85E-09 |
| Hu32a-71.IgG4AA | 8.60E+04 | 3.96E-04 | 4.61E-09 |
| Hu32a-85.IgG4AA | 9.90E+04 | 3.15E-04 | 3.18E-09 |
| M33 | 3.08E+05 | 2.27E-04 | 7.37E-10 |



Date Reçue/Date Received 2021-07-28

| | | | |
|---|---|---|---|
| Hu33-1.IgG4AA | 6.61E+04 | 1.28E-03 | 1.93E-08 |
| Hu33-4.IgG4AA | 8.11E+04 | 2.55E-03 | 3.14E-08 |
| Hu33-7.IgG4AA | 7.69E+04 | 2.60E-03 | 3.38E-08 |
| Hu33-2.IgG4AA | 1.35E+05 | 1.43E-04 | 1.06E-09 |
| Hu33-5.IgG4AA | 1.46E+05 | 1.35E-04 | 9.26E-10 |
| Hu33-8.IgG4AA | 1.53E+05 | 1.62E-04 | 1.06E-09 |
| Hu33-3.IgG4AA | 1.25E+05 | 1.36E-04 | 1.09E-09 |
| Hu33-6.IgG4AA | 1.30E+05 | 1.40E-04 | 1.08E-09 |
| Hu33-9.IgG4AA | 1.40E+05 | 1.53E-04 | 1.09E-09 |

**Example 3. Construction and expression of PD-1 humanized antibodies**

Each humanized antibody VH/VK gene fragment was constructed with the designed primers via PCR, and then was used to construct full-length antibody expressing vector VH-CH1-Fc-pHr/VK-CL-pHr by homologous recombination with the expression vector pHr (with signal peptide and constant region gene (CH1-Fc/CL) fragment). IgG4-P represents S228P (corresponding to position 108 of SEQ ID NO: 72 or SEQ ID NO: 79) mutation, and IgG4-AA represents F234A (corresponding to position 114 of sequence SEQ ID NO: 72 or SEQ ID NO: 79), L235A (corresponding to position 115 of SEQ ID NO: 72 or SEQ ID NO: 79) and S228P (corresponding to position 108 of SEQ ID NO: 72 or SEQ ID NO: 79) mutations. IgG4-AA and IgG4-P antibody formats can be obtained by simple point mutations in the IgG4 antibody format.

The sequence of IgG4-AA heavy chain constant region is as follows (SEQ ID NO: 72):

ASTKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQS
SGLYSLSSVVTVPSSSLGTKTYTCNVDHKPSNTKVDKRVESKYGPPCPPCPAPEAAGG
PSVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQFNWYVDGVEVHNAKTKPREE
QFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKTISKAKGQPREPQVYTL
PPSQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSRL
TVDKSRWQEGNVFSCSVMHEALHNHYTQKSLSLSLGK.

The sequence of the antibody light chain (Kappa chain) constant region is as follows (SEQ ID NO: 73):

RTVAAPSVFIFPPSDEQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSGNSQESVTE
QDSKDSTYSLSSTLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC.



Date Reçue/Date Received 2021-07-28

The constructed IgG4AA form full-length antibody sequences are exemplified as follows:

Hu23-11.IgG4AA antibody heavy chain (SEQ ID NO: 74):

EVQLVQSGAEVKKPGSSVKVSCKASGGTFSDYEMHWVRQAPGQGLEWMGLIDPET
GGTVYNQKFKDRVTITADKSTSTAYMELSSLRSEDTAVYYCARERFSYYGSTSDWYF
DVWGQGTTVTVSSASTKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSG
ALTSGVHTFPAVLQSSGLYSLSSVVTVPSSSLGTKTYTCNVDHKPSNTKVDKRVESKY
GPPCPPCPAPEAAGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQFNWYVD
GVEVHNAKTKPREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKTIS
KAKGQPREPQVYTLPPSQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTT
PPVLDSDGSFFLYSRLTVDKSRWQEGNVFSCSVMHEALHNHYTQKSLSLSLGK.

Hu23-11.IgG4AA light chain (SEQ ID NO: 75):

DIVMTQTPLSLPVTPGEPASISCRSSQSLVHSTGNTYLEWYLQKPGQSPQLLIYKVSNR
FSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIKRTVAA
PSVFIFPPSDEQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSGNSQESVTEQDSK
DSTYSLSSTLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC.

Hu32a-85.IgG4AA heavy chain (SEQ ID NO: 76):

EVQLVQSGAEVKKPGSSVKVSCKASDFTFTDYEIHWVKQAPGHGLEWIGLFDPETGG
IVYNQKFKGKATLTADKSTSTAYMEFSSLRSEDTAVYYCTREGYNRDWYFDVWGQG
TTVTVSSASTKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSGALTSGVHT
FPAVLQSSGLYSLSSVVTVPSSSLGTKTYTCNVDHKPSNTKVDKRVESKYGPPCPPCPA
PEAAGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQFNWYVDGVEVHNAK
TKPREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKTISKAKGQPREP
QVYTLPPSQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSF
FLYSRLTVDKSRWQEGNVFSCSVMHEALHNHYTQKSLSLSLGK.

Hu32a-85.IgG4AA light chain (same as Hu23-11.IgG4AA light chain, SEQ ID NO: 75):

DIVMTQTPLSLPVTPGEPASISCRSSQSLVHSTGNTYLEWYLQKPGQSPQLLIYKVSNR
FSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIKRTVAA
PSVFIFPPSDEQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSGNSQESVTEQDSK



Date Reçue/Date Received 2021-07-28

DSTYSLSSTLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC.

Hu33-6.IgG4AA heavy chain (SEQ ID NO: 77):

KVQLVESGGGLVQPGGSLRLSCAASGFTFSSYAMSWVRQAPGKGLEWVATISGGGVD
TYYQDNVQGRFTISRDNAKNSLYLQMNSLRAEDTAVYYCASPYGHGYFDVWGQGTT
VTVSSASTKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFP
AVLQSSGLYSLSSVVTVPSSSLGTKTYTCNVDHKPSNTKVDKRVESKYGPPCPPCPAPE
AAGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQFNWYVDGVEVHNAKT
KPREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKTISKAKGQPREPQ
VYTLPPSQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFF
LYSRLTVDKSRWQEGNVFSCSVMHEALHNHYTQKSLSLSLGK.

Hu33-6.IgG4AA light chain (SEQ ID NO: 78):

DIQMTQSPSSLSASVGDRVTITCRASQDINNFLNWYQQKPGKAPKLLIYYTSSLHSGV
PSRFSGSGSGTDYTLTISSLQPEDFATYYCQQGNTLPWTFGGGTKVEIKRTVAAPSVFIF
PPSDEQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSGNSQESVTEQDSKDSTYSL
SSTLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC.

The sequence of IgG4-P heavy chain constant region is as follows (SEQ ID NO: 79):

ASTKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQS
SGLYSLSSVVTVPSSSLGTKTYTCNVDHKPSNTKVDKRVESKYGPPCPPCPAPEFLGGP
SVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQFNWYVDGVEVHNAKTKPREEQ
FNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKTISKAKGQPREPQVYTLPP
SQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSRLT
VDKSRWQEGNVFSCSVMHEALHNHYTQKSLSLSLGK.

The sequences of the constructed IgG4-P form full-length antibodies are exemplified as follows:

Hu23-11.IgG4P antibody heavy chain (SEQ ID NO: 80):

EVQLVQSGAEVKKPGSSVKVSCKASGGTFSDYEMHWVRQAPGQGLEWMGLIDPET
GGTVYNQKFKDRVTITADKSTSTAYMELSSLRSEDTAVYYCARERFSYYGSTSDWYF
DVWGQGTTVTVSSASTKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSG
ALTSGVHTFPAVLQSSGLYSLSSVVTVPSSSLGTKTYTCNVDHKPSNTKVDKRVESKY
GPPCPPCPAPEFLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQFNWYVD



Date Reçue/Date Received 2021-07-28

GVEVHNAKTKPREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKTIS
KAKGQPREPQVYTLPPSQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTT
PPVLDSDGSFFLYSRLTVDKSRWQEGNVFSCSVMHEALHNHYTQKSLSLSLGK.

Hu23-11.IgG4P light chain (same as Hu23-11.IgG4AA light chain, SEQ ID NO: 75):
DIVMTQTPLSLPVTPGEPASISCRSSQSLVHSTGNTYLEWYLQKPGQSPQLLIYKVSNR
FSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIKRTVAA
PSVFIFPPSDEQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSGNSQESVTEQDSK
DSTYSLSSTLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC.

Hu32a-85.IgG4P heavy chain (SEQ ID NO: 81):
EVQLVQSGAEVKKPGSSVKVSCKASDFTFTDYEIHWVKQAPGHGLEWIGLFDPETGG
IVYNQKFKGKATLTADKSTSTAYMEFSSLRSEDTAVYYCTREGYNRDWYFDVWGQG
TTVTVSSASTKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSGALTSGVHT
FPAVLQSSGLYSLSSVVTVPSSSLGTKTYTCNVDHKPSNTKVDKRVESKYGPPCPPCPA
PEFLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQFNWYVDGVEVHNAK
TKPREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKTISKAKGQPREP
QVYTLPPSQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSF
FLYSRLTVDKSRWQEGNVFSCSVMHEALHNHYTQKSLSLSLGK.

Hu32a-85.IgG4P light chain (same as Hu23-11.IgG4AA light chain, SEQ ID NO: 75):
DIVMTQTPLSLPVTPGEPASISCRSSQSLVHSTGNTYLEWYLQKPGQSPQLLIYKVSNR
FSGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCFQGSHVPYTFGGGTKVEIKRTVAA
PSVFIFPPSDEQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSGNSQESVTEQDSK
DSTYSLSSTLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC.

Hu33-6.IgG4P heavy chain (SEQ ID NO: 82):
KVQLVESGGGLVQPGGSLRLSCAASGFTFSSYAMSWVRQAPGKGLEWVATISGGGVD
TYYQDNVQGRFTISRDNAKNSLYLQMNSLRAEDTAVYYCASPYGHGYFDVWGQGTT
VTVSSASTKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFP
AVLQSSGLYSLSSVVTVPSSSLGTKTYTCNVDHKPSNTKVDKRVESKYGPPCPPCPAPE
FLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQFNWYVDGVEVHNAKTK
PREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKTISKAKGQPREPQV
YTLPPSQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFL



Date Reçue/Date Received 2021-07-28

YSRLTVDKSRWQEGNVFSCSVMHEALHNHYTQKSLSLSLGK.

Hu33-6.IgG4P light chain (same as Hu33-6.IgG4AA light chain, SEQ ID NO: 78):
DIQMTQSPSSLSASVGDRVTITCRASQDINNFLNWYQQKPGKAPKLLIYYTSSLHSGV
PSRFSGSGSGTDYTLTISSLQPEDFATYYCQQGNTLPWTFGGGTKVEIKRTVAAPSVFIF
PPSDEQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSGNSQESVTEQDSKDSTYSL
SSTLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC.

**Test Examples**

**Test Example 1. ELISA experiment of anti-PD-1 antibodies binding to PD-1 ligand and binding blockade *in vitro***

PD-L1 on the surface of tumor cells binds to PD-1 on the surface of T cells, thereby inhibiting T cell proliferation. PD-1 antibodies can block the PD-L1/PD-1 signaling pathway by binding to PD-1, thereby stimulating T cell proliferation. The PD-1/PD-L1 binding blockade experiment was used to detect the blocking activity of anti-PD-1 antibodies on the signaling pathway.

In this experiment, after coating of PD-1-His protein (Cat.# 10377H08H, Sino Biological) on 96-well plates, the anti-PD-1 antibodies to be tested (including antibodies: Hu23-11.IgG4AA, Hu32a-85.IgG4AA and Hu33-6.IgG4AA, positive control antibody: H005-1 (see H005-1 antibody in WO2015085847)) were separately added and the reaction was incubated; later, HRP-labeled goat anti-human IgG (H+L) antibody (Cat. #109-035-003, Jackson ImmunoResearch) was added and incubated. After washing the plates, the binding amounts of HRP-labeled goat anti-human IgG (H+L) were detected, and the $EC_{50}$ values of the binding of anti-PD-1 antibodies to the ligand PD-1 were calculated.

In this experiment, after coating of PD-1 protein fused with Fc in extracellular region (PD-1-Fc, see SEQ ID NO: 1 for the sequence) on 96-well plates, the anti-PD-1 antibodies to be tested (including antibodies: Hu23-11.IgG4AA, Hu32a-85.IgG4AA and Hu33-6.IgG4AA, positive control antibody: H005-1 (see H005-1 antibody in WO2015085847)) were separately added and incubated; later, biotin-labeled PD-L1/PD-L2 was added and incubated. After washing the plates, the binding amounts of biotin-labeled PD-L1/PD-L2 were detected, and the $IC_{50}$ values of anti-PD-1 antibodies to block the binding of the ligand to PD-L1/PD-L2



Date Reçue/Date Received 2021-07-28

were calculated.

CB buffer pH 9.6 (1.59 g $Na_2CO_3$ and 2.93 g $NaHCO_3$ dissolved in 1 L distilled water) was used to dilute PD-1-Fc to 1 μg/ml, which was added to the 96-well plates at a volume of 100 μl/well and allowed to stand at 4°C for 16 h-20 h. PBS buffer was aspirated from the 96-well plates, and the plates were washed with PBST (pH 7.4 PBS containing 0.05% tween20) buffer once. 120 μl/well PBST/1% milk was added and incubated at room temperature for 1 h for blocking. The blocking solution was removed and the plates were washed with PBST buffer once. 90 μl anti-PD-1 antibody to be tested diluted to appropriate concentration with the sample diluent (pH 7.4 PBS containing 5% BSA, 0.05% Tween20) was added and pre-incubated at 4°C for 1 h. 10× concentration of biotin-labeled PD-L1/PD-L2 (Beijing Sino Biological Co., Ltd.) (10 μg/ml) was added at a volume of 10 μl/well, shaken and mixed well on a shaker, and then incubated at 37°C for 1 h. The reaction system was removed and the plates were washed with PBST 6 times. 100 μl/well Streptavidin-Peroxidase Polymer 1:400 diluted with PBST buffer was added and incubated with shaking at room temperature for 50 min. The plates were washed with PBST 6 times. 100 μl/well TMB was added and incubated at room temperature for 5-10 min. 100 μl/well 1 M $H_2SO_4$ was added to stop the reaction. The absorbance values at 450 nm were read by using a microplate reader and the $IC_{50}$ values of the anti-PD-1 antibodies to block the binding of the ligand to PD-L1/PD-L2 were calculated. The data is shown in Table 17 below in detail.

Table 17. ELISA of anti-PD-1 antibodies of the present disclosure to bind to PD-1 and to block the binding of the ligand to PD-L1/PD-L2

| Antibody | Antigen binding | | PD-1 and PD-L1/PD-L2 binding blockade | |
|---|---|---|---|---|
| | hu PD-1-his OD value MAX | hu PD-1-his EC50 (ng/ml) | Hu PD-1-Fc/ PD-L1 IC50 (ng/ml) | Hu PD-1-Fc/ PD-L2 IC50(ng/ml) |
| Hu23-11.IgG4AA | 1.46 | 237.3 | 92.35 | 245.1 |
| Hu32a-85.IgG4AA | 1.265 | 135.9 | 78.63 | 205.9 |
| Hu33-6.IgG4AA | 1.706 | 205.6 | 103.5 | 207.2 |
| H005-1 | 1.21 | 113.1 | 109.6 | 225.3 |



Date Reçue/Date Received 2021-07-28

The exemplary anti-PD-1 antibodies Hu23-11.IgG4AA, Hu32a-85.IgG4AA and Hu33-6.IgG4AA of the present disclosure can all effectively block the binding of PD-1 to PD-L1/PD-L2, and their blocking activity is similar to that of the positive control antibody.

**Test Example 2. Ligand blockade test of exemplary antibodies**

The blocking effect of antibodies on the binding of PD-1 and PD-L1 was studied. The experiment process is briefly described as follows:

CHOK1/PD-L1 cells (Promega) were digested, added to 96-well plates at 100 μL/well and placed in a 37°C, 5% $CO_2$ incubator for incubation for 24 h. The control and samples were diluted to desired concentrations by using PBS. Jurkat/PD-1 cells (Jurkat cells stably transfected with PD-1) were counted and seeded at a certain proportion (90 μL/well) to cell culture plates with CHOK1/PD-L1 cells, and 10 μL/well diluted antibody (antibody: Hu23-11.IgG4AA, Hu32a-85.IgG4AA and Hu33-6.IgG4AA, positive control antibody: H005-1, negative control: IgG4 protein, antibody gradient dilution concentration: 0.3 mg/ml, 3 mg/ml, 30 mg/ml) was added and placed in a 37°C, 5% $CO_2$ incubator for incubation for 5 h. The cell culture plates were taken out and placed at room temperature for 5 min. Then 50 μl Bio-Glo™ Reagent was added to each well and incubated at room temperature for 5 min before reading the plate. The experimental results are shown in Figure 1.

The results showed that the exemplary anti-PD-1 antibodies Hu23-11.IgG4AA, Hu32a-85.IgG4AA and Hu33-6.IgG4AA in the present disclosure can effectively block the binding of PD-1 and PD-L1.

**Test Example 3. BIAcore antibody affinity experiment of exemplary antibodies**

IgG was affinity captured by using a Protein A biosensor chip (Cat. # 29127556, GE). Human PD-1 antigen (Cat.# 10377H08H, Sino Biological) and Cyno PD-1 antigen (purchased from Sino Biological) flowed across the surface of the chip, and the binding and dissociation curves were obtained by real time detection of PD-1 antibody and antigen PD-1 reaction signals by a Biacore T200 instrument. After the dissociation of each experimental cycle was completed, the biosensor chip was washed and regenerated with 10 mM Glycine-HCl pH 1.5 buffer. The experimental buffer system was 1×HBS-EP buffer solution (Cat# BR-1001-88,



Date Reçue/Date Received 2021-07-28

GE). After the experiment, GE Biacore T200 Evaluation version 3.0 software was used to fit the data with a (1:1) Langmuir model, and the affinity value was obtained. The results are shown in Table 18.

Table 18. Affinity of anti-PD-1 antibodies to human PD1 and simian PD-1

| Antibody | Antigen | ka (1/Ms) | kd (1/s) | KD (M) |
|---|---|---|---|---|
| Hu23-11.IgG4AA | hPD-1-His | 6.06E+04 | 1.13E-04 | 1.86E-09 |
| | Cyno PD-1 | 4.79E+04 | 1.26E-04 | 2.62E-09 |
| Hu32a-85.IgG4AA | hPD-1-His | 8.56E+04 | 2.78E-04 | 3.25E-09 |
| | Cyno PD-1 | 1.16E+05 | 4.75E-04 | 4.11E-09 |
| Hu33-6.IgG4AA | hPD-1-His | 1.24E+05 | 1.14E-04 | 9.18E-10 |
| | Cyno PD-1 | 2.51E+05 | 2.41E-04 | 9.60E-10 |

The results showed that the exemplary anti-PD-1 antibodies Hu23-11.IgG4AA, Hu32a-85.IgG4AA and Hu33-6.IgG4AA of the present disclosure can all bind to human PD-1 and simian PD-1.

**Test Example 4. The effect of antibodies on IFNγ secretion by cells in PBMC-T lymphocyte activation experiment**

In order to study the effect of anti-PD-1 antibodies on the function of human primary T lymphocytes, human peripheral blood mononuclear cells (PBMC) were collected and purified, stimulated with tuberculin (TB) for 5 days, and the secretion level of cytokine IFNγ was detected. The experiment process is briefly described as follows:

PBMCs were obtained from fresh blood using Ficoll-Hypaque (17-5442-02, GE) for density gradient centrifugation (Stem Cell Technologies), cultured in RPMI 1640 (SH30809.01, GE) medium supplemented with 10% (v/v) FBS (10099-141, Gibco) at 37°C and 5% $CO_2$.

The freshly isolated and purified PBMCs were adjusted to a density of $2\times10^6$ cells/ml with RPMI 1640 medium. 40 μl tuberculin (97-8800, Synbiotics) was added to 20 mL cell suspension and cultured in a 37°C, 5% $CO_2$ incubator for 5 days. On day 5, the aforementioned cultured cells were collected by centrifugation, resuspended in fresh RPMI 1640 medium, adjusted to a density of $1.1\times10^6$ cells/ml, and seeded into 96-well cell culture plates at 90 μl per well. At the same time added were antibody samples (including the



Date Reçue/Date Received 2021-07-28

antibodies of the present disclosure: Hu23-11.IgG4AA, Hu32a-85.IgG4AA and Hu33-6.IgG4AA, positive control antibody H005-1, and negative control IgG4 protein, antibody gradient dilution concentration 0.3 mg/ml, 3 mg/ml and 30 mg/ml) gradient diluted with PBS (B320, Shanghai BasalMedia Technologies Co., Ltd.), 10μl/well. The cell culture plates were placed in a 37°C, 5% $CO_2$ incubator for incubation for 3 days. The cell culture plates were taken out and the cell culture supernatant was collected by centrifugation (4000 rpm, 10 min). IFN-γ levels were detected by using ELISA method (human IFN-γ detection kit (EHC102g.96, Neobioscience)). Instructions of the reagents were referred to for specific operations.

The test results are shown in Figure 2. The results showed that the anti-PD-1 antibodies Hu23-11.IgG4AA, Hu32a-85.IgG4AA and Hu33-6.IgG4AA of the present disclosure can all effectively activate IFN-γ secretion.

**Test Example 5. The effect of anti-PD-1 antibodies on colon cancer model MC38 in transgenic PD-1 mice**

MC38 cells were inoculated at $5\times10^5$ cells/mouse/100 μl into 90 hPD-1 TG mice (Biocytogen) subcutaneously at the right ribs. After 10 days, animals with too large or too small tumors were excluded. Based on the average tumor volume of about 120 $mm^3$, the mice were randomly divided into: the blank control Vehicle (PBS), the positive control H005-1 3 mpk, Hu32a-85.IgG4AA 1 mpk, Hu32a-85.IgG4AA 3 mpk, Hu23-11.IgG4AA 1 mpk, Hu23-11.IgG4AA 3 mpk and Hu33-6.IgG4AA 3 mpk, a total of 7 groups, each with 8 animals. Antibody of each group was injected intraperitoneally three times a week starting from Day 0. After the first week of administration, the tumors were found to be significantly inhibited. In the second and third weeks, the frequency of administration was adjusted to once a week for a total of 5 administrations. The tumor volume and animal weight were monitored twice a week and the data was recorded. When the tumor volume exceeded 2000 $mm^3$ or most tumors appeared ulcerated or the body weight was reduced by 20%, the tumor-bearing animals were euthanized as the experimental endpoint.

Tumor volume (TV) = $1/2 \times L_{long} \times L_{short}^2$

Tumor growth rate (T/C%) = (T-T0)/(C-C0) × 100%



Date Reçue/Date Received 2021-07-28

Tumor growth inhibition rate (TGI%) = 1- T/C %

Wherein T and T0 represent the tumor volumes at the end of the test and the start of the test in the antibody administration group, respectively, and C and C0 represent the tumor volumes at the end of the test and the start of the test in the blank control group, respectively.

The test results are shown in Table 19 and Figure 3. The test results showed that compared with the blank control, the antibodies of the present disclosure can all significantly inhibit the growth of mouse colon cancer MC38 xenograft tumors. Among them, Hu32a-85.IgG4AA-3 mpk group had the highest tumor inhibition rate, and the tumor inhibition rate was 77.64% at the last measurement. When the dosing frequency was three times a week for 3 administrations, in the measurement on the seventh day, the results showed that the tumor inhibition rates of the antibodies of the present disclosure were all significantly better than that of the positive control antibody H005-1; after that, the dosing frequency was reduced to once a week, after two administrations (Day 21), the difference in the efficacy of the antibodies of the present disclosure gradually increased, and showed a dose-dependent manner, among which Hu32a-85.IgG4AA was significantly better than the same dose of H005-1 ($p < 0.05$). In addition, the tumor-bearing mice can tolerate all the anti-PD-1 antibodies well, with body weight rising steadily during the whole administration process, and no obvious drug-induced body weight loss and other symptoms occurred.

Table 19. The effect of anti-PD-1 antibodies on the tumor growth inhibition rate of mouse colon cancer MC38 ($mm^3$)

| Days after first administration | H005-1 | Hu32a-85.IgG4AA | | Hu23-11.IgG4AA | | Hu33-6.IgG4AA |
|---|---|---|---|---|---|---|
| | 3mpk | 1mpk | 3mpk | 1mpk | 3mpk | 3mpk |
| 21 | 46.82% | 67.12% | 77.64% | 45.12% | 75.32% | 59.31% |

**Test Example 6. The effect of anti-PD-1 antibodies on colon cancer model MC38 in transgenic PD-1 mouse**

The transgenic PD-1 mice were purchased from ISIS INNOVATION LIMITED, University Offices, Wellington Square, Oxford OX1 2JD, England, and bred in Cephrim Biosciences, Inc. to obtain the fifth generation of mice. MC38 cells were inoculated at $5\times10^5$ cells/100 μl/animal into hPD-1 transgenic mice (half females and half males) subcutaneously



Date Reçue/Date Received 2021-07-28

at posterior right ribs. When the average tumor volume of mice reached between 80-100 $mm^3$, animals with too large or too small body weight or tumors were excluded. According to the tumor volume, the tumor-bearing mice were randomly divided into 5 groups (each with 8 animals): the negative control hIgG control 30 mpk, H005-1 10 mpk, H005-1 30 mpk, Hu33-6.IgG4AA 10 mpk and Hu33-6.IgG4AA 30 mpk. The grouping and administration date was set to Day 0. After grouping, each drug was administered intraperitoneally for a period of 22 days, once every two days, for a total of 11 times. The tumor volume was measured 2 times a week, the body weight was measured, and the data was recorded. The animal body weight and tumor volume of each group were all presented as mean ± standard deviation (Mean ± SEM), and Graphpad Prism 5 and Excel software were used for graphing, and student t test was used for statistical analysis.

Tumor volume (TV) = $0.5236 \times L_{long} \times L_{short}^2$

Tumor growth rate T/C% = (T-T0)/(C-C0) × 100%

Tumor growth inhibition rate %TGI = 1- T/C %

Wherein T and T0 represent the tumor volumes at the end of the test and the start of the test in the antibody administration group, respectively, and C and C0 represent the tumor volumes at the end of the test and the start of the test in the blank control group, respectively.

The test results are shown in Table 20 and Figure 4. The test results showed that compared with the control group, the antibodies of the present disclosure can significantly inhibit the growth of xenograft tumors of mouse colon cancer MC38. Among them, Hu33-6.IgG4AA-30 mpk group has the highest tumor inhibition rate, and the tumor inhibition rate is 80.4% at Day 20. In the low-dose group (10 mpk), the efficacy of Hu33-6.IgG4AA-10 mpk is better than that of the positive control H005-1-10 mpk.

Table 20. The effect of anti-PD-1 antibodies on tumor volume of mouse colon cancer MC38

| Days after first administration | hIgG control group | H005-1 10 mpk group | H005-1 30 mpk group | Hu33-6.IgG4AA 10 mpk group | Hu33-6.IgG4AA 30 mpk group |
|---|---|---|---|---|---|
| 0 | 96.2 | 96.1 | 95.3 | 94.7 | 94.5 |
| 20 | 1797.2 | 794.0 | 434.9 | 550.1 | 352.8 |
| 23 | | 1034.2 | 534.1 | 632.4 | 387.6 |

Note: the unit of the average tumor volume of each group in the table is: $mm^3$.



Date Reçue/Date Received 2021-07-28

**Test Example 7. Pharmacokinetic test of anti-PD-1 antibodies in cynomolgus monkeys**

Cynomolgus monkeys used in the experiment were 6 males, 2-5 years old, 2-5 kg, purchased from Guangdong Frontier Biotechnology Co., Ltd., license number: SCXK (Guangdong) 2015-0037, animal certificate number: 44613900000219.

Housing environment: the room temperature was controlled at 18°C-26°C, the relative humidity was 40%-70%, and the lighting was alternately light and dark of 12 h. Mice were allowed free access to food and water, except in the case that fasting was required.

The animals were weighed before administration, and the body weight was between 2.81 to 3.52 kg. Administration was performed by using an injection pump for subcutaneous intravenous infusion at the forelimbs or hindlimbs. The dose of each group was all 1 mg/kg (1 mpk), administered by a single intravenous injection at a rate of 0.1 mL/kg/min for an administration period of about 30 min. Before administration and 5 min, 0.25 h, 0.5 h (immediately after the administration was completed), 1 h, 2 h, 4 h, 8 h, 1 d, 2 d, 3 d, 4 d, 5 d, 7 d, 10 d, 13 d, 14 d, 21 d and 28 d after the start of intravenous infusion, whole blood of the animal was collected at the hind limb veins and the serum was separated. Among them, about 2 mL whole blood was collected before administration and 14 d, 21 d and 28 d after the start of intravenous infusion, and about 1 mL whole blood was collected at the rest of blood sampling time points. The blood drug concentration in the serum was detected by ELISA and PK analysis was performed. The results are shown in Table 21.

Table 21. Pharmacokinetics of humanized anti-PD1 antibodies in cynomolgus monkeys

| | Hu23-11.IgG4AA | Hu33-6.IgG4AA |
|---|---|---|
| t1/2 (day) | 5.5±0.7 | 4.6±1.3 |
| Cmax (μg/mL) | 23.75±2.29 | 21.47±2.13 |
| AUC (h*μg/ml) | 2775±241 | 2319±518 |
| CL (ml/day/kg) | 8.7±0.7 | 10.7±2.3 |
| Vz (mL/kg) | 69±3.6 | 67.9±3.4 |

The results showed that Hu23-11.IgG4AA and Hu33-6.IgG4AA have good pharmacokinetic activities.



Date Reçue/Date Received 2021-07-28

Although for a clear understanding, the aforementioned invention has been described in detail with the aid of figures and examples, the descriptions and examples should not be interpreted as limiting the scope of the present disclosure. The disclosures of all patents and scientific documents cited in this article are fully and clearly incorporated by reference.



Date Reçue/Date Received 2021-07-28

**What is claimed is:**

1. An anti-PD-1 antibody or antigen-binding fragment thereof, which comprises a heavy chain variable region and a light chain variable region, wherein:

the heavy chain variable region comprises: HCDR1 as shown in SEQ ID NO: 65, HCDR2 as shown in SEQ ID NO: 66, and HCDR3 as shown in SEQ ID NO: 67; and

the light chain variable region comprises: LCDR1 as shown in SEQ ID NO: 68, LCDR2 as shown in SEQ ID NO: 12, and LCDR3 as shown in SEQ ID NO: 69;

preferably,

the heavy chain variable region comprises HCDR1 as shown in SEQ ID NO: 8, HCDR2 as shown in SEQ ID NO: 9, and HCDR3 as shown in SEQ ID NO: 10; and

the light chain variable region comprises LCDR2 as shown in SEQ ID NO: 12, LCDR3 as shown in SEQ ID NO: 13, and LCDR1 as shown in the general formula RSSQSX$_{13}$VHSX$_{14}$X$_{15}$X$_{16}$TYLE (SEQ ID NO: 68), wherein X$_{13}$ is L, X$_{14}$ is selected from the group consisting of N, Q, L, T and D, X$_{15}$ is selected from the group consisting of G, A and V, and X$_{16}$ is N.

2. An anti-PD-1 antibody or antigen-binding fragment thereof, which comprises a heavy chain variable region and a light chain variable region, wherein the combination of the heavy chain variable region and the light chain variable region is selected from any one of the following (a) to (e):

(a) the heavy chain variable region comprising HCDR1, HCDR2 and HCDR3 as shown in SEQ ID NO: 8, SEQ ID NO: 9 and SEQ ID NO: 10, respectively, and

the light chain variable region comprising LCDR2 and LCDR3 as shown in SEQ ID NO: 12 and SEQ ID NO: 13, respectively, and LCDR1 as shown in SEQ ID NO: 11, 47, 48, 49, 50, 51 or 52;

(b) the heavy chain variable region comprising HCDR1, HCDR2 and HCDR3 as shown in SEQ ID NO: 14, SEQ ID NO: 15 and SEQ ID NO: 16, respectively, and

the light chain variable region comprising LCDR1, LCDR2 and LCDR3 as shown in SEQ ID NO: 17, SEQ ID NO: 12 and SEQ ID NO: 18, respectively;

(c) the heavy chain variable region comprising HCDR1, HCDR2 and HCDR3 as



Date Reçue/Date Received 2021-07-28

shown in SEQ ID NO: 21, SEQ ID NO: 22 and SEQ ID NO: 23, respectively, and

the light chain variable region comprising LCDR1, LCDR2 and LCDR3 as shown in SEQ ID NO: 24, SEQ ID NO: 25 and SEQ ID NO: 26;

(d) the heavy chain variable region comprising HCDR1, HCDR2 and HCDR3 as shown in SEQ ID NO: 14, SEQ ID NO: 15 and SEQ ID NO: 16, respectively, and

the light chain variable region comprising LCDR2 and LCDR3 as shown in SEQ ID NO: 12 and SEQ ID NO: 13, respectively, and LCDR1 as shown in SEQ ID NO: 11, 47, 48, 49, 50, 51 or 52; and

(e) the heavy chain variable region comprising HCDR1, HCDR2 and HCDR3 as shown in SEQ ID NO: 8, SEQ ID NO: 9 and SEQ ID NO: 10, respectively, and

the light chain variable region comprising LCDR1, LCDR2 and LCDR3 as shown in SEQ ID NO: 17, SEQ ID NO: 12 and SEQ ID NO: 18, respectively;

preferably, the anti-PD-1 antibody comprises a combination of the heavy chain variable region and the light chain variable region as shown below:

(a1) the heavy chain variable region comprising HCDR1, HCDR2 and HCDR3 as shown in SEQ ID NO: 8, SEQ ID NO: 9 and SEQ ID NO: 10, respectively, and

the light chain variable region comprising LCDR1, LCDR2 and LCDR3 as shown in SEQ ID NO: 49, SEQ ID NO: 12 and SEQ ID NO: 13, respectively; or

(a2) the heavy chain variable region comprising HCDR1, HCDR2 and HCDR3 as shown in SEQ ID NO: 21, SEQ ID NO: 22 and SEQ ID NO: 23, respectively, and

the light chain variable region comprising LCDR1, LCDR2 and LCDR3 as shown in SEQ ID NO: 24, SEQ ID NO: 25 and SEQ ID NO: 26, respectively.

3. An anti-PD-1 antibody or antigen-binding fragment thereof, which comprises a combination of the heavy chain variable region and the light chain variable region selected from any one of the following iv) to vi):

iv) the heavy chain variable region comprising HCDR1, HCDR2 and HCDR3 with the same sequences as those of the heavy chain variable region shown in sequence SEQ ID NO: 4, and the light chain variable region comprising LCDR1, LCDR2 and LCDR3 with the same sequences as those of the light chain variable region shown in sequence SEQ ID NO: 5;



Date Reçue/Date Received 2021-07-28

v) the heavy chain variable region comprising HCDR1, HCDR2 and HCDR3 with the same sequences as those of the heavy chain variable region shown in sequence SEQ ID NO: 6, and the light chain variable region comprising LCDR1, LCDR2 and LCDR3 with the same sequences as those of the light chain variable region shown in sequence SEQ ID NO: 7; and

vi) the heavy chain variable region comprising HCDR1, HCDR2 and HCDR3 with the same sequences as those of the heavy chain variable region shown in sequence SEQ ID NO: 19, and the light chain variable region comprising LCDR1, LCDR2 and LCDR3 with the same sequences as those of the light chain variable region shown in sequence SEQ ID NO: 20.

4. The anti-PD-1 antibody or antigen-binding fragment thereof according to any one of claims 1 to 3, wherein the anti-PD-1 antibody or antigen-binding fragment thereof is a murine antibody or antigen-binding fragment thereof, a chimeric antibody or antigen-binding fragment thereof, a fully human antibody or antigen-binding fragment thereof, or a humanized antibody or antigen-binding fragment thereof.

5. The anti-PD-1 antibody or antigen-binding fragment thereof according to claim 4, wherein the anti-PD-1 antibody is a humanized antibody, said humanized antibody comprises a framework region derived from a human antibody or a framework region variant thereof, wherein:

the framework region variant has at most 11 amino acid back mutations in each of the light chain framework region and/or the heavy chain framework region of the human antibody;

preferably, the framework region variant comprises mutation(s) selected from any one of the following (f) to (h):

(f) 2G amino acid back mutation comprised in the light chain variable region, and/or

one or more amino acid back mutations selected from the group consisting of 27Y, 48I, 67T, 69L, 82F and 93T comprised in the heavy chain variable region;

(g) 2V amino acid back mutation comprised in the light chain variable region, and/or

one or more amino acid back mutations selected from the group consisting of 26D,



Date Reçue/Date Received 2021-07-28

27F, 30T, 38K, 43H, 48I, 66K, 67A, 69L, 82F and 93T comprised in the heavy chain variable region; and

(h) one or more amino acid back mutations selected from the group consisting of 42G, 44V and 71Y comprised in the light chain variable region, and/or

1K and/or 94S amino acid back mutations comprised in the heavy chain variable region; wherein the amino acid positions are numbered and determined according to the Kabat Criteria.

6. The anti-PD-1 antibody or antigen-binding fragment thereof according to claim 4, the combination of the heavy chain variable region and the light chain variable region of the antibody is selected from any one of the following (i) to (o):

(i) a heavy chain variable region, the sequence of which is as shown in SEQ ID NO: 4 or has at least 90% sequence identity with SEQ ID NO: 4, and/or

a light chain variable region, the sequence of which is as shown in SEQ ID NO: 5 or has at least 90% sequence identity with SEQ ID NO: 5;

(j) a heavy chain variable region, the sequence of which is as shown in SEQ ID NO: 6 or has at least 90% sequence identity with SEQ ID NO: 6, and/or

a light chain variable region, the sequence of which is as shown in SEQ ID NO: 7 or has at least 90% sequence identity with SEQ ID NO: 7;

(k) a heavy chain variable region, the sequence of which is as shown in SEQ ID NO: 19 or has at least 90% sequence identity with SEQ ID NO: 19, and/or

a light chain variable region, the sequence of which is as shown in SEQ ID NO: 20 or has at least 90% sequence identity with SEQ ID NO: 20;

(l) a heavy chain variable region, the sequence of which is as shown in SEQ ID NO: 27, 30, 31 or 32, or has at least 90% sequence identity with SEQ ID NO: 27, 30, 31 or 32, and/or

a light chain variable region, the sequence of which is as shown in SEQ ID NO: 28, 29, 34, 35, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63 or 64, or has at least 90% sequence identity with SEQ ID NO: 28, 29, 34, 35, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63 or 64;

(m) a heavy chain variable region, the sequence of which is as shown in SEQ ID NO:



Date Reçue/Date Received 2021-07-28

33, 36, 37, 38, 39 or 40, or has at least 90% sequence identity with SEQ ID NO: 33, 36, 37, 38, 39 or 40, and/or

a light chain variable region, the sequence of which is as shown in SEQ ID NO: 34, 35, 28, 29, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63 or 64, or has at least 90% sequence identity with SEQ ID NO: 34, 35, 28, 29, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63 or 64;

(n) a heavy chain variable region, the sequence of which is as shown in SEQ ID NO: 41, 45 or 46, or has at least 90% sequence identity with SEQ ID NO: 41, 45 or 46, and/or

a light chain variable region, the sequence of which is as shown in SEQ ID NO: 42, 43 or 44, or has at least 90% sequence identity with SEQ ID NO: 42, 43 or 44, and

(o) a heavy chain variable region, the sequence of which is as shown in SEQ ID NO: 70 or has at least 90% sequence identity with SEQ ID NO: 70, and/or

a light chain variable region, the sequence of which is as shown in SEQ ID NO: 71 or has at least 90% sequence identity with SEQ ID NO: 71;

preferably, the combination of the heavy chain variable region and the light chain variable region is selected from:

(p) a heavy chain variable region, the sequence of which is as shown in SEQ ID NO: 27 or has at least 90% sequence identity with SEQ ID NO: 27, and/or

a light chain variable region, the sequence of which is as shown in SEQ ID NO: 55 or has at least 90% sequence identity with SEQ ID NO: 55; or

(q) a heavy chain variable region, the sequence of which is as shown in SEQ ID NO: 46 or has at least 90% sequence identity with SEQ ID NO: 46, and/or

a light chain variable region, the sequence of which is as shown in SEQ ID NO: 43 or has at least 90% sequence identity with SEQ ID NO: 43.

7. The anti-PD-1 antibody or antigen-binding fragment thereof according to any one of claims 1 to 6, wherein the antibody further comprises an antibody constant region; preferably, the heavy chain constant region of the antibody constant region is selected from the group consisting of human IgG1, IgG2, IgG3 and IgG4 constant regions and conventional variants thereof, the light chain constant region of the antibody constant region is selected from the group consisting of human antibody κ and λ chain constant regions and conventional variants



Date Reçue/Date Received 2021-07-28

thereof; more preferably, the antibody comprises the heavy chain constant region as shown in SEQ ID NO: 72 or 79, and the light chain constant region as shown in SEQ ID NO: 73.

8. The anti-PD-1 antibody or antigen-binding fragment thereof according to any one of claims 1 to 7, wherein the anti-PD-1 antibody comprises: a light chain as shown in SEQ ID NO: 78 and a heavy chain as shown in SEQ ID NO: 77 or 82; or the anti-PD-1 antibody comprises a light chain as shown in SEQ ID NO: 75 and a heavy chain as shown in SEQ ID NO: 74, 76, 80 or 81; preferably, the anti-PD-1 antibody comprises:

a heavy chain as shown in SEQ ID NO: 74 and a light chain as shown in SEQ ID NO: 75; or

a heavy chain as shown in SEQ ID NO: 77 and a light chain as shown in SEQ ID NO: 78.

9. The anti-PD-1 antibody or antigen-binding fragment thereof according to any one of claims 1 to 8, wherein the antigen-binding fragment is selected from the group consisting of Fab, Fab', $F(ab')_2$, single-chain antibody (scFv), dimerized V region (diabody) and disulfide bond stabilized V region (dsFv).

10. The anti-PD-1 antibody or antigen-binding fragment thereof according to any one of claims 1 to 9, wherein the antibody is a bispecific antibody, a multispecific antibody or an antibody fusion protein.

11. An isolated monoclonal antibody or antigen-binding fragment thereof, said antibody competitively binds to human PD-1 with the anti-PD-1 antibody or antigen-binding fragment thereof according to any one of claims 1 to 10.

12. A pharmaceutical composition comprising:

a therapeutically effective amount of the anti-PD-1 antibody or antigen-binding fragment thereof according to any one of claims 1 to 10 or a therapeutically effective amount of the isolated monoclonal antibody or antigen-binding fragment thereof according to claim



Date Reçue/Date Received 2021-07-28

11, and one or more pharmaceutically acceptable carriers, diluents, buffers or excipients.

13. A nucleic acid molecule encoding the anti-PD-1 antibody or antigen-binding fragment thereof according to any one of claims 1 to 10, or encoding the isolated monoclonal antibody or antigen-binding fragment thereof according to claim 11.

14. A host cell comprising the nucleic acid molecule according to claim 13.

15. A method for the immunodetection or determination of PD-1, comprising a step of using the anti-PD-1 antibody or antigen-binding fragment thereof according to any one of claims 1 to 10, or

a step of using the isolated monoclonal antibody or antigen-binding fragment thereof according to claim 11.

16. A kit comprising the anti-PD-1 antibody or antigen-binding fragment thereof according to any one of claims 1 to 10 or the isolated monoclonal antibody or antigen-binding fragment thereof according to claim 11.

17. A method for treating diseases associated with PD-1, comprising administering to a subject a therapeutically effective amount of the anti-PD-1 antibody or antigen-binding fragment thereof according to any one of claims 1 to 10, or the isolated monoclonal antibody or antigen-binding fragment thereof according to claim 11, or the pharmaceutical composition according to claim 12, or the nucleic acid molecule according to claim 13; wherein the disease is preferably tumor; more preferably the disease is selected from the group consisting of: head and neck squamous cell carcinoma, head and neck cancer, brain cancer, glioma, glioblastoma multiforme, neuroblastoma, central nervous system cancer, neuroendocrine tumor, pharyngeal cancer, nasopharyngeal cancer, esophageal cancer, thyroid cancer, malignant pleural mesothelioma, lung cancer, breast cancer, liver cancer, hepatoma, hepatocellular carcinoma, hepatobiliary cancer, pancreatic cancer, gastric cancer, gastrointestinal cancer, bowel cancer, colon cancer, colorectal cancer, kidney cancer, clear cell renal cell carcinoma, ovarian cancer,



Date Reçue/Date Received 2021-07-28

endometrial cancer, cervical cancer, bladder cancer, prostate cancer, testicular cancer, skin cancer, melanoma, leukemia, lymphoma, bone cancer, chondrosarcoma, myeloma, multiple myeloma, myelodysplastic syndrome, myeloproliferative neoplasm, squamous cell carcinoma, Ewing's sarcoma, systemic light chain amyloidosis and Merkel cell carcinoma; more preferably, the lymphoma is selected from the group consisting of: Hodgkin's lymphoma, non-Hodgkin's lymphoma, diffuse large B-cell lymphoma, follicular lymphoma, primary mediastinal large B-cell lymphoma, mantle cell lymphoma, small lymphocytic lymphoma, T-cell/histiocyte rich large B-cell lymphoma and lymphoplasmacytic lymphoma, the lung cancer is selected from the group consisting of: non-small cell lung cancer and small cell lung cancer, the leukemia is selected from the group consisting of: chronic myeloid leukemia, acute myeloid leukemia, lymphocytic leukemia, lymphoblastic leukemia, acute lymphoblastic leukemia, chronic lymphocytic leukemia and myeloid leukemia; most preferably, the disease is selected from the group consisting of: PD-L1 positive melanoma, lung cancer, non-small cell lung cancer, breast cancer, gastric cancer, kidney cancer, bladder cancer, bowel cancer and colon cancer.



Date Reçue/Date Received 2021-07-28

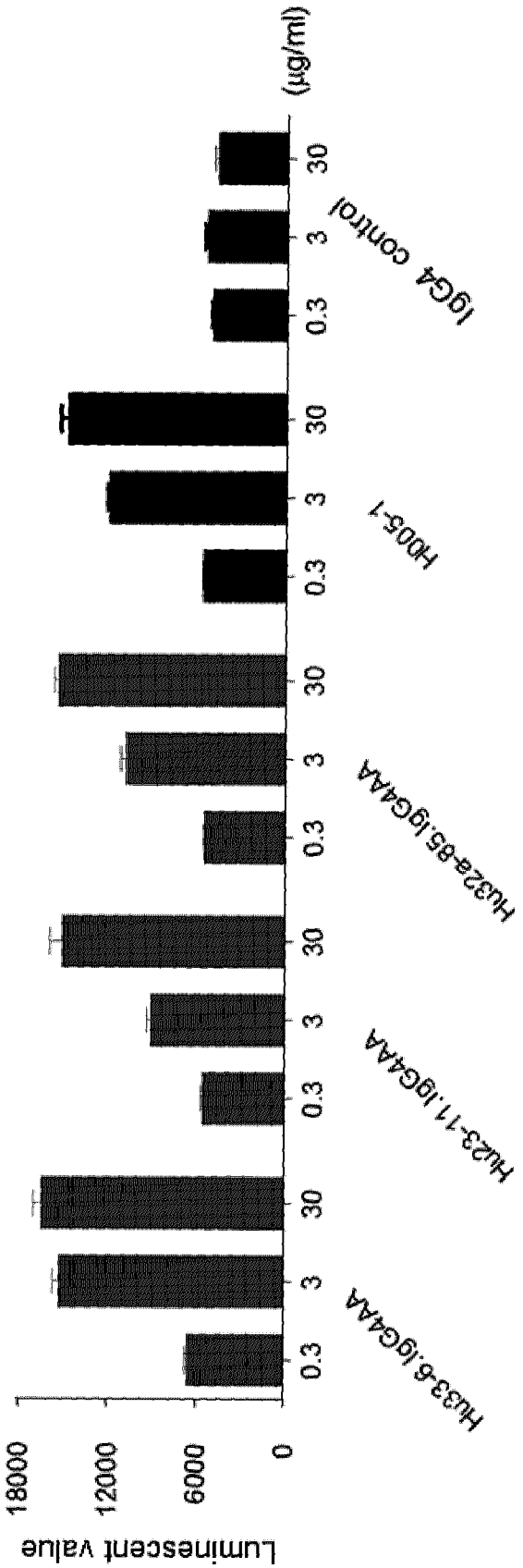

Luminescent value
18000
12000
6000
0
Hu33-6.IgG4AA
Hu23-11.IgG4AA
Hu32a-85.IgG4AA
H005-1
IgG4 control
0.3
3
30
(μg/ml)

Figure 1

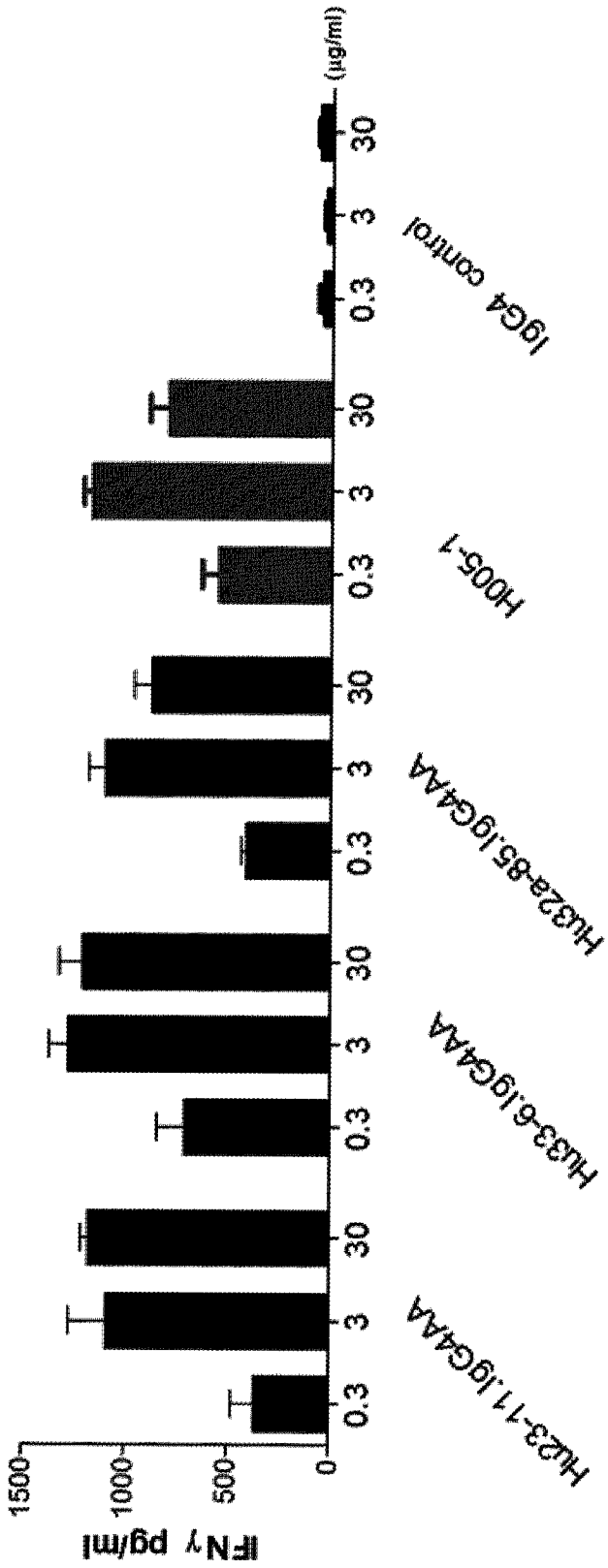

IFNγ pg/ml
1500
1000
500
0
(μg/ml)
0.3
3
30
hL23-11.IgG4AA
hL33-6.IgG4AA
hL32a-85.IgG4AA
H005-1
IgG4 control

Figure 2

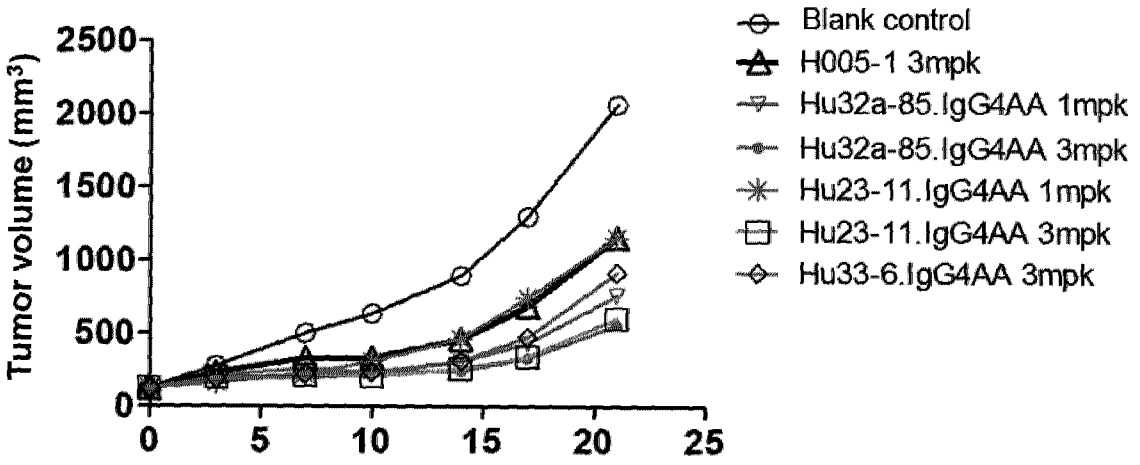



**Figure 3**

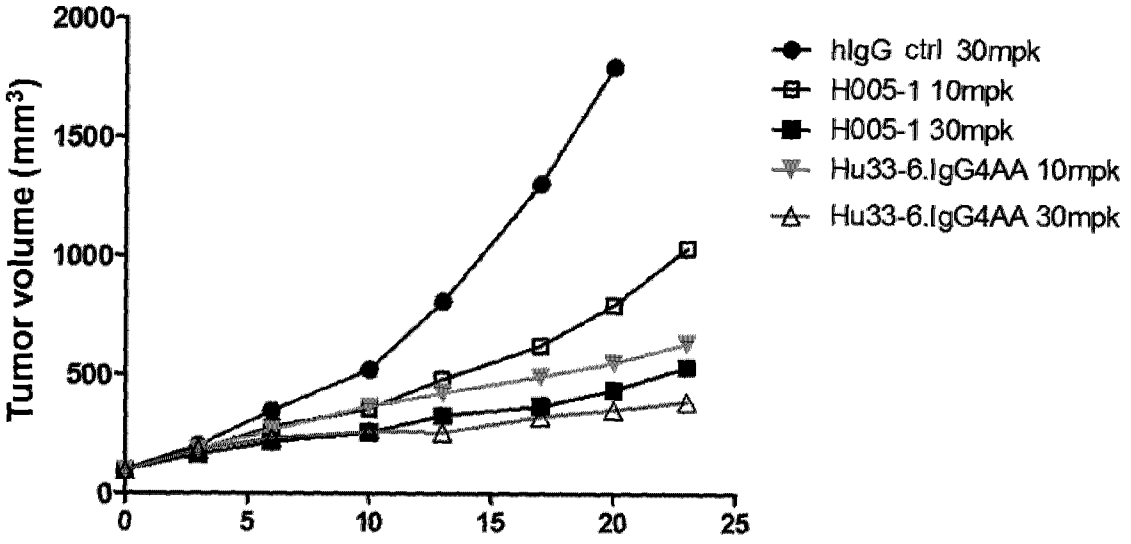



**Figure 4**

Date Reçue/Date Received 2021-07-28