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Honjo et al.

(10) **Patent No.: US 8,728,474 B2**
(45) **Date of Patent: *May 20, 2014**

(54) **IMMUNOPOTENTIATIVE COMPOSITION**

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(73) Assignees: **Ono Pharmaceutical Co., Ltd.**, Osaka (JP); **Tasuku Honjo**, Kyoto (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 823 days.

This patent is subject to a terminal disclaimer.

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(22) Filed: **Dec. 2, 2010**

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Related U.S. Application Data

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Feb. 6, 2003 (JP) 2003-029846

(51) **Int. Cl.**
A61K 39/395 (2006.01)

(52) **U.S. Cl.**
USPC **424/144.1**; 424/141.1; 424/154.1

(58) **Field of Classification Search**
CPC A61K 2039/505; A61K 39/3955; C07K 16/2803; C07K 16/2818; C07K 16/18
See application file for complete search history.

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Primary Examiner — Ilia Ouspenski
(74) *Attorney, Agent, or Firm* — Sughrue Mion, PLLC

(57) **ABSTRACT**

Compositions for cancer or infection treatment via immunopotentiation caused by inhibition of immunosuppressive signal induced by PD-1, PD-L1, or PD-L2 and therapies using them, immunopotentiative substrates included as the active ingredient, screening methods of the substrates for cancer or infection treatment, cell lines used for the screening methods, evaluation methods that select the substrates for cancer treatment, and carcinoma cell transplanted mammals used for the evaluation methods. The compositions of the present invention that inhibits the function of PD-1, PD-L1, or PD-L2 are useful for treatment of cancer or infection.

17 Claims, 17 Drawing Sheets

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FIG. 1 (A)

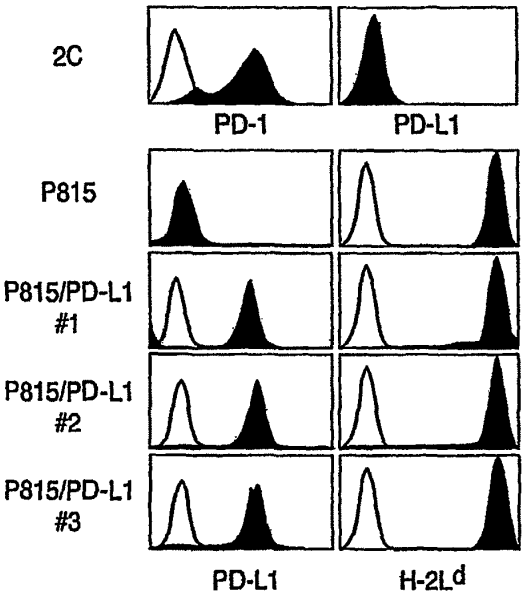

2C
PD-1
PD-L1
P815
P815/PD-L1 #1
P815/PD-L1 #2
P815/PD-L1 #3
PD-L1
H-2L^d

FIG. 1 (B)

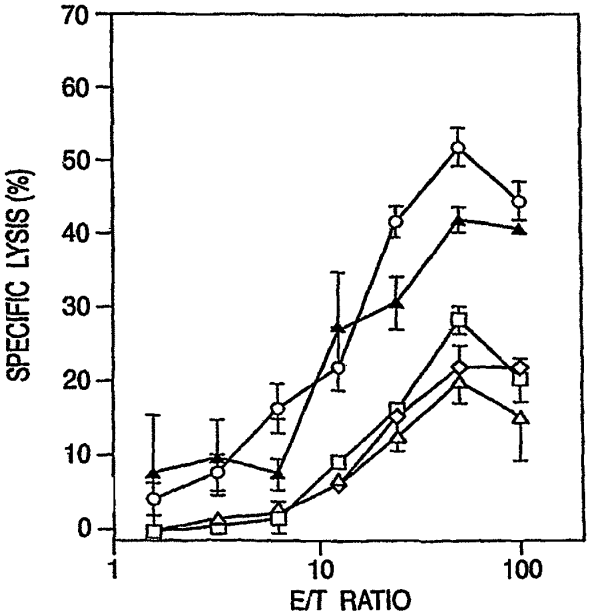

SPECIFIC LYSIS (%)
70
60
50
40
30
20
10
0
1
10
100
E/T RATIO

FIG. 2 (A)

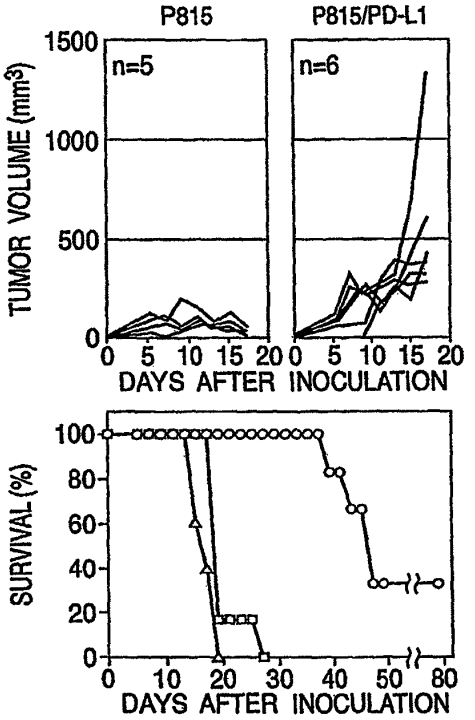

P815
P815/PD-L1
n=5
n=6
TUMOR VOLUME (mm3)
1500
1000
500
0
0 5 10 15 20
0 5 10 15 20
DAYS AFTER INOCULATION
SURVIVAL (%)
100
80
60
40
20
0
0 10 20 30 40 50 80
DAYS AFTER INOCULATION

FIG. 2 (B)

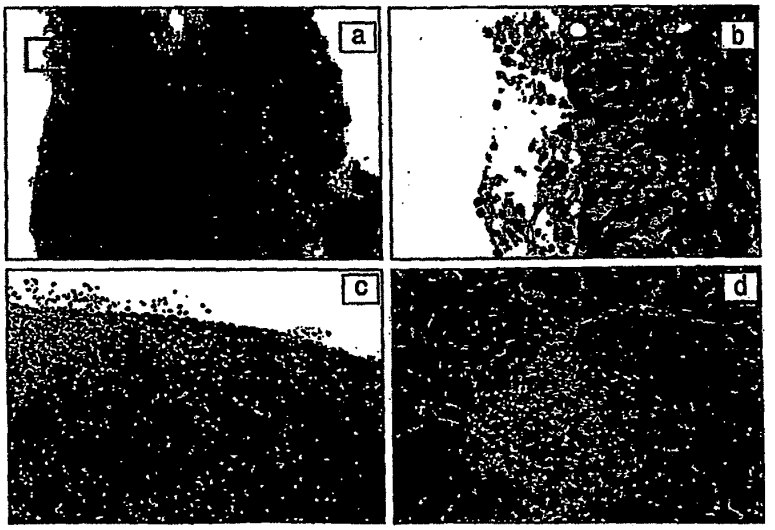

a
b
c
d

FIG. 3 (A)

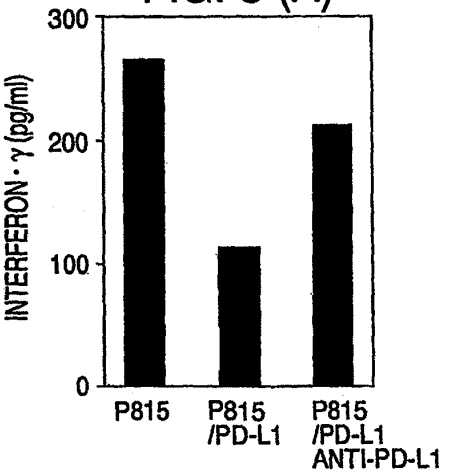

INTERFERON · γ (pg/ml)
300
200
100
0
P815
P815 /PD-L1
P815 /PD-L1 ANTI-PD-L1

FIG. 3 (B)

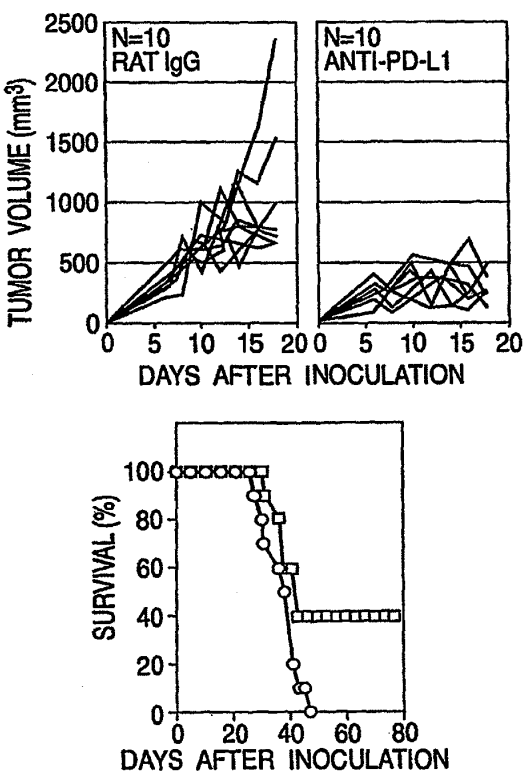

N=10
RAT IgG
N=10
ANTI-PD-L1
TUMOR VOLUME (mm³)
2500
2000
1500
1000
500
0
0 5 10 15 20
DAYS AFTER INOCULATION
SURVIVAL (%)
100
80
60
40
20
0
0 20 40 60 80
DAYS AFTER INOCULATION

FIG. 4

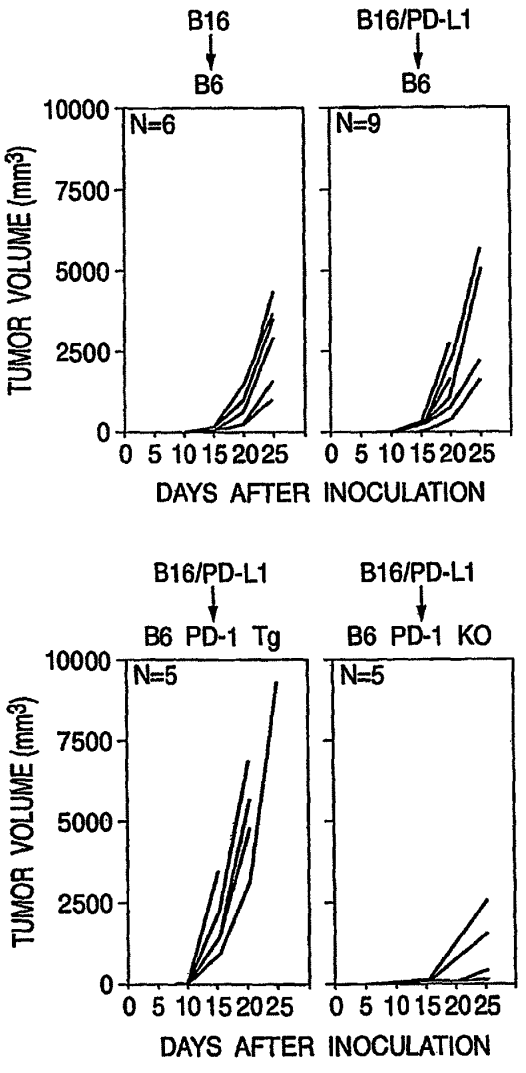

B16
B6
B16/PD-L1
B6
N=6
N=9
TUMOR VOLUME (mm3)
10000
7500
5000
2500
0
0 5 10 15 20 25
0 5 10 15 20 25
DAYS AFTER INOCULATION
B16/PD-L1
B6 PD-1 Tg
B16/PD-L1
B6 PD-1 KO
N=5
N=5
TUMOR VOLUME (mm3)
10000
7500
5000
2500
0
0 5 10 15 20 25
0 5 10 15 20 25
DAYS AFTER INOCULATION

FIG. 5 (A)

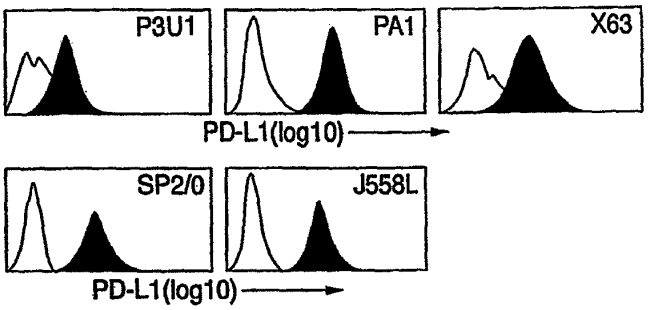


FIG. 5 (B)

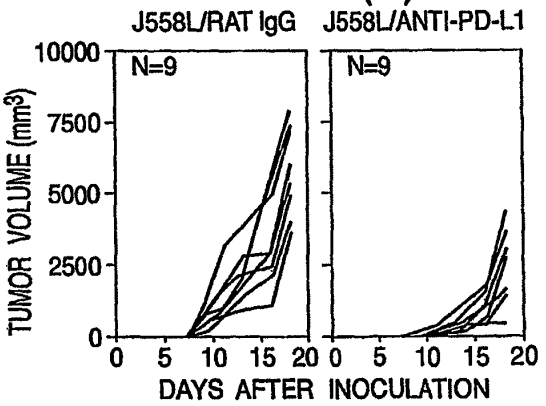


FIG. 5 (C)

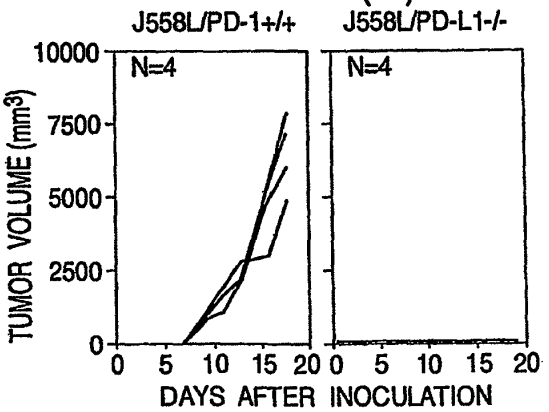


FIG. 6 (A)

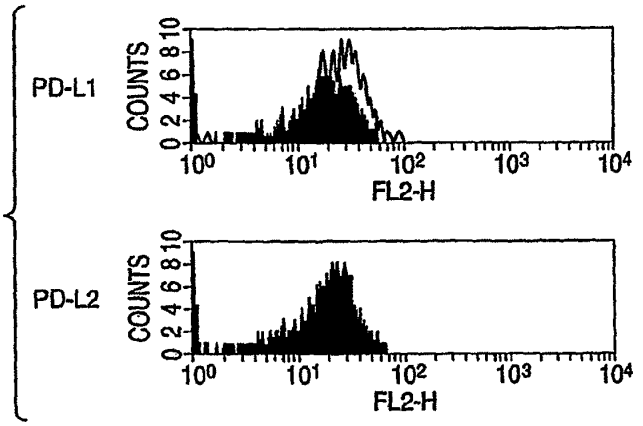

PD-L1
COUNTS
0 2 4 6 8 10
10^0 10^1 10^2 10^3 10^4
FL2-H
PD-L2
COUNTS
0 2 4 6 8 10
10^0 10^1 10^2 10^3 10^4
FL2-H

FIG. 6 (B)

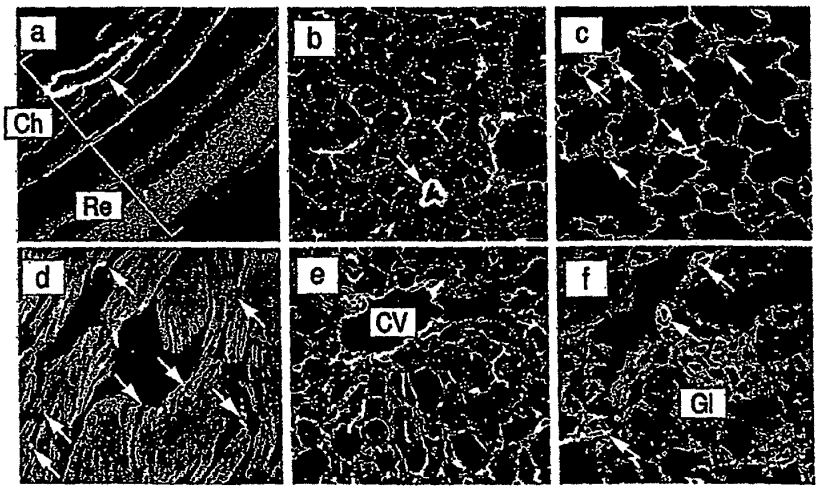

a
Ch
Re
b
c
d
e
CV
f
Gl

FIG. 7 (A)

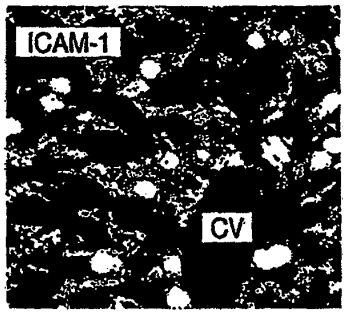
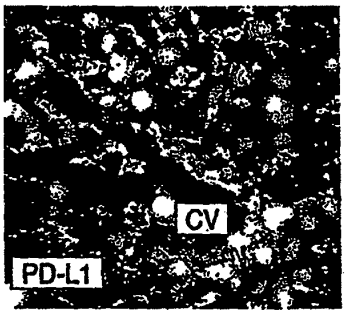


FIG. 7 (B)



x 40

FIG. 8

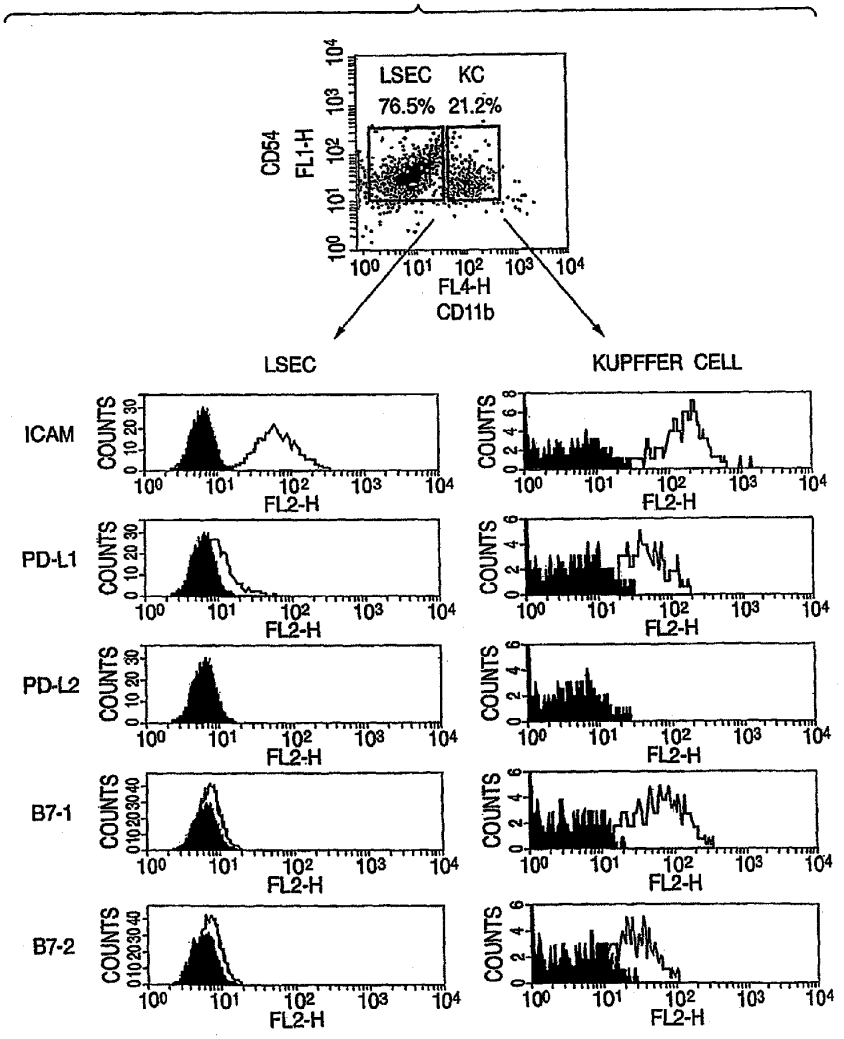

LSEC KC
76.5% 21.2%
CD54
FL1-H
FL4-H
CD11b
LSEC
KUPFFER CELL
ICAM
PD-L1
PD-L2
B7-1
B7-2
COUNTS
FL2-H

FIG. 9

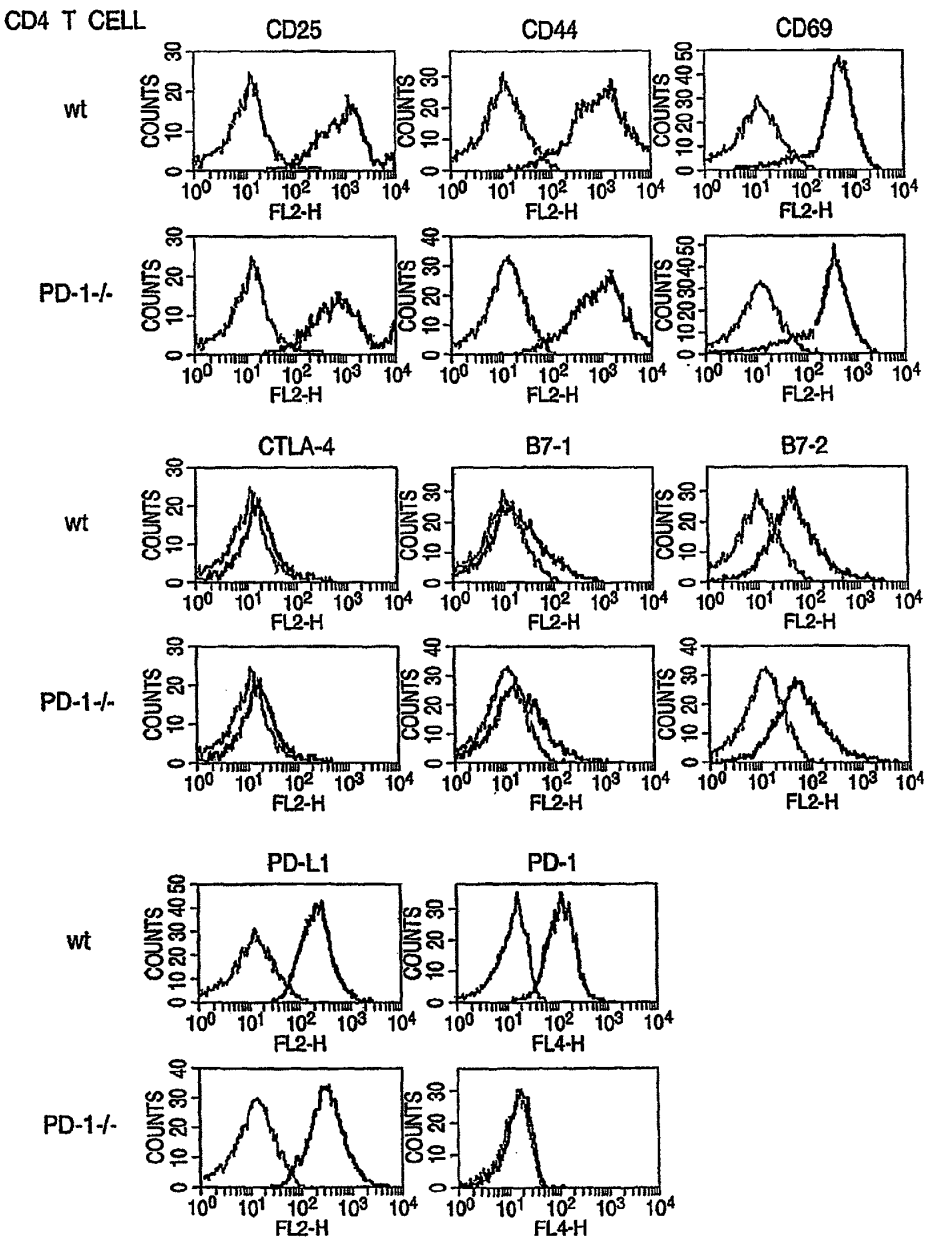

CD4 T CELL
CD25
CD44
CD69
wt
PD-1-/-
CTLA-4
B7-1
B7-2
PD-L1
PD-1
COUNTS
FL2-H
FL4-H

FIG. 10

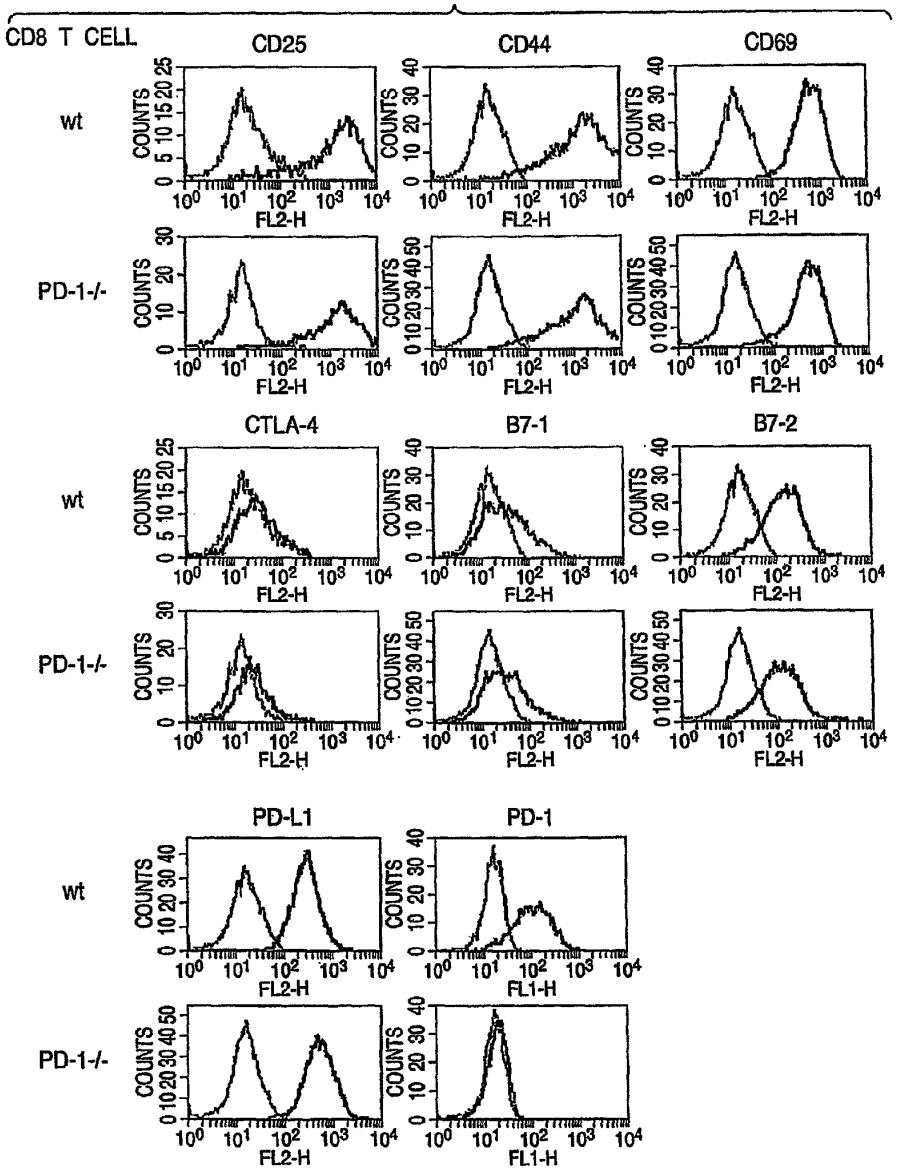

CD8 T CELL
CD25
CD44
CD69
wt
PD-1-/-
CTLA-4
B7-1
B7-2
PD-L1
PD-1
COUNTS
FL2-H
FL1-H

FIG. 11 (A)

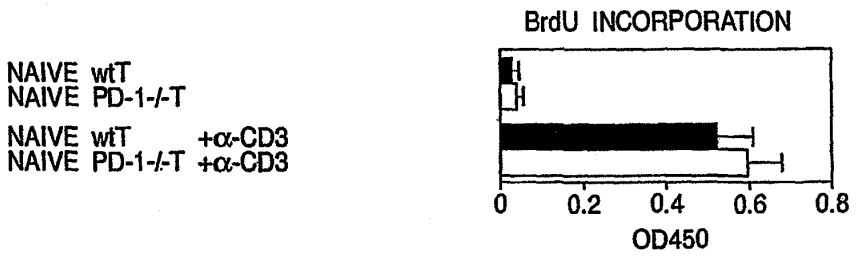


FIG. 11 (B)

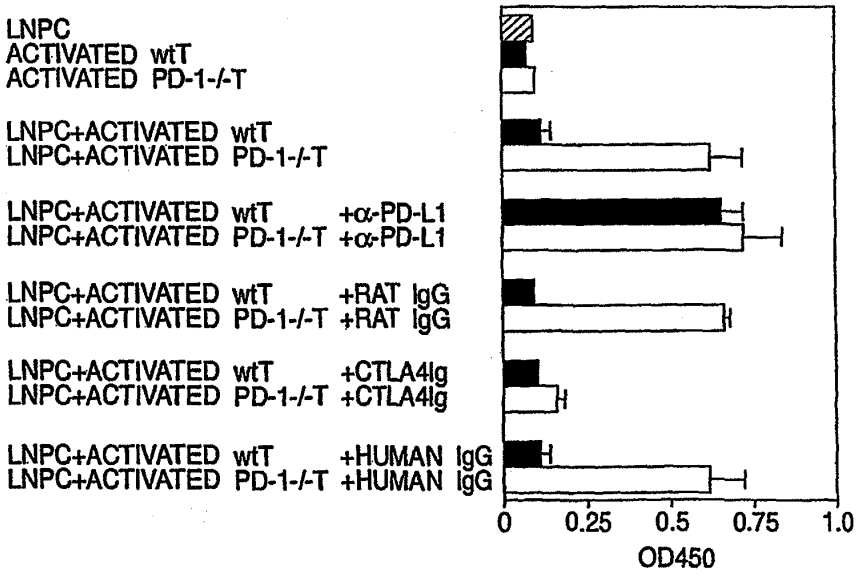


FIG. 12 (A)

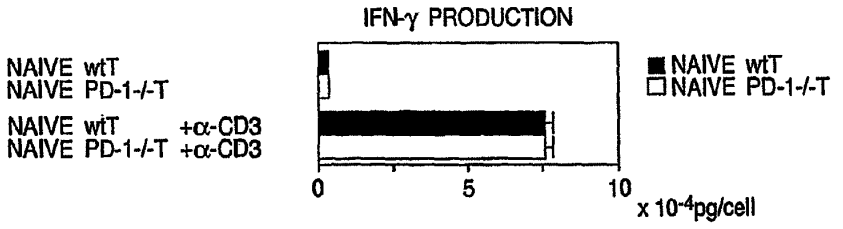


FIG. 12 (B)

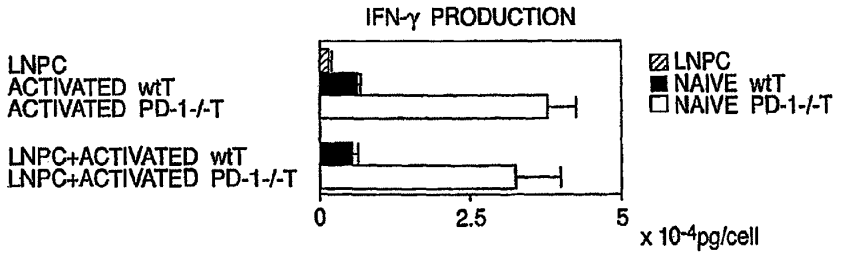


FIG. 12 (C)

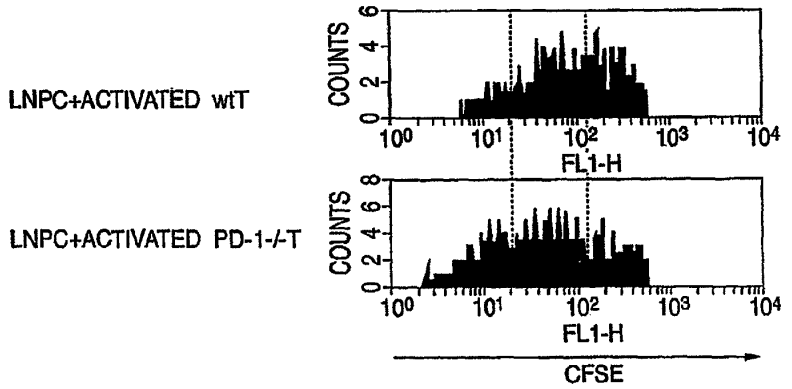


FIG. 13 (A)

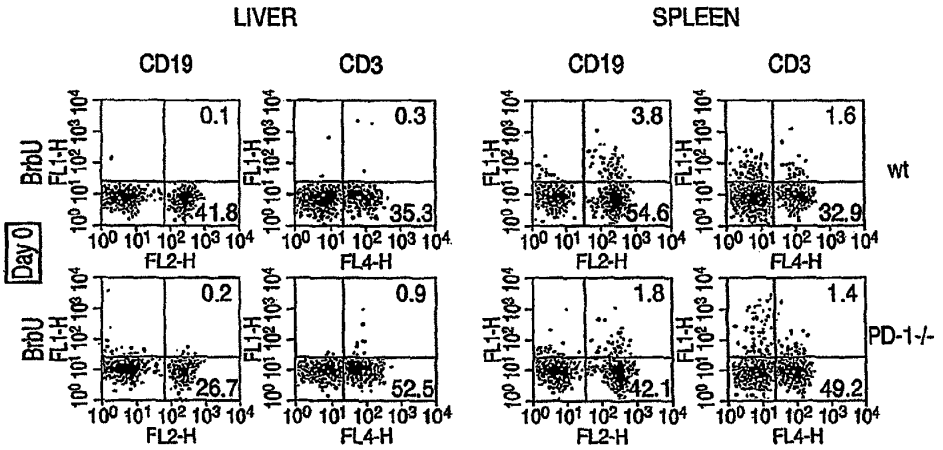


FIG. 13 (B)

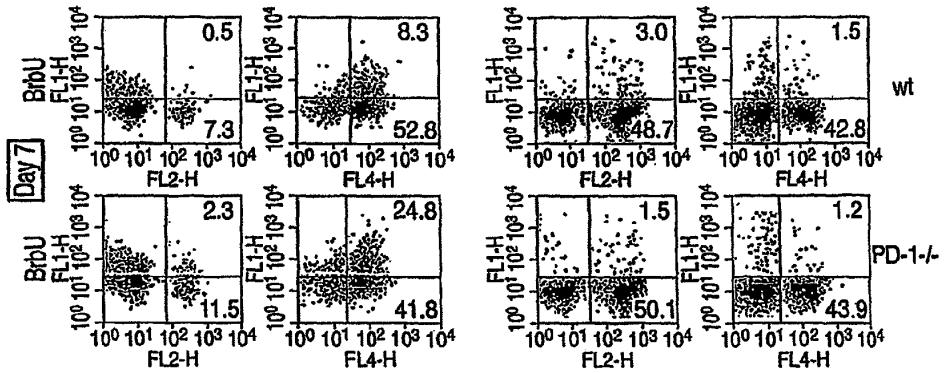


FIG. 14 (A)

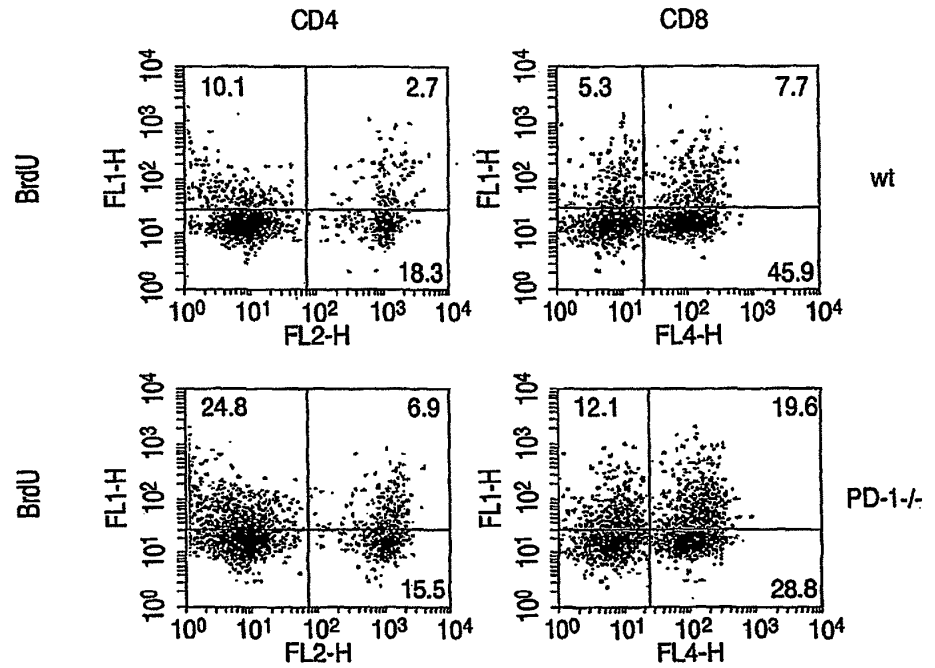


FIG. 14 (B)

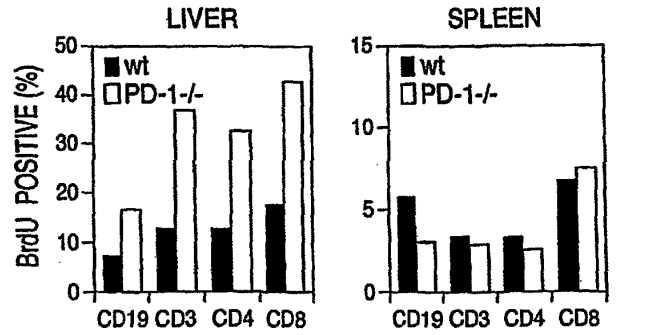


FIG. 15

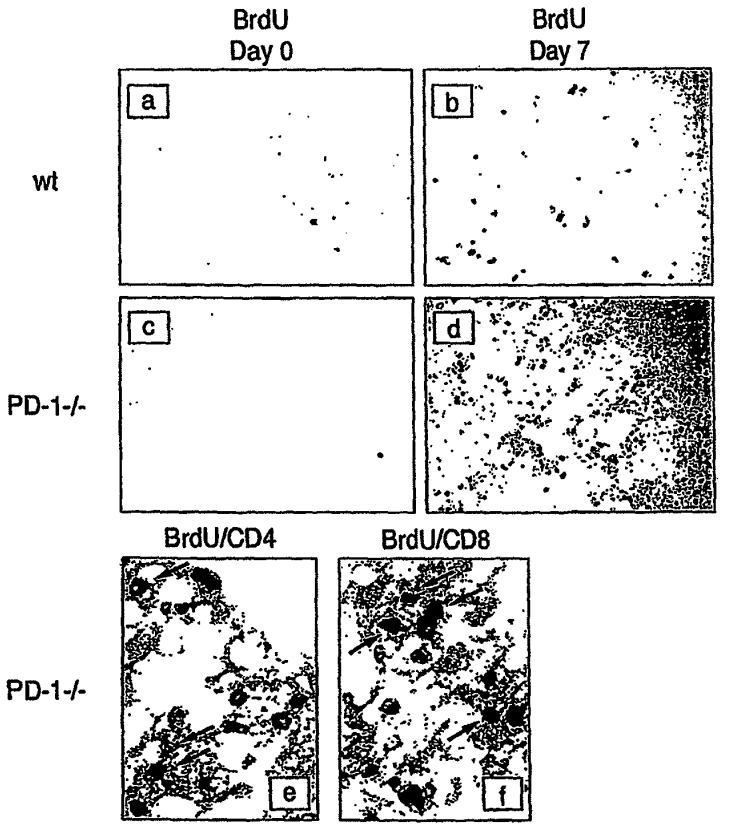


FIG. 16

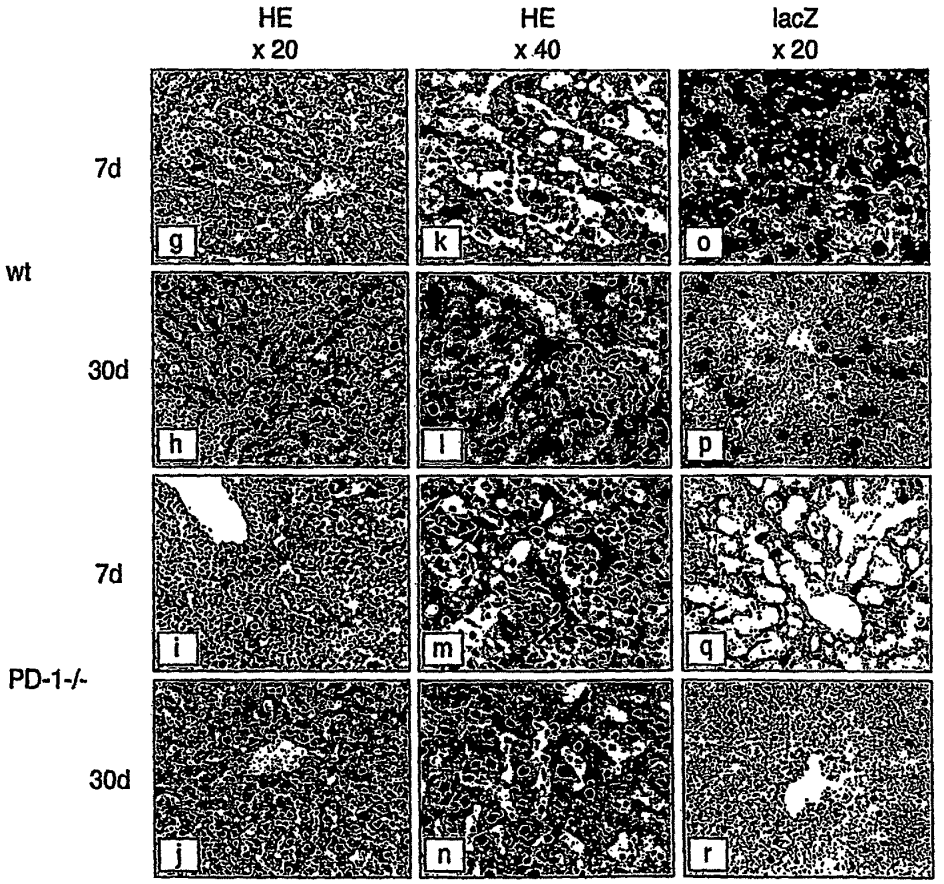


FIG. 17 (a)

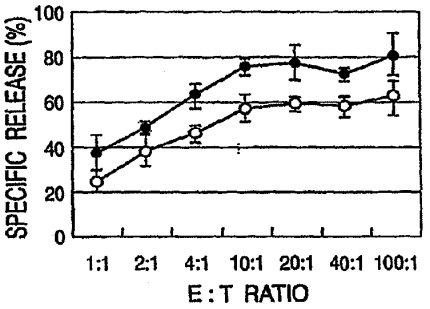


FIG. 17 (b)

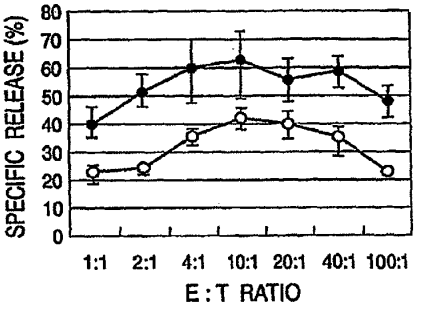


FIG. 17 (c)

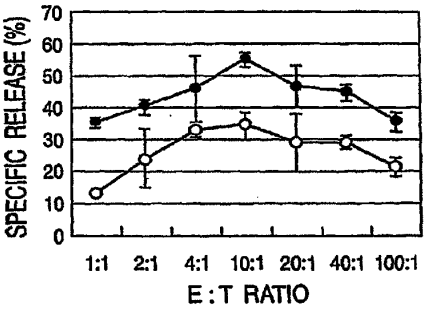
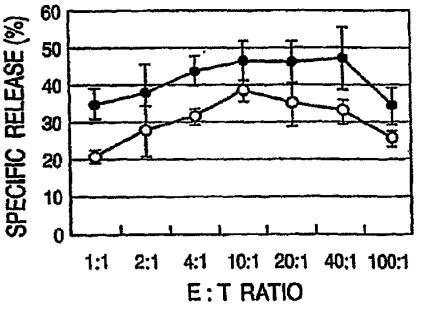


FIG. 17 (d)



-●- mPD-1 Fc -○- CONTROL Ig

-●- hPD-1 Fc -○- CONTROL Ig

IMMUNOPOTENTIATIVE COMPOSITION

This application is a divisional application of U.S. application Ser. No. 12/538,698, filed Aug. 10, 2009 (pending), which is a divisional application of U.S. application Ser. No. 10/519,925, filed Jan. 3, 2005 (now U.S. Pat. No. 7,595,048), which is a National Stage Entry of PCT/JP03/08420 filed Jul. 2, 2003, which claims priority based on Japanese Patent Application Nos. 2002-194491 and 2003-029846 filed Jul. 3, 2002 and Feb. 6, 2003, respectively. The entire disclosures of the prior applications are hereby incorporated by reference.

TECHNICAL FIELD

The present invention relates to immunopotentiation characterized by inhibiting immunosuppressive signals induced by PD-1, PD-L1 or PD-L2, compositions for cancer or infection treatment, and therapies that use them.

More specifically, the present invention relates to the compositions for cancer or infection treatment through an immunopotentiation caused by inhibition of immunosuppressive signals induced by PD-1, PD-L1 or PD-L2, the therapies that use them, screening methods of immunopotentiative substances, or substances for cancer treatment or for infection treatment that are contained in the composition as an active ingredient, cell lines used for those screening methods, an evaluation that selects the substances for cancer treatment, and carcinoma cells transplanted mammals used for the evaluation.

BACKGROUND ART

Immunotherapies can reduce side reactions that can't be avoided easily in most chemotherapies, and is expected as a therapy with extremely high specificity. The Immunotherapies can be executed in the purpose to recover patient's QOL by activating the immune reaction that human originally has by an extrinsic method and subrogating a part of the load by medication.

Immunopotentiation can be executed by methods of activating immune reaction of T lymphocytes. It is said that not only stimulation through antigen receptors (TCR) but also an additionally stimulative inducement through conjugated stimulative molecular groups (for example, CD28) could be necessary for the activation of T cells. However, it is reported that as the molecular groups with homologous structures to the conjugated stimulative molecular groups, CTLA-4 and PD-1 were discovered recently and give signals that suppress signals of antigen receptors (TCR). It is thought that a method of activating T cells could be an effective mean to suppress the function of those conjugated control molecules.

PD-1 was cloned as 55 kD of I type membrane protein that belong to an immunoglobulin family (The EMBO Journal (1992), vol. 11, issue 11, p. 3887-3895, JP5336973, JP7291996). Human PD-1 cDNA is composed of the base sequence shown in EMBL/GenBank Acc. No. NM_005018 and mouse PD-1 cDNA is composed of the base sequence shown in Acc. No. X67914, and those expression are observed when thymus cells differentiate from CD4−CD8− cell into CD4+CD8+ cell (International Immunology (1996), vol. 18, issue 5, p. 773-780, Journal of Experimental Medicine (2000), vol. 191, issue 5, p. 891-898). It is reported that PD-1 expression in periphery is observed in myeloid cells including T cells or B lymphocytes activated by stimulation from antigen receptors, or activated macrophages (*International Immunology* (1996), vol. 18, issue 5, p. 765-772).

In an intracellular domain of PD-1, there are ITIM motifs (Immunoreceptor Tyrosine-based Inhibitory Motif) that could been thought to be a repression domain to immune reaction. Since PD-1-deficient mice develop lupus-like autoimmune disease such as glomerular nephritis and arthritis (for C57BL/6 gene background.) (*International Immunology* (1998), vol. 10, issue 10, p. 1563-1572., Immunity (1999), vol. 11, issue 2, p. 141-151.) and a disease like dilated cardiomyopathy (for BALB/c gene background.) (*Science* (2001), vol. 291, issue 5502, p. 319-332.), it has been suggested that PD-1 could be a control factor of development of autoimmune disease, especially the peripheral self-tolerance.

PD-L1 (human PD-L1 cDNA is composed of the base sequence shown by EMBL/GenBank Acc. No. AF233516 and mouse PD-L1 cDNA is composed of the base sequence shown by NM_021893) that is a ligand of PD-1 is expressed in so-called antigen-presenting cells such as activated monocytes and dendritic cells (Journal of *Experimental Medicine* (2000), vol. 19, issue 7, p. 1027-1034). These cells present interaction molecules that induce a variety of immuno-inductive signals to T lymphocytes, and PD-L1 is one of these molecules that induce the inhibitory signal by PD-1. It has been revealed that PD-L1 ligand stimulation suppressed the activation (cellular proliferation and induction of various cytokine production) of PD-1 expressing T lymphocytes. PD-L1 expression has been confirmed in not only immunocompetent cells but also a certain kind of tumor cell lines (cell lines derived from monocytic leukemia, cell lines derived from mast cells, cell lines derived from hepatic carcinomas, cell lines derived from neuroblasts, and cell lines derived from breast carcinomas) (*Nature Immunology* (2001), vol. 2, issue 3, p. 261-267).

Though PD-L2 (human PD-L2 cDNA is composed of the base sequence shown by EMBL/GenBank Acc. No. NM_025239 and mouse PD-L2 cDNA is composed of the base sequence shown by NM_021896) had been identified as a second ligand of PD-1, it has been reported that the expression and function are almost same as PD-L1 (*Nature Immunology* (2001), vol. 2, issue 3, p. 261-267).

It has been thought that the inhibitory signals from the conjugated suppressive molecules represented by PD-1 could control abnormal immune reaction to autoantigen and immunological tolerance in lymphocyte generation or maturation by a mechanism that appropriately controls positive signals with antigen receptors (TCR) and conjugated stimulation molecules. It has been thought that a certain kind of tumour and virus could use those conjugated suppressive molecules to intercept the activation and proliferation of T cells and weaken the host immunity reaction to oneself by a direct or indirect mechanism (*Cell* (1992), vol. 71, issue 7, p. 1093-1102, *Science* (1993), vol. 259, issue 5093, p. 368-370). It has been thought that those conjugated suppressive molecules could have caused the impairment of T cells in a part of disease thought to originate in impairment of T cells.

DISCLOSURE OF THE INVENTION

A problem of the present invention is to provide compositions to activate immunity by inhibiting the inhibitory signals of PD-1, PD-L1 or PD-L2 and compositions for cancer or infection treatment through this mechanism.

The present inventors paid attention to PD-1, PD-L1, or PD-L2 as a new target in cancer or infection treatment and found that substances that inhibit the inhibitory signals of PD-1, PD-L1 or PD-L2 inhibit cancer proliferation through the mechanism of the recovery and activation of immune function. Further, they found that PD-1 signal, concretely, an

interaction of PD-1 and PD-L1 or PD-1 and PD-L2 took part in the exclusion of infectious virus. According to those facts, they found the substances that could inhibit the inhibitory signals of PD-1, PD-L1 or PD-L2 having therapeutic potential for cancer or infection and completed the present invention.

That is, the present invention relates to

1. an immunopotentiative composition containing an immunosuppressive signal inhibitor of PD-1, PD-L1 or PD-L2,
2. a composition for cancer treatment containing the immunosuppressive signal inhibitor of PD-1, PD-L1 or PD-L2,
3. the composition for cancer treatment of the subsection 2, which is a composition that suppresses cancer metastasis,
4. a composition for infection treatment containing an immunosuppressive signal inhibitor of PD-1, PD-L1 or PD-L2,
5. the composition for cancer treatment of the subsection 2 or 3, which is characterized by acting through immunopotentiation,
6. the composition for infection treatment of the subsection 4, which are characterized by acting through immunopotentiation,
7. the composition of either of the subsection 1 to 6, which the immunosuppressive signal inhibitor is/are one or more selected from an interaction inhibitor of PD-1 and PD-L1 or PD-1 and PD-L2, an intracellular signaling inhibitor of PD-1, and an inhibitory substance of PD-1, PD-L1 or PD-L2 production,
8. the composition of the subsection 7, which is/are one or more of the interaction inhibitor(s) of PD-1 and PD-L1 selected from PD-1 antibody, PD-L1 antibody, soluble PD-1, and soluble PD-L1,
9. the composition of the subsection 8, which is PD-1 antibody selected from anti-human PD-1 antibody of which hybridomas identified by International Trust Number FERM BP-8392 product, anti-PD-1 antibody humanized from non-human antibody, and human type anti-human PD-1 antibody,
10. the composition of either of the subsection 1 to 6, which the immunosuppressive signal inhibitor is a lymphocyte of which PD-1 expression is inhibited by gene-recombination,
11. the composition of the subsection 7, which the interaction inhibitor of PD-1 and PD-L1 or PD-1 and PD-L2, an intracellular signaling inhibitor of PD-1, or the inhibitory substance of PD-1, PD-L1 or PD-L2 production is one or more of substance(s) selected from protein, polypeptide or peptide, polynucleotide or polynucleoside, antibody or the derivative, organic synthesis compound, inorganic compound, and natural product,
12. an immunopotentiative method containing a method of administering the immunosuppressive signal inhibitor of PD-1, PD-L1 or PD-L2,
13. a method for cancer treatment containing a method of administering the immunosuppressive signal inhibitor of PD-1, PD-L1 or PD-L2,
14. the method of cancer treatment of the subsection 13, which is a method of suppressing cancer metastasis,
15. a method for infection treatment containing a method of administering the immunosuppressive signal inhibitor of PD-1, PD-L1 or PD-L2,
16. the method for cancer treatment of the subsection 13 or 14, which is characterized by acting through immunopotentiation,
17. the method for infection treatment of the subsection 15, which is characterized by acting through immunopotentiation,
18. the method of either of the subsection 12 to 17, which the immunosuppressive signal inhibitor is/are one or more selected from the interaction inhibitor of PD-1 and PD-L1 or PD-1 and PD-L2, the intracellular signaling inhibitor of PD-1, and the inhibitory substance of PD-1, PD-L1 or PD-L2 production,
19. the method of the subsection 18, which the interaction inhibitor is/are one or more selected from PD-1 antibody, PD-L1 antibody, soluble PD-1, and soluble PD-L1,
20. the method of the subsection 19, which PD-1 antibody is an antibody selected from anti-human PD-1 antibody of which hybridomas identified by international trust number FERM BP-8392 product, anti-PD-1 antibody humanized from non-human antibody, and human type anti-human PD-1 antibody,
21. the method of either of the subsection 12 to 17, which the immunosuppressive signal inhibitor is a lymphocyte of which PD-1 expression is inhibited by gene-recombination,
22. the method of the subsection 18, which the interaction inhibitor of PD-1 and PD-L1 or PD-1 and PD-L2, the intracellular signaling inhibitor of PD-1, or the inhibitory substance of PD-1, PD-L1 or PD-L2 production are one or more of substance(s) selected from protein, polypeptide or peptide, polynucleotide or polynucleoside, antibody or the derivative, organic synthesis compound, inorganic compound, and natural product,
23. use of the immunosuppressive signal inhibitor of PD-1, PD-L1 or PD-L2 to manufacture the immunopotentiative composition,
24. use of the immunosuppressive signal inhibitor of PD-1, PD-L1 or PD-L2 to manufacture the composition for cancer treatment,
25. use of the substance of the subsection 24, which the composition for cancer treatment is the composition for suppression of cancer metastasis,
26. use of the immunosuppressive signal inhibitor of PD-1, PD-L1 or PD-L2 to manufacture the composition for infection treatment,
27. carcinoma cell lines for screening, which are transformed to express PD-L1 or PD-L2,
28. a screening method for the immunopotentiative substance characterized by touching the cells of the subsection 27 to lymphocytes and a subject substance, followed by evaluating the enhancement of the subject substance for immune reaction of lymphocytes to the cells of the subsection 27,
29. a screening method for a substance for cancer treatment characterized by touching the carcinoma cells of the subsection 27 to lymphocytes and a subject substance, followed by evaluating the enhancement of the subject substance for immune reaction of lymphocytes to carcinoma cells and inhibitory effect on the subject substance for carcinoma cells proliferation,
30. a screening method for a substance for infection treatment characterized by touching the infected cells of the subsection 27 to lymphocytes and a subject substance, followed by evaluating the enhancement of the subject substance for immune reaction of lymphocytes to the infected cells and inhibitory effect on the subject substances for pathogens proliferation,
31. a mammal created by transplant the carcinoma cell lines of the subsection 27, and
32. a screening method for a substance for cancer treatment characterized by administering the subject substance to the mammal of the subsection 31, followed by evaluating the inhibitory ratio of the subject substance for the transplanted carcinoma cells proliferation.

PD-1, PD-L1, or PD-L2 of the present invention includes each one derived from mammal, for example, mouse, rat,

hamster, guinea pig, dog, pig, ape, or primate including human. They are suitable to be human PD-L1, PD-1, and PD-L2, respectively.

The immunosuppressive signal of PD-1, PD-L1, or PD-L2 in the present invention is at least composed of the interaction of PD-1 and PD-L1 or PD-1 and PD-L2, and the intracellular signalings of PD-1. Production of PD-1, PD-L1 or PD-L2 itself is included in them.

The immunosuppressive signal of PD-1, PD-L1, or PD-L2 in the present invention is inhibited by direct or indirect inhibition of the interaction of PD-L1 or PD-1 and PD-L2 or the intracellular signalings of PD-1. A substance that selectively binds to PD-1, PD-L1, or PD-L2 respectively is included as a substance with those inhibitory activities. For example, it is suitable to be protein, polypeptide or peptide, polynucleotide or polynucleoside, antibody or the derivative, organic synthesis compound, inorganic compound, or natural product. Especially, an antibody to PD-1, PD-L1 or PD-L2 is enumerated as an excellent substance in specificity.

The immunosuppressive signals are inhibited by inhibiting production of PD-1, PD-L1 or PD-L2 itself.

As an antibody to PD-1, PD-L1 or PD-L2, all antibodies derived from human, mouse, rat, rabbit, or goat which can inhibit the immunosuppressive signals by PD-1, PD-L1, or PD-L2, those polyclonal or monoclonal antibodies, complete or shorten (for example, F(ab') 2, Fab', Fab, or Fv fragment) antibodies, chimeric antibodies, humanized antibodies, or completely humanized antibodies will be acceptable.

Such antibodies can be manufactured using a partial protein of the extracellular region of PD-1, PD-L1, or PD-L2 as an antigen according to well-known production methods of antibody or antiserum. The partial protein of the extracellular region can be prepared by well-known protein expression and purification techniques.

The polyclonal antibodies can be manufactured according to well-known methods. For example, they can be manufactured by separation and refinement of the antibody of which a mixture of an antigen and a carrier protein is immunized to suitable animal, and an antibody inclusion to the antigen is gathered from the immunized animal. As such animal, mouse, rat, sheep, goat, rabbit, and guinea pig are generally enumerated. To improve the antibody producibility, Freund's complete adjuvant or Freund's incomplete adjuvant can be administered with the antigen. The administering is usually executed once every two weeks about 3-10 times in total. The polyclonal antibody can be gathered from the immunized animal's blood and peritoneal fluid, etc. by the above method. The measurement of the polyclonal antibody's titer in antiserum can be measured by ELISA. The separation and refinement of the polyclonal antibody can be executed by refining techniques that use active adsorbents such as antigen binding solid phase, protein A, or protein G, etc., salting-out, alcohol precipitation, isoelectric precipitation, electrophoresis, adsorption and desorption with ion exchanger, ultracentrifugation, or separation and refinement of immunoglobulins such as gel filtration technique, etc.

As an antibody preparation, the monoclonal antibody or the modifier is more suitable.

The monoclonal antibody producing cells can be prepared as hybridomas to be possible to subculture which produce the monoclonal antibody by selecting the individual of which the antibody titre is confirmed in an antigen immunized animals, gathering the spleen or the lymph node on day 2-5 after the final immunization, and fusing the antibody producting cells included in them with homogeneous or heterozoic myeloma cells. The antigen itself or with the carrier and the diluent is administered to the part in which the antibody production is possible. To improve the antibody producibility, Freund's complete adjuvant or Freund's incomplete adjuvant can be administered with the antigen. According to the method of calling "DNA immunization", animals are immunized. This method is a method using a phenomenon in which antigen-expressing vectors are introduced into the part and are taken into myocytes on the process of tissue repair, and expresses the antigenic protein (*Nature Immunology*(2001), vol. 2, issue 3, p. 261-267) after Cardiotoxin is treated to immune animal's tibialis anterior muscle of hind leg.

As an immune animal, mouse, rat, sheep, goat, rabbit, or guinea pig can be used, mouse and rat are suitable. The fusion operation can be executed by the method (*Nature* (1975), vol. 256, issue 5517, p. 495-497.) of Kohler and Milstein, and as fusion accelerants, polyethylene glycol (PEG) and Sendai virus, etc. are used. As those myeloma cells, myeloma cells such as P3U1, NS1, SP2/0, and AP1 can be used, P3U1 are often used usually. The monoclonal antibody producing cells can be selected by detecting by ELISA, etc. executed by adding hybridoma culture supernatant to solid phase in which antigenic proteins are adsorbed direct or with carrier perhaps. Hybridoma culture supernatant's antibody titre can be measured by ELISA. The separation and refinement of the monoclonal antibody can be executed according to the separation refining method similar to the separation and refinement of immunoglobulin for the above polyclonal antibody. Concretely, it is anti-mouse PD-L1 antibody producted by hybridomas identified by International Trust Number FERM BP-8396 or anti-human PD-1 antibody producted by a hybridoma identified by International Trust Number FERM BP-8392.

The hybridomas identified by International Trust Number FERM BP-8392 had been deposited as Trust Number FERM P-19162 to National Institute of Advanced Industrial Science and Technology, International Patent Organism Depositary in Central 6, 1-1-1 Higashi, Tsukuba, Ibaraki, Japan (ZIP code 305-8566) at Dec. 19, 2002, and had been transferred to International Deposit at Jun. 5, 2003. The hybridomas identified by International Trust Number FERM BP-8396 had been deposited as Trust Number FERM P-18908 at Jun. 25, 2002, and had been transferred to International Deposit at Jun. 11, 2003.

The antibody fragment means $F(ab')_2$, Fab', Fab, or scFv antibody fragment and can be prepared by reducing optionally after processing with protease enzyme.

$F(ab')_2$ antibody fragments can be purified by either method of affinity chromatography such as ion-exchange chromatography, gel filtration, or protein A or protein G column, etc. after the purified monoclonal antibody is completely digested by pepsin. Because digestive time by pepsin is different depending on Ig subtype, it is necessary to prepare it suitably. Fab' antibody fragment can be prepared by reducing $F(ab')_2$ by 2-mercaptoethylamine partly. Fab antibody fragment can be prepared by the direct digestion under the presence of cysteine by the digestive enzyme papain followed by refining.

Further, the monoclonal antibody is prepared as a rearrangement antibody and a hybrid antibody modified by gene recombination technology using DNA sequence that codes the amino acid sequence of antibody isolated from the hybridomas. For example, it can be prepared as a single-chain antibody but not a usual complete type antibody. scFv antibody (single chain Fv) can be prepared by the method of Jost (*Journal of Biological Chemistry* (1994), vol. 269, issue 42, p. 26267-26273). The single-chain antibody with the characteristic and the affinity of an original antibody can be prepared by making expression an expression vector including a fused

DNA of which DNA fragments respectively coding a variable region of the heavy chain and the light chain had been connected with a spacer coding neutral amino acids (glycine or serine) in suitable host cells.

When non-human antibody is used to treat for human, it is indispensable to decrease the antigenicity of the antibody. Since the immune reaction to patient's antibody often shortens an effective treatment period, the process of decreasing the antigenicity of the antibody by making the antibody humanize or completely human type is necessary. The humanized antibody modified to be acceptable for administering to human is the antibody which is modified so that the decrease of antigenicity or the blood movement may improve to extent that can be allowed in pharmacology when the antibody is administered to human.

Human PD-1 antibody or human PD-L1 antibody in specification of the present invention includes the humanized or the complete human type antibody, too.

The humanized antibody can be prepared by substituting a part of non-human antibody which was prepared by being immunized to mammals other than human for a part of human antibody. Concretely, it has been known to be able to be prepared by constructing a chimera with a gene coding a constant region of the human antibody (*Proc. Natl. Acad. Sci.* (USA) (1987), vol. 84, p. 3439-3443, *Journal of Immunology* (1987), vol. 139, issue 1, p. 3521). The DNA sequence of the human constant region has been described to a prior art and the constant region gene can be easily obtained from an already-known clone. Then, the DNA sequence coding the variable region of the antibody can be fused to the human constant region. An isotype of the human constant region can be selected due to desire effective function or antibody dependent cytotoxicity. A suitable isotype is IgG1, IgG3, and IgG4. Both human light-chain constant region, K chain, and A chain can be used. It is possible to make this humanized chimeric antibody expression by a routine method.

The complete human type antibody can be prepared by using mice (XenoMouse (*Chemical Biology* (2000), vol. 7, issue 8, p. R185-6), HuMAb-Mouse (*Infection and Immunity* (2002), vol. 70, issue 2, p. 612-9), TC mouse (*Biotechnology and Genetics Engineering Review* (2002), vol. 19, p. 73-82), and KM mouse (*Cloning Stem Cells* (2002), vol. 4, issue 1, p. 91-102)) of which a constant region gene of human immunoglobulin have been transferred, and a target antibody can be mass-produced by making the antibody production lymphocytes separated from mice to hybridomas. It can be prepared by phage display method (*FEBS Letter* (1998), vol. 441, p. 20-24). In this method, by using phages of which the human antibody gene have been incorporated into a cyclic single strand DNA, the human type antibody can be expressed on the surface of the phage as a form fused with coat protein of the phages.

Polypeptides or the derivatives that bind to PD-1, PD-L1, or PD-L2 include each partial proteins of PD-1, PD-L1 or PD-L2 of which the immunosuppressive signal is not induced. The presence of PD-1 in the neighborhood of the antigen receptors is indispensable for the inducement of the immunosuppressive signal of PD-1, for that purpose it is necessary to be restrained by the interaction with PD-L1 or PD-L2 in antigen-presenting cells, tumours, or carcinoma cells. Therefore, soluble PD-L1 or soluble PD-L2 with a part which is only extracellular domains and interacts with PD-1 can inhibit the immunosuppressive signal of PD-1. On the other hand, soluble PD-1 with a part which has a similar structure and can interact with PD-L1 or PD-L2 can inhibit the immunosuppressive signal. These soluble proteins have only to include an extracellular region which is necessary and sufficient to bind to PD-1, PD-L1, or PD-L2 and can be prepared by a well-known expression and refining technique.

If an interaction inhibitor of PD-1 and PD-L1 or PD-1 and PD-L2 is a protein or a polypeptide and an essential area for the interaction is composed by only consecutive polypeptide, such a polypeptide fragment can become a mutual antagonist. Further, an antagonist with stronger activity can be identified from molecular groups of which this polypeptide fragment is chemically modified, or designed by computer based on the spatial structure of the polypeptide fragment. Also, the best antagonist can be more efficiently selected from molecular groups designed by computer based on protein stereoanalysis data of the interaction area.

A substance that inhibits the interaction of PD-1 and PD-L1, or PD-1 and PD-L2 can be screened directly. Such a substance can be identified from each libraries of protein, polypeptide or peptide, polynucleotide or polynucleoside, non-peptide compound, organic synthesis compound, or natural product (for example, fermentational product, cell extract, plant extract, and animal tissue extract).

Since the inhibitory signals of PD-1 intracellular domain are caused by contacting dephosphorylation enzymes (for example, SHP-1 and 2 (Sathish J G, *Journal of Immunology* (2001), vol. 166, issue 3, p. 1763-70)) that bind to ITIM in PD-1 intracellular domain with an intracellular complex including an antigen receptor complex, they are generally inhibited by inhibiting the contact between the antigen receptor complex and PD-1. The substance that inhibits the inhibitory signals includes a substance that directly inhibits the activity of dephosphorylation enzymes, a substance that inhibit phosphorylation of tyrosine residue in ITIM, a substance that inhibits bonds of dephosphorylation enzymes to ITIM, or a substance that directly inhibits activity of dephosphorylation enzymes, etc. The antigen receptor complex includes T cell receptor complex or B cell receptor complex.

The production of PD-1, PD-L1, or PD-L2 is inhibited by specific polynucleotide or polynucleoside, organic synthesis compound, inorganic compound, or natural product, etc. Especially, the suitable polynucleotide or polynucleoside includes antisense nucleotide derivative so-called ribozyme. This uses a mechanism of which the expressed mRNA is destroyed by which the polynucleotide derivative that is complement to mRNA of PD-1, PD-L1, or PD-L2 is transferred into subject cells. Further, the vector can be used for the gene manipulation to lymphocyte stem cells gathered from a patient so that it inhibits the expression of PD-1, and the manipulated cells can be used for cell medical treatment of which the cells will be proliferated, differentiated, activated, and administered to the patient again. Especially, in immunotherapy for cancer, more specific and clonal lymphocytes to target cells can be prepared by adding a specific antigen of the target cells on the process of the maturation and activation of lymphocyte stem cells.

The screening method of the present invention can be executed by a method of measuring cell function. The carcinoma cell lines for screening of which PD-L1 or PD-L2 used by the method is transformed to be expressed includes carcinoma cell lines transformed transitory or stably after expression vectors constructed to express PD-L1 or PD-L2 have been introduced to the cells by well-known methods. As the carcinoma cell lines used, ape COS-1 cells, COS-7 cells, Vero, chinese hamster CHO cells (hereafter, abbreviated with CHO cells), dhfr gene deficient chinese hamster CHO cells (hereafter, abbreviated with CHO (dhfr-) cells), mouse L cells, mouse AtT-20, mouse myeloma cells, rat GH3, HEK293 T cells, and human FL cells, etc. are used. Especially, the transformation of animal cells can be executed

according to methods described in, for example, *Cell Tehcnology* separate volume 8, *New Experimental Protocol of Cell Technology* (1995), vol. 263, published by SHUJUNSHA Co., Ltd., and Virology (1973), vol. 52, issue 456.

Cells naturally expressing PD-L1 or PD-L2 can be also used. Such cells include leukocyte, suitablely, monocytes, macrophages or antigen-presenting cells, epithelial cells, tumor cells, carcinoma cells, or those cell lines, etc. As tumor cells or carcinoma cells, for example, P38D1 cells, P815 cells, NB41A3 cells, MDA-231 cells, SKBR-3 cells, MCF-7 cells, BT474 cells, J558L cells, P3U1 cells, PAI cells, X63 cells, or SP2/0 cells can be used. Cells infected with pathogens, which express PD-L1 or PD-L2 naturally or compellingly, can be used. Infectious pathogens include human hepatitis virus (hepatitis B, hepatitis C, and hepatitis A) or hepatitis E), human retrovirus, human immunodeficiency virus (HIV1 and HIV2), human T cell leukemia virus, human T lymphocytic virus (HTLV1 and HTLV2), simple herpes virus type 1 or 2, Epstein-Barr virus, cytomegalovirus, varicella-zoster virus, human herpesvirus including human herpesvirus 6, poliovirus, measles virus, rubella virus, Japanese encephalitis virus, mumps virus, influenza virus, adenovirus, enterovirus, rhinovirus, virus developing severely acute respiratory syndrome (SARS), Ebola virus, West Nile virus, or these virus modified artificially. Other pathogens include, for example, pathogenesis protozoan (for example, trypanosome, malaria, and toxoplasma), *bacillus* (for example, mycobacterium, salmonella, and listeria) or fungus (for example, candida), etc.

The lymphocytes used in the screening method of the present invention are T or B lymphocytes, and suitably cytotoxic T lymphocytes (CTL). The immune reaction of lymphocytes in the screening method of the present invention includes citotoxic response (for example, tumor immunity reaction), mixed lymphocyte reaction, production of cytokines, antibodies, complements or other cell surface antigens, or cellular proliferation, etc.

In the present invention, the screening method of an active ingredient contained in the composition for immunopotentiation or cancer treatment can be executed by measuring cytotoxic activity of cytotoxic T lymphocytes against subject cells followed by measuring an effect of a subject substance against the activity. This method is an assay of recovery and reinforcement of cytotoxic activity by adding the subject substance to a culture mixed cytotoxic T lymphocytes (CTL) naturally expressing PD-1 or cell lines (for example, 2C cells) with cells naturally or compulsorily expressing PD-L1 or PD-L2 which are derived from syngeneic mouse. Since the cytotoxic activity against PD-L1 or PD-L2 expressing cells is lower than that against PD-L1 or PD-L2 non-expressing cells, this method has a feature of which the recovery of cytotoxic activity (rising part) due to the subject substance can be measured more clearly. The recovery of cytotoxicity due to the subject substance can be evaluated as an equivalent to inhibition of suppression of cytotoxicity. Further, it is preferable that the the cytotoxicity due to the subject substance is arbitrarily measured. As these cells, tumor cell lines or carcinoma cell lines naturally expressing PD-L1 or PD-L2 (*Nature Immunology* (2001), vol. 2, issue 3, p. 261-267), for example, P38D1 cells, P815 cells, NB41A3 cells, MDA-231 cells, SKBR-3 cells, MCF-7 cells, BT474 cells, J558 L cells, P3U1 cells, PAI cells, X63 cells, or SP2/0 cells can be used, and tumor cell lines or carcinoma cell lines transformed so as to stably or transiently express PD-L1 or PD-L2 can be also used.

On the other hand, it is preferable that the cytotoxic lymphocytes are PD-1 expressing cells derived from syngeneic animal to targeted cells.

In the present invention, the screening method of an active ingredient contained in the composition for infection treatment is an assay of enhancement effect on immune reaction of lymphocytes to infected cells or inhibitory effect on proliferation activity of pathogen or virus by adding the subject substance to a culture mixed cytotoxic T lymphocytes (CTL) or cell lines (for example, 2C cells) naturally expressing PD-1 with cells naturally or compulsorily expressing PD-L1 or PD-L2 which are derived from syngeneic mouse and was infected with pathogen or virus.

Further, in evaluations using a similar principle, a mammal created by transplanting the above carcinoma cell lines for screening which are transformed so as to express PD-L1 or PD-L2 or cells naturally expressing PD-L1 or PD-L2 to a syngeneic mammal can be used. To a manufacture method of the mammal, a process of transplanting cells and a process of breeding the mammal until becoming appropriate for the evaluation is indispensable. This evaluation is characterized in evaluating proliferation of the transplant cells and the amount of production of various cytokines or cell surface antigens, especially, in case of carcinoma cells, proliferation, permeation, or histological analysis of metastasis of the cells, or survival rates of the transplanted mammal. The cellular proliferation can be evaluated as the number of carcinoma cells per unit capacity in case of ascites tumors or blood cancers, or the size or the weight after removing in case of solid cancer. The effect of the subject substance for cancer treatment in this method can be evaluated as an equivalent to effect due to inhibition of suppression of cytotoxicity caused in PD-L1 or PD-L2. As such cells, syngeneic cells to a mammal for transplant, with good proliferation are more suitable. The mammal includes primates except human, mouse, rat, hamster, guinea pig, dog, pig, and ape.

INDUSTRIAL AVAILABILITY

As a substance that demonstrates remarkable suppression of cancer proliferation and life prolongation of an individual by administering to the carcinoma cells-transplanted animal model, the present inventors invented each specific antibody (anti-PD-1 antibody and anti-PD-L1 antibody) that inhibited PD-1 and PD-L1 function respectively. These antibodies showed actions that recover or reinforce cytotoxic activity that has relatively decreased by presenting PD-L1 ligand to PD-1-expressing CTL (cytotoxic T lymphocyte) (example 1 and FIG. **1**). This suggests that the cytotoxic activity to carcinoma cells by CTL could be reinforced by administering these antibodies. In the carcinoma cells-transplanted animal model (*Protein, Nucleic acid, and Enzyme* (1981), vol. 26, issue 3, p. 208-22) which uses syngeneic mouse of which cell lines artificially expressing PD-L1 derived from mastocytomas have been imported, administration of anti-PD-L1 antibody presented suppression of proliferation, invasion, and metastasis of carcinoma cells, and life prolongation of an individual (FIGS. **2** and **3**). It was suggested that inhibition of PD-1 function or production could achieve an effect similar to the effect on inhibition of PD-L1 function by this antibody. This is based on non-proliferation of imported carcinoma cells in the cancer imported model using PD-1-deficient mice, and presents that inhibition of PD-1 function or production could be effective on cancer treatment (Example 5 and FIG. **3**).

Actually, it had been proven that administration of anti-PD-1 antibody significantly suppressed metastasis of imported carcinoma cells to liver in the cancer imported animal model (Example 13).

The inventors presented that the substance that inhibits the immunosuppressive signal induced by PD-1, PD-L1 or PD-L2 was useful for infection treatment (Example 11, FIG. **15** and **16**).

These results experimentally presented by the present inventors prove that only PD-1 antibody or PD-L1 antibody don't presents aforementioned effect, but also any substance that can inhibit the immunosuppressive signal from PD-1, PD-L1, or PD-L2 present almost similar effect. The substances with such effects include, for example, anti-PD-L2 antibody, soluble PD-1, soluble PD-L1, soluble PD-L2, PD-1 antagonists, PD-L1 antagonists, PD-L2 antagonists, substances that inhibits interaction between PD-1 and PD-L1 or PD-1 and PD-L2, PD-1 production inhibitors, PD-L1 production inhibitors, PD-L2 production inhibitors, and intracellular inhibitory signal inhibitors by PD-1.

Cancer or tumour of which the therapeutic potential could be expected by administration of the composition for cancer treatment of the present invention include, for example, carcinoma, squamous carcinoma (for example, cervical canal, eyelid, tunica conjunctiva, vagina, lung, oral cavity, skin, urinary bladder, tongue, larynx, and gullet), and adenocarcinoma (for example, prostate, small intestine, endometrium, cervical canal, large intestine, lung, pancreas, gullet, intestinum rectum, uterus, stomach, mammary gland, and ovary). Further, they include sarcomata (for example, myogenic sarcoma), leukosis, neuroma, melanoma, and lymphoma.

The effect on the ones that remarkably express PD-L1 or PD-L2 in these cancers or tumours is remarkable. PD-L1 or PD-L2 expression can be identified by checking up surgically excised cancer, tumour mass, or lesioned part gathered outside of the body as a sample. Administration of the composition of the present invention will become an efficient and available method as a treatment after surgery for tumour or cancer patient that PD-L1 or PD-L2 is remarkably expressed. PD-L1 or PD-L2 expression can be identified by, for example, immunochemical method using PD-L1 antibody or PD-L2 antibody, RT-PCR, or DNA array.

A side reaction violently decreasing lymphocytes proliferation in chemotherapy and radiotherapy for cancer is inevitable. Administration of the composition of the present invention presents an effect on stimulating and proliferating the decreased lymphocytes and can suppress a fierce side reaction accompanied by usual chemotherapy to minimum. Further, it is similar as to radiotherapy. Concomitant use with the composition of the present invention can greatly decrease the dose of chemotherapy drug or the exposure dose of irradiation from the dose or the exposure dose used usually.

The composition for cancer treatment of the present invention can be used together with existing chemotherapy drugs or be made as a mixture with them. Such a chemotherapy drug include, for example, alkylating agents, nitrosourea agents, antimetabolites, antitumor antibiotics, alkaloids derived from plant, topoisomerase inhibitors, hormone therapy medicines, hormone antagonists, aromatase inhibitors, P-glycoprotein inhibitors, platinum complex derivatives, other immunotherapeutic drugs, and other anticancer agents. Further, they can be used together with hypoleukocytosis (neutrophil) medicines that are cancer treatment adjuvant, thrombopenia medicines, antiemetic drugs, and cancer pain medicines for patient's QOL recovery or be made as a mixture with them.

The composition for cancer treatment of the present invention can be used together with immunopotentiative substances or be made as a mixture with them. Such immunopotentiative substances include, for example, various cytokines and a tumor antigen, etc. Cytokines that stimulate immune reactions include, for example, GM-CSF, M-CSF, G-CSF, interferon-α, β, γ, IL-1, IL-2, IL-3, and IL-12, etc. B7 ligand derivatives, anti-CD3 antibodies and anti-CD28 antibodies, and anti-CTLA-4 antibodies can also improve the immune reactions.

Administration of the tumor antigen can also improve a specific immune reaction against T lymphocytes against carcinoma cells and additionally or synergistically reinforce by using together with the composition for cancer treatment of the present invention. The tumor antigen can be prepared as a purified protein in case of an already-known gene, or as a lysate of carcinoma cells in case of an unknown gene.

Such the tumor antigen includes, for example, HLA-A1 and HLA-A2 restrictive peptides of malignant melanoma MAGE-1 or MAGE-3, MART-1, and gp100. Further, they include HER2/neu peptide of mammary carcinomas and ovarian carcinomas, MUC-1 peptide of adenocarcinoma, and NY-ESO-1 of metastatic carcinomas.

It has been thought that viruses could use conjugate suppressive factors of T lymphocytes as one of methods to escape from host's immuno-protection. It is thought that a part of virus infection could attribute the escape function of such viruses and administration of the composition of the present invention could improve the immune reaction of T lymphocytes to viruses.

Administration of the composition for infection treatment of the present invention is effective on treatment for, for example, human hepatitis virus (hepatitis B, Hepatitis C, hepatitis A, or hepatitis E), human retrovirus, human immunodeficiency virus (HIV1, HIV2), human T leukemia virus (HTLV1, HTLV2), or human lymphocytic cell type virus. Further, it is thought to be effective on treatment for simple herpes virus type 1 or 2, epstein-barr virus, cytomegalovirus, varicella-zoster virus, human herpesvirus including human herpesvirus 6, poliovirus, measles virus, rubella virus, Japanese encephalitis virus, mumps virus, influenza virus, adenovirus, enterovirus, rhinovirus, virus developing severely acute respiratory syndrome (SARS), ebola virus, west nile virus, or these virus modified artificially.

It is thought to be also effective on infection treatment for other pathogens such as, for example, pathogenesis protozoan (for example, trypanosome, malaria, and toxoplasma), bacillus (for example, mycobacterium, salmonella, and listeria) or fungus (for example, candida), etc.

The composition for infection treatment of the present invention can be used together with existing anti-HIV drugs, antiviral agents, antibiotic agents, antimicrobial agents, or visceral mycosis medicines or be made as a mixture with them. The anti-HIV drugs include, for example, reverse transcriptase inhibitors (for example, AZT, ddl, 3TC, and d4T), protease inhibitors (for example, saquinavir mesylate, ritonavir, nelfinavir mesylate, amprenavir, delavirdine mesylate, saquinavir, and lopinavir/ritonavir) or CCR5 receptor antagonists. The antiviral agents include, for example, anti-herpesvirus agents, anti-influenza virus agents, interferon-α and β, or various immunoglobulins.

The composition for infection treatment of the present invention can be used together with vaccines of virus or pathogen or be made as a formulation with them. Such vaccines include, for example, poliovaccine, measles vaccine, Japanese encephalitis vaccine, BCG vaccine, triple vaccine, mumps virus vaccine, varicella virus vaccine, influenza vaccine, hepatitis A vaccine, hepatitis B vaccine, and cholera vaccine.

The composition of the present invention is usually administered systemically or locally, and orally or parenterally.

The dosage is determined depending on medicines used for the present invention, age, body weight, symptom, therapeutic effect, administration route, and duration of the treatment, etc. For oral administration, generally, the dosage range from 1 μg to 100 mg per an adult is orally administered once to several times per day, or the dosage range from 0.1 ng to 10 mg per an adult is administered once to several times per day parenterally, suitably intravenously, and is intravenously administered for 1 to 24 hours per day continuously.

Since the dosage changes depending on various conditions as described above, there are cases in which doses lower or greater than the above dosage may be used.

When a concomitant drug of the composition of the present invention and other medicines is administered, it is used as solid medicines for internal use, and injections, external preparations, suppositoriums, inhalant, pernasal preparation, etc. for parenteral administration.

The solid medicines for oral administration include compressed tablets, pills, capsules, dispersing powders, granules, etc. The capsules include hard capsules and soft capsules. The tablets include sublingual tablets, intraoral strapping tablets, and intraoral speed disintegrators, etc.

As to such the solid medicines, one or more active compound(s) may be pharmaceutically manufactured as itself/themselves or a formulation with excipients (lactose, mannitol, glucose, microcrystal cellulose, and starch, etc.), binders (hydroxypropylcellulose, polyvinyl pyrrolidone, and magnesium metasilicate aluminate, etc.), disintegrators (cellulose calcium glycolate, etc.), lubricants (magnesium stearate etc.), stabilizers, or solubilizers (glutamate and aspartic acid, etc.), etc. according to usual methods. Further, they may be optionally coated by coatings (sucrose, gelatin, hydroxypropylcellulose, and hydroxypropylmethylcellulose phthalate, etc.) or coated in the layer of two or more. Further, capsules of absorbable materials such as gelatin may be included.

The sublingual tablets are manufactured according to a well-known method. For example, they may be pharmaceutically manufactured as a mixture one or more active compound(s) with excipients (lactose, mannitol, glucose, microcrystal cellulose, colloidal silica, and starch, etc.), binders (hydroxypropylcellulose, polyvinylpyrrolidone, and magnesium metasilicate aluminate, etc.), disintegrator (starch, L-hydroxypropylcellulose, carboxymethylcellulose, crosscarmellose sodium, and cellulose calcium glycolate, etc.), lubricants (magnesium stearate etc.), swelling agents (hydroxypropylcellulose, hydroxypropylmethylcellulose, carbopole, carboxymethylcellulose, polyvinyl alcohol, xanthan gum, and Cyamoposis Gum, etc.), swelling adjuvants (glucose, fructose, mannitol, xylitol, erythritol, maltose, trehalose, phosphate salt, citrate, silicate, glycine, glutamate, and arginine, etc.), stabilizers, solubilizers (polyethylene glycol, propylene glycol, glutamate, and aspartic acid, etc.), or spices (orange, strawberry, mint, lemon, and vanilla, etc.), etc. according to usual methods. Further, they may be optionally coated by coatings (sucrose, gelatin, hydroxypropylcellulose, and hydroxypropylmethylcellulose phthalate, etc.) or coated in the layer of two or more. Additives such as preservatives, anti-oxidants, coloring agents, and sweeteners used regularly may be optionally added.

The intraoral strapping tablets are manufactured according to a well-known method. For example, they may be pharmaceutically manufactured as a mixture one or more active compound(s) with excipients (lactose, mannitol, glucose, microcrystal cellulose, colloidal silica, and starch, etc.), binders (hydroxypropylcellulose, polyvinylpyrrolidone, and magnesium metasilicate aluminate, etc.), disintegrator (starch, L-hydroxypropylcellulose, carboxymethylcellulose, crosscarmellose sodium, and cellulose calcium glycolate, etc.), lubricants (magnesium stearate etc.), swelling agents (hydroxypropylcellulose, hydroxypropylmethylcellulose, carbopole, carboxymethylcellulose, polyvinyl alcohol, xanthan gum, and Cyamoposis Gum, etc.), swelling adjuvants (glucose, fructose, mannitol, xylitol, erythritol, maltose, trehalose, phosphate salt, citrate, silicate, glycine, glutamate, and arginine, etc.), stabilizers, solubilizers (polyethylene glycol, propylene glycol, glutamate, and aspartic acid, etc.), or spices (orange, strawberry, mint, lemon, and vanilla, etc.), etc. according to usual methods. Further, they may be optionally coated by coatings (sucrose, gelatin, hydroxypropylcellulose, and hydroxypropylmethylcellulose phthalate, etc.) or coated in the layer of two or more. Additives such as preservatives, anti-oxidants, coloring agents, and sweeteners used regularly may be optionally added.

The intraoral speed disintegrators are manufactured according to a well-known method. For example, they may be pharmaceutically manufactured as one or more active compound(s) itself/themselves or a mixture bulk or granulated bulk particle with suitable coatings (ethyl cellulose, hydroxypropylcellulose, hydroxypropylmethylcellulose, and acrylic acid methacrylate copolymer, etc.), plasticizers (polyethylene glycol and triethyl citrate, etc.), excipients (lactose, mannitol, glucose, crystallite cellulose, colloidal silica, and starch, etc.), binders (hydroxypropylcellulose, polyvinyl pyrrolidone, and magnesium metasilicate aluminate, etc.), disintegrators (starch, L-hydroxypropylcellulose, carboxymethylcellulose, crosscarmellose sodium, and cellulose calcium glycolate, etc.), lubricants (magnesium stearate etc.), dispersant adjuvants (glucose, fructose, mannitol, xylitol, erythritol, maltose, trehalose, phosphate salt, citrate, silicate, glycine, glutamate, and arginine, etc.), stabilizers, solubilizer (polyethylene glycol, propylene glycol, glutamate, and aspartic acid, etc.), spices (orange, Strawberry, Mint, lemon, and vanilla, etc.) etc. according to usual methods. Further, they may be optionally coated by coatings (sucrose, gelatin, hydroxypropylcellulose, and hydroxypropylmethylcellulose phthalate, etc.) or coated in the layer of two or more. Additives such as preservatives, anti-oxidants, coloring agents, and sweeteners used regularly may be optionally added.

The liquid compositions for oral administration include pharmaceutically acceptable waters, suspensions, emulsions, syrups, and elixirs, etc. As to such liquid medicines, one or more active compound(s) may be dissolved, suspended, or emulsified to generally used diluent (purified water, ethanol or those mixing liquids, etc.). Further, those liquid medicines may contain humectants, suspending agents, emulsifying agents, sweeteners, flavor agents, flavoring agents, preservatives, and buffers, etc.

The external preparations for parenteral administration include, for example, ointments, gels, creams, fomentations, patchs, embrocations, aerosols, inhalants, sprays, aerosols, eye drops, and nasal drops, etc. These include one or more activator(s) and are manufactured by a well-known method or the formula usually used.

The ointments include one or more activator(s) and are manufactured by a well-known method or the formula usually used. For example, they are manufactured by levigating and melting one or more activator(s) to basis.

The ointment bases are chosen from a well-known or the one usually used. They are used mixing one or two or more kinds chosen from, for example, higher fatty acid or higher fatty acid ester (adipic acid, myristic acid, palmitic acid, stearic acid, oleic acid, adipic acid ester, myristic acid ester,

palmitate, stearic acid ester, and oleic acid ester, etc.), rows (yellow wax, spermaceti, and ceresin, etc.), surfactants (polyoxyethylene alkyl ether phosphate etc.), higher alcohols (cetanol, stearyl alcohol, and cetostearyl alcohol, etc.), silicone oils (dimethylpolysiloxane etc.), hydrocarbons (hydrophilic petrolatum, white petrolatum, purified lanolin, and liquid paraffin, etc.), glycols (ethylene glycol, diethylene glycol, propylene glycol, polyethylene glycol, and macrogol, etc.), vegetable oils (castor oil, olive oil, sesame oil, and oil of turpentine, etc.), animal oils (mink oil, yolk oil, squalane, and squalene, etc.), water, absorption enhancer, and poisoned inhibitor. Further, they may include moisturizing agents, preservatives, stabilizing agents, anti-oxidants, and flavors, etc.

The gels are manufactured by a well-known method or a formula usually used. For example, they are manufactured by levigating and melting one or more activator(s) to a basis. The base is chosen from a well-known or the one usually used. It is used mixing one or two or more kinds chosen from, for example, lower alcohols (ethanol and isopropyl alcohol, etc.), gelatinizers (carboxymethylcellulose, hydroxyethyl cellulose, hydroxypropylcellulose, and ethyl cellulose, etc.), neutralizers (triethanolamine and diisopropanolamine, etc.), surfactants (mono-stearic acid polyethylene glycol, etc.), gums, water, absorption enhancers, and poisoned inhibitors. Further, they may include preservatives, anti-oxidants, and flavors, etc.

The creams are manufactured by a well-known method or a formula usually used. For example, they are manufactured by levigating one or more activator(s) to a basis and spreading and rolling on the support after kneading. The base is chosen from a well-known or the one usually used. It is used mixing one or two or more kinds chosen from, for example, higher fatty acid esters, lower alcohols, hydrocarbons, polyhydric alcohols (propylene glycol, 1,3-butylene glycol, etc.), higher alcohols (2-hexyl decanol and cetanol, etc.), and emulsifiers (polyoxyethylene alkyl ethers and fatty acid esters, etc.), water, absorption enhancers, and poisoned inhibitors. Further, they may include preservatives, anti-oxidants, and flavors, etc.

The fomentations are manufactured by a well-known method or a formula usually used. For example, they are manufactured by levigating one or more activator(s) to a basis and spreading and rolling on the support after kneading. The base is chosen from a well-known or the one usually used. It is used mixing one or two or more kinds chosen from, for example, thickeners (polyacrylic acid, polyvinyl pyrrolidone, arabic gum, starch, gelatin, and methyl cellulose, etc.), humectants (urea, glycerin, and propylene glycol, etc.), and fillers (china clay, flower of zinc, talc, calcium, and magnesium, etc.), water, absorption enhancers, and poisoned inhibitors. Further, they may include preservatives, anti-oxidants, and flavors, etc.

The patchs are manufactured by a well-known method or a formula usually used. For example, they are manufactured by levigating one or more activator(s) to a basis and spreading and rolling on the support after kneading. The base for the patch is chosen from a well-known or the one usually used. It is used mixing one or two or more kinds chosen from, for example, high molecular basis, oils, fats, higher fatty acids, tackifiers, and poisoned inhibitors. Further, they include preservatives, anti-oxidants, and flavors, etc.

The liniments are manufactured by a well-known method or a formula usually used. For example, they are manufactured by dissolving, suspending, or emulsifying one or more activator(s) to one or two or more kinds chosen from water, alcohols (ethanol and polyethylene glycol, etc.), higher fatty acids, glycerins, soaps, emulsifiers, suspending agents, etc. Further, they may include preservatives, anti-oxidants, and flavors, etc.

The aerosols, the inhalants, and the sprays may contain stabilizers such as sodium hydrogen sulfite besides the diluent generally used, buffers giving isotonicity, and isotonic agents such as, for example, sodium chloride, sodium citrate, and citrates.

The injections for parenteral administration include solid shots that are dissolved or suspended to solution, suspension, emulsion, or time of use solvent. The injections are used by dissolving, levigating and melting one or more activator(s) to the solvent. As the solvent, for example, water for injection, distilled saline, vegetable oil, propylene glycol, polyethylene glycol, alcohols such as ethanol, etc., and these combination are used. Further, this injection may include stabilizers, solubilizers (glutamate, aspartic acid, and polysorbate 80 (registered trademark), etc.), suspending agents, emulsifying agents, soothing agents, buffers, and preservatives, etc. These are sterilize in the final process or are manufactured from the aseptic manipulation. Aseptic solid medicines may be manufactured as a freeze-drying product and may be used by making to be aseptic or dissolving to aseptic distilled water for injection or other solvents before use.

The inhalant for parenteral administration includes aerosols, inhalant powders, or inhalant solutions, which may be used by making to dissolve or suspend to water or other suitable media at the time of use.

These inhalants are manufactured according to a well-known method.

For example, the inhalant solutions are prepared by properly selecting from preservatives (benzalkonium chloride and paraben, etc.), coloring agent, buffers (sodium phosphate and sodium acetate, etc.), tonicity agents (sodium chloride and concentrated glycerin, etc.), thickeners (carboxyvinyl polymer, etc.), and absorption enhancers, etc., optionally.

The inhalant powders are prepared by properly selecting from lubricants (stearic acid and the salt, etc.), binders (starch and dextrin, etc.), excipients (lactose and cellulose, etc.), coloring agents, preservatives (benzalkonium chloride and paraben, etc.), and absorption enhancers, etc., optionally.

When the inhalant solution is administered, a sprayer (atomizer and nebulizer) is usually used. When the inhalant powder is administered, an inhalation administering machine for powder is usually used.

Other compositions for parenteral administration contain one or more activator(s) and include suppository for intrarectal administration which is prescribed according to a routine procedure and pessary, etc. for intravaginal administering.

The sprays may contain a stabilizer such as sodium hydrogen sulfite besides the diluent generally used, a buffer giving isotonicity, and an isotonic medicine such as, for example, sodium chloride, sodium citrate, or citrates. Production methods of the sprays have been described in, for example, U.S. Pat. No. 2,868,691 specification and U.S. Pat. No. 3,095,355 specification in detail.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** (A) shows a flow cytometry that presents PD-1 expression in H-2L^d-specific 2C CTL clone and PD-L1 expression of P815 (cell line derived from mastocytoma) stable transfectant clone, and (B) shows a cytotoxic activity of 2C CTL cell line to PD-L1-expressing P815 cell lines and the effect on the cytotoxic activity of anti-PD-L1 antibody (anti-PD-L1 F(ab')$_2$ IgG).

FIG. **2** shows tumor growth and infiltrating of PD-L1-expressing P815 cell lines transplanted into syngeneic mouse. (A) shows the tumour volume (upper) of the transplanted PD-L1-expressing P815 tumours and the survival rate (under) after the transplant, (B) shows the tissue staining view of the transplanted PD-L1-expressing P815 tumour mass in syngeneic DBA/2 mouse (a shows a view (×40) that presents invasion of tumor cells across the abdominal wall and the peritoneum, b shows the same view (×400), c shows the view of invasion into spleen, and d shows the view of invasion into liver).

FIG. **3** shows in vivo effect of anti-PD-L1 antibody for the tumor growth of the transplanted PD-L1-expressing P815 cell lines in syngeneic mice. (A) shows in vivo effect of anti-PD-L1 antibody for IFN-γ production from the tumor-specific CD8+ T cells in mice, (B) shows in vivo effect of anti-PD-L1 antibody for the tumour volume (upper) and the survival rate (under) of the transplanted PD-L1-expressing P815 tumors in mice (squares show control group (rat IgG administrated group) and circles show anti-PD-L1 antibody (anti-PD-L1 $F(ab')_2$ IgG) administrated group in the figure).

FIG. **4** shows proliferation suppression of PD-L1-expressing B16 melanomas in homo-deficient syngeneic mice (PD-1−/−).

FIG. **5** shows in vivo effect of anti-PD-L1 antibody to tumor growth of transplanted myeloma cell lines in syngeneic mouse (BALB/c) and the involvement of PD-1. (A) shows a flow cytometry that shows PD-L1 expression in various myeloma cell lines, (B) shows in vivo effect of anti-PD-L1 antibody for tumor growth of J558L tumors transplanted in the above mouse, and (C) shows comparison of tumor growth of J558L tumors transplanted in wild type and PD-1 gene deficient (PD-1−/−) syngeneic mice.

FIG. **6** shows PD-L1 expression in capillary endothelium. (A) shows PD-L1 and PD-L2 expression in vascular endothelial cells of mice heart. (B) shows tissue staining of PD-L1 expression in each tissue of mice. Each PD-L1 expression in (a): eyeball, (b): submandibular gland, (c): heart, (d): lungs, (e): liver, (f): kidney is shown. In the figure, Ch means choroidea, CV means middle cardiac vein, GI means glomerule, and Re means retina. Each arrow shows vascular endothelial cells. Each staining image is enlargement view (×40).

FIG. **7** shows PD-L1 expression in liver non-parenchymal cells.

FIG. **8** shows cell surface molecule phenotype in Kupffer cells and liver sinusoidal endothelial cells (LSECs).

FIG. **9** shows cell surface molecule phenotype in CD4 positive T cells of PD-1 gene homo-deficient mice (PD-1−/−) or wild type mice (wt).

FIG. **10** shows cell surface molecule phenotype in CD8 positive T cells of PD-1 gene homo-deficient mice (PD-1−/−) or wild type mice (wt).

FIG. **11** shows the effect of PD-L1 on T-cell proliferation in LNPC. (A) shows cellular proliferation when stimulating each naive T cells of PD-1−/− mice and wt mice. (B) shows the effect of anti-PD-L1 antibody on cellular proliferation in the co-culture of T cells that has already been activated and derived from PD-1−/− mice or wt mice and LNPC.

FIG. **12** shows the effect of PD-L1 on cytokine production in LNPC. (A) shows cytokine production when stimulating each naive T cell of PD-1−/− mice and wt mice. (B) shows the effect of anti-PD-L1 antibody on cytokine production in the co-culture of T cells that has already been activated and derived from PD-1−/− mice or wt mice and LNPC. (C) shows cell division of the activated T cells from PD-1−/− mice or wt mice in the co-culture with LNPC.

FIG. **13** shows the involvement of PD-1 in T lymphocytes proliferation in virus infected mouse liver. Cellular proliferation of CD19- and CD3-positive lymphoid cells in liver and spleen of PD-1−/− mice or wt mice on (A) day 0 and (B) day 7 after adenovirus infection are shown.

FIG. **14** shows the involvement of PD-1 to cellular proliferation of T lymphocytes in virus infected mouse liver. (A) shows cellular proliferation of CD4- and CD8-positive lymphoid cells in liver of PD-1−/− mice or wt mice on day 7 after adenovirus infection. (B) shows the ratio of various proliferative lymphocytes on day 7 after the infection.

FIG. **15** shows the involvement of PD-1 in virus infection. In this figure, (*a*)-(*d*) show tissue staining images that presents each cellular proliferation in liver of PD-1−/− mice and wt mice on day 0 and day 7 after adenovirus infection. (*e*) and (*f*) show cellular proliferation of CD4- and CD8-positive T cells in PD-1−/− mice on day 7 after adenovirus infection.

FIG. **16** shows the involvement of PD-1 to virus infection. In this figure, (*g*)-(*n*) show hematoxylin & eosin tissue staining images in liver of PD-1−/− mice and wt mice on day 0 and day 7 after adenovirus infection. (*o*)-(*r*) show X-gal tissue staining images in liver of PD-1−/− mice and wt mice on day 0 and day 7 after adenovirus infection.

FIG. **17** shows the enhancement of each material to cytotoxic activity. In this figure, (a) the enhancement of anti-mouse PD-1 antibody, (b) the enhancement of anti-mouse PD-L1 antibody, (c) the enhancement of mouse PD-1 Fc, and (d) the enhancement of human PD-1 Fc are shown.

BEST MODE FOR CARRYING OUT INVENTION

The following example explains the present invention more concretely, but do not limit the range of the present invention.

Example 1

A mouse PD-L1 expression vector was constructed by being inserted and ligated mouse PD-L1 cDNA (Journal of Experimental Medicine (2000), vol. 19, issue 7, p. 1027-1034) digested with restriction enzyme EcoRI to pApuroXS expression vector (*The EMBO Journal* (1994), vol. 13, issue 6, p. 1341-1349). The expression vector pApuroXS-PD-L1 was transfected into P815 cells by electroporation (360V, 500 μF). The P815 cells were cultured in RPMI-1640 medium including FCS (10%), 2-mercaptoethanol (10^{-5}M), and various antibiotics. The P815 cell lines which stably expressed mouse PD-L1 can be cloned by subculturing as resistant cells under medium including antibiotic puromycin (3 μg/ml). PD-L1 expression can be confirmed by flow cytometric analysis. FIG. **1** (A) shows flow cytometries presenting (i) PD-1 expression of H-$2L^d$-specific 2C CTL clones and (ii) PD-L1 expression in PD-L1 expressing stable transformant of P815 (cell line derived from mastocytoma). Transformed B16 cell lines (B16/PD-L1) stably expressing PD-L1 were cloned by a similar method (FIG. **1**(A) (iii)-(v)). pEFBOSneo-PD-L1 (Nucleic Acid Research (1990), vol. 18, issue 17, p. 5322) constructed as a expression vector by a similar method was used, and G418 (0.5 mg/ml) was used for selective culture of the cell lines.

cDNA coding protein to connect tandem 6×his peptide tag (His-Tag) to 3' end side of total length mouse PD-L1 cDNA was inserted in expression vector pVL1393 (the trade name: purchase from Clonetech) after being digested by restriction enzyme EcoRI and NotI. Then, this expression vector was continuously introduced to SF9 insect cells (purchased from Invitrogen), and the inclusion body was collected. This inclu-

sion body virus was infected to HiFive insect cells (purchased from Invitrogen) by culturing for 2 days at 27° C. The purified PD-L1 protein that are used as antigen was obtained by processing cell lysate dissolved with buffer solution (Tris-HCl (50 mM, pH7, and 1% TritonX-100), EDTA (10 mM), and NaCl (150 mM), various protease inhibitors) with Ni-sepharose column chromatography.

The dialyzed PD-L1 protein was immunized to female wister rat at 8 weeks age (purchased from SLC Japan) with a complete Freund adjuvant (purchased from Amersham) and after several days, 2×10^8 of cells collected from peripheral lymph node were fused with the same number of SP2/0 cells using PEG1500. Further, the fused cells were selected by culturing in RPMI1640 medium (HAT (purchased from Sigma), Origen (10%, purchased from Igen), and FCS (10%), 2-mercaptoethanol (10^{-5}M), and various antibiotics), and the presence of the antibody production was confirmed by flow cytometric analysis. The monoclonal antibody (1-111) to PD-L1 was obtained by purification of the collected peritoneal fluid with protein G sepharose column chromatography after transferring the established hybridoma (hybridomas recognized with International Trust Number: FERM BP-8396) to Balb/C nu/nu mice. As antibodies used by flow cytometry, etc., biotinated antibodies using Sulfo-NHS-LC-biotin (the trade name: purchased from Pierce) can be used.

Further, anti-human PD-1 antibody (the monoclonal antibody producted from hybridomas recognized with International Trust Number: FERM BP-8392) was prepared according to a similar method.

Cytotoxicity assay was executed by ^{51}Cr (chromium) separation assay.

2C cells (*Journal of Immunology* (1996), vol. 157, issue 2, p. 670-678) are $(H\text{-}2L)^d$ alloreactive cytotoxic T-cells derived from 2C transgenic B6 mice. After mixing 2C cells (E: effector) together with ^{51}Cr-labeled P815 cells (T: target) (circle), three kinds of PD-L1-expressing P815 cells (P815/PD-L1) (square, diamond, and triangle) respectively, or further under the presence of 10 mg/ml rat anti-PD-L1 $F(ab')_2$ IgG (filled triangle), a result of measuring separated ^{51}Cr for 4 hours with various E/T ratio is shown in FIG. **1** (B).

Anti-PD-L1 antibody (anti-PD-L1 $F(ab')_2$) recovered the decreased cytotoxic activity of cytotoxic T lymphocytes. Those results suggested that inhibition of PD-1 and PD-L1 signal by inhibiting PD-L1 function could reinforce cytotoxic activity to carcinoma cells.

Example 2

The tumor growth and the survival rate of mice was evaluated by hypodermically transferring 1×10^6 of P815 cells (n=6) or P815/PD-L1 cells (n=6) to syngeneic DBA/2 mice respectively. The result is shown in FIG. **2**(A). In this figure, circles show P815 cell lines transplanted group, and squares and triangles show PD-L1-expressing P815 cell lines transplanted group respectively. Further, histological analysis of P815/PD-L1 cells transferred group was executed. FIG. **2**(B) shows staining images dyed with hematoxylin & eosin after being fixed by 10% formaldehyde and embedded into paraffin. In this figure, a shows a view (×40) that presents invasion of tumor cells across the abdominal wall and the peritoneum, b shows the same view (×400), c shows the view of invasion into spleen, and d shows the view of invasion into liver.

In the P815 cells transplanted group, P815 cells proliferation was suppressed and 30 percent of mice in this group lived by 6-7 weeks, while in PD-L1-expressing P815 cells (P815/PD-L1) transplanted group, carcinoma cells proliferation was remarkable and all mice died by 2-4 weeks (FIG. **2**(A)). P815/PD-L1 cells were observed to permeate across the peritoneal cavity and the abdominal cavity, and further those metastases to liver and spleen (FIG. **2**(B) *a-d*).

Example 3

After co-culturing 2×10^6 of 2C cells together with 5×10^6 of P815 cells or P815/PD-L1 cells only, or P815/PD-L1 cells under the presence of 10 mg/ml rat anti-PD-L1 $F(ab')_2$ IgG respectively, IFN-γ in culture supernatant at 24 hours was measured with ELISA kit (purchased from Bioscience). The result is shown in FIG. **3**(A).

FIG. **3**(B) shows the result of evaluating of the tumor growth and the survival rate of mice of which anti-rat IgG (square) or anti-PD-L1 $F(ab')_2$ IgG (0.1 mg/mouse) (circle) was intraperitoneally administered to syngeneic DBA/2 mice (n=10) to which 3×10^6 of P815/PD-L1 cells had been hypodermically transferred on day 1, 3, 5, and 7 after the cell-transfer.

Anti-PD-L1 antibody restored IFN-γ production from cytotoxic T lymphocytes which had been suppressed by P815/PD-L1 (FIG. **3**(A)). Administration of anti-PD-L1 antibody suppressed carcinoma cell growth, and showed the clear survival effect (FIG. **3**(B)). This result presents that administration of anti-PD-L1 antibody is effective on cancer treatment.

Example 4

1×10^6 of B16 melanomas (n=6) or B16/PD-L1 cells (n=6) were hypodermically transferred to B6 mice (n=6) respectively, and the same number of B16/PD-L1 cells were transferred to PD-1 transgenic B6 mice (n=5) and PD-1 gene homo-deficient B6 mice (PD-1-(n=4)) (*Science* (2001), vol. 291, issue 5502, p. 319-332), each tumor growth was measured by 25 days thereafter. FIG. **4** shows the result.

Example 5

Tumor growth of which (n=9) anti-rat IgG or anti-PD-L1 $F(ab')_2$ IgG (0.1 mg/mouse) was intraperitoneally administered to syngeneic Balb/C mice to which 2.5×10^8 of J558 myeloma cells had been hypodermically transferred on day 3, 5, and 7 after the cell-transfer was evaluated. Each tumor growth in PD-1 gene homo-deficient Balb/C mice and Balb/C mice (n=4) to which J558 myeloma cells had been hypodermically transferred were compared (FIG. **5**(B)).

Administration of anti-PD-L1 antibody suppressed PD-L1-expressing J558 carcinoma cells proliferation (flow cytometries of PD-L1 expression in various myeloma cell lines are shown in FIG. **5**(A)) (FIG. **5**(B)). The transplanted tumor cells proliferation was completely inhibited in PD-1-deficient mice to which J558 cells had been transplanted (FIG. **5**(*c*)). These results present that inhibition of PD-L1 or PD-1 is effective on cancer treatment.

Example 6

Vascular endothelial cells (hereafter, abbreviated as ECs) was gathered from mouse heart by the method of Marelli-Berg (*Journal of immunological methods* (2000), vol. 244, issue 1-2, p. 205-215). Concretely, heart tissue digested by collagenase was pre-cultured followed by being pre-cultured with mouse Ig and co-cultured together with FITC-modified anti-CD3 antibody, the same modified anti-CD105 antibody, the same modified anti-isolectin B4 antibody, and anti-FITC bead. These vascular endothelial cells were purified by posi-

tive selection using Magnetic-activated cell-sorting separation columns (the trade name: purchased from Miltenyi Biotec).

PD-L1 and PD-L2 expressions in the gathered vascular endothelial cells were confirmed by flow cytometry. The cell labelling was executed using anti-PD-L1 antibody (the antibody name: 1-111), anti-PD-L2 antibody (the antibody name: #122), and fluorescent labelling second antibody (FIG. **6**(A)). The analysis was executed 10,000 events with Facscalibur (the equipment name: purchased from Becton Dickinson) using CellQuest software (purchased from Dickinson). PD-L1 or PD-L2 expression is shown as shedding curve, and control Ig is shown as filling curve.

PD-L1 expression in each mouse tissue was confirmed by tissue staining. Before 1 hour each tissue sampling, 100 μl of PBS which 100 μg of biotin-labelling anti-PD-L1 antibody (1-111) had been dissolved was intravenously administered to mouse. Then, 5 μm frozen section was fixed by 4% paraformaldehyde (PFA), and dyed with Streptavidin-FITC. Each section was countered staining by Phalloidin (FIG. **6**(B) shows PD-L1 expression in (a) eyeball, (b) submaxillary gland, (c) heart, (d) lung, (e) liver, (f) kidney. In this figure, Ch presents choroid, CV presents vena centralis, GI presents glomerule, and Re presents retina. Each arrow presents vascular endothelial cells. Each staining figure is 40× enlargement view). PD-L1 expression was observed in capillary endothelium of heart, lung, kidney, stomach, small intestine, submandibular gland, eyeball, and liver. The expression in liver was localized in liver sinusoidal capillary.

Example 7

PD-L1 expression in liver non-parenchymal cells (hereafter, abbreviated with LNPCs) was confirmed by tissue staining (FIG. **7**(A)) and flow cytometry (FIG. **7**(B)). In the tissue staining, 5 μm liver frozen section fixed with 3% of PFA was preprocessed by rat serum followed by being reacted for 1 hour at room temperature using biotin-labeled anti-PD-L1 antibody (1-111) or biotin-labeled anti-ICAM-1 antibody (the trade name: purchased from BD Pharmingen), and then the biotin antibodies were visualized by tyramide signal amplification (TSA) fluorescence system (the equipment name: purchased from PerkinElmer Life Sciences) (FIG. **7**(A) shows ICAM-1 expression, FIG. **7**(B) shows PD-L1 expression, and CV presents vena centralis. Each staining figure is 40× enlargement view).

LNPCs were isolated from mouse liver according to the pronaseE method (*Experimental Cell Research* (1976, vol. 99, p. 444-449). Concretely, LNPCs obtained by which liver is circulated with pronaseE solution (Merck) were cultured and were separated by density gradient centrifugation. Relative distribution of Kupffer cells (CD54+, CD11bhigh) in the cell suspension is 20-25%, and that of liver perisinusoidal space endothelial cells (hereafter, abbreviated with LSECs) (CD54+, CD11bhigh) is 75-80%. Kupffer cells and LSECs were doubly stained using FITC-labeled anti-CD11b antibody, each biotinated monoclonal antibody to ICAM-1, PD-L1, B7-1, and B7-2, and PE-labeled Streptavidin, respectively. Kupffer cells and LSECs were gate as CD11b high and CD11b low cell, respectively (FIG. **8**).

PD-L1 expressed together with ICAM-1, B7-1, and B7-2 in Kupffer cells, while the expression was weak in LSECs (FIG. **8**).

Example 8

Native T cells were refined (refining degree 90% or more) from spleen and lymphoid of PD-1 gene homo-deficient mice (PD-1−/−) or wild type C57BL/6 mice (wt) by a negative selection using T-cell enrichment column (the trade name: purchased from Genzyme). The cells cultured for 48 hours with 10 μg/ml of anti-CD3 monoclonal antibody (2C11) were activated. The naive T cells activated by the above method were doubly stained using FITC-labeled anti-CD4 antibody or APC-labeled anti-CD8 antibody, PE-labeled anti-CD25 antibody, PE-labeled anti-CD4 antibody, PE-labeled anti-CD69 antibody, or PE-labeled anti-CTLA-4 antibody, biotin-labeled anti-B7-1 (CD80) antibody or biotin-labeled anti-B7-2 (CD86) antibody, and anti-PD-1 antibody (the antibody name: J43, monoclonal antibody producted from hybridomas recognized by International Trust Number FERM BP-8118) or anti-PD-L1 antibody (1-111), and each molecule expressions were analyzed by flow cytometry (FIG. **9** and **10**).

The hybridomas identified by International Trust Number FERM BP-8118 had been deposited as Trust Number FERM P-18356 to National Institute of Advanced Industrial Science and Technology, International Patent Organism Depositary in Central 6, 1-1-1 Higashi, Tsukuba, Ibaraki, Japan (ZIP code 305-8566) at May 30, 2001, and was transferred to International Deposit at Jul. 16, 2002.

Example 9

The naive T cells activation of PD-1 gene homo-deficient mice (PD-1−/−) or wild type mice (wt) was executed by the method described in example 8. Proliferation of these activated cells was measured by BrdU incorporation method (FIG. **11**(A)). The proliferation was measured by adding BrdU at the last 6 hours of 48 hours to label the cells and measuring using Proliferation ELISA kit (the trade name: Purchased from Roche). The amount of IFN-γ production at this time was measured in ELISA Kit (the trade name: purchased from Genzyme) (FIG. **12**(A)).

T cells derived from PD-1 gene homo-deficient mice (PD-1−/−) or wild type mice (wt) was beforehand activated by the method described in example 8. The activated T cells were respectively cultured for 60 hours under the presence or the absence of Mitomycin C-processed LNPCs of wild type mice and under the presence or the absence of 30 μg/ml of anti-PD-L1 antibody (1-111) (rat IgG as control) and 20 μg/ml of CTLA4-Ig (Genzyme) (human IgG as control), and the cells proliferation for the last 12 hours was measured by BrdU incorporation method (FIG. **11**(B)). Further, the amount of IFN-γ production at 48 hours was measured (FIG. **12**(B)).

As to the amount of IFN-γ production when naive T cells were activated, a significant difference between PD-1−/− and wild type mice was not observed. On the other hand, in the activated T cells, the amount of IFN-γ production of T cells derived from wild type mice was significantly lower than that derived from PD-1−/−(FIG. **12**). Therefore, it was suggested that the effect of PD-1 inhibitory action on the activated T cells could be higher than the effect on naive T cells activation.

In co-culture of the activated T cells derived from wild type mice and LNPCs, a significant difference in the cellular proliferation and the amount of IFN-γ production of these T cells was not observed, while in the co-culture of the activated T cells derived from PD-1−/− mice and LNPCs, a significant increase in the cellular proliferation of these T cells was observed (FIG. **11**(B), FIG. **12**(B)). In adding anti-PD-L1 antibody to the co-culture of the activated T cells derived from wild type mice and LNPCs, an increase in the cellular proliferation of these T cells was observed (FIG. **11**(B)). These results suggest that PD-1 or PD-L1 of LNPCs could take part

in suppression of T cells activation and lack of PD-1 or inhibition of interaction between PD-1 and PD-L1 could activate T cells.

The activated T cells of PD-1 gene homo-deficient mice (PD-1−/−) or wild type mice (wt) was labeled by 5 μM CFSE (5-(6)-carboxy-fluorescein diacetate succinimidyl diester) (the trade name: purchased from Molecular probes) and was co-cultured together with LNPCs for 48 hours. Cell division at this time was decided by CFSE activity measurement using FACS (FIG. **12**(C)).

It was suggested that the cellular proliferation suppression of the activation T cells could cause in cytostasis suppression and PD-1 signal could suppress cell division of T cells (FIG. **12**(C)).

Example 10

PD-1 gene homo-deficient mice (PD-1−/−) or wild type mice (wt) (3 per a group) were infected in adenoviruses by intravenous administration of 10^9-10^{10} PFU (plaque-forming units) of Ad-lacZ. Ad-lacZ used here, which are 5 type adenovirus with lacZ gene, lacks E1 and E3 region and can be purified by cesium chloride density-gradient centrifugation (*Nucleic Acid Research* (1995), vol. 234, issue 19, p. 3816-3821) after proliferating them in 293 cells. On day 0 or 7 after infection, spleen cells and intrahepatic lymphocytes that had been gathered after intravenous administration of 0.5 mg of BrdU (the trade name: purchased from Sigma) to the mice at 1 hour before slaughtering were doubly labeled by anti-BrdU antibody and anti-CD19 antibody, or anti-CD3 antibody (FIG. **13**).

The cells on day 7 after infection were doubly labeled by anti-BrdU antibody, anti-CD19 antibody, anti-CD3 antibody, anti-CD4 antibody, and anti-CD8 antibody (FIG. **14**(B), each bar graph shows the ratio of BrdU-positive cells).

In adenovirus infected PD-1−/− mice liver, the ratio of each proliferative (BrdU positive) lymphocyte (CD19 positive, CD3 positive, CD4 positive, or CD8 positive) had increased compared to that in similarly infected wild type mice liver. On the other hand, since such a phenomenon in spleen was not observed, it was suggested that PD-1 could inhibit T cells proliferation in inflammatory tissues (FIG. **14**(B)).

Example 11

On day 0 or 7 after 10^9-10^{10} PFU of Ad-lacZ had been intravenously administered to PD-1 gene homo-deficient mice (PD-1−/−) or wild type mice (wt) (3 per a group), liver slices that had been gathered after intravenous administration of 0.5 mg of BrdU (the trade name: purchased from Sigma) to the mice at 1 hour before slaughtering were doubly labeled by anti-BrdU antibody (FIG. **15**(*a*)-(*d*), 20× enlargement view). Liver slices of PD-1 gene homo-deficient mice (PD-1−/−) on day 7 after infection were doubly labeled by anti-BrdU antibody, anti-CD19 antibody, anti-CD3 antibody, anti-CD4 antibody, and anti-CD8 antibody (FIG. **15**(*e*), (*f*), 40× enlargement view).

In wild type mice liver on day 30 after infection, the locally and medium cell invasion to sinusoidal capillary and non-parenchymal region was observed, but in PD-1−/− mice, hepatitis symptom was not observed (FIG. **16**(*h*), (*i*) and (*i*), (*n*)).

Liver slices of PD-1 gene homo-deficient mice (PD-1−/−) or wild type mice (wt) on day 7 or 30 after infection were stained by hematoxylin & eosin (FIG. **16**(*g*)-(*j*), 20× enlargement view, (*k*)-(*n*), 40× enlargement view) and X-gal (FIG. **16** (*o*)-(*r*), 40× enlargement view). In liver of wild type mouse on day 7 and 30 after infection, adenovirus infection indicated by X-Gal stain was confirmed, while the infection in that of PD-1−/− mouse had been almost eliminated on day 30 (FIG. **16** (*o*), (*p*) (*q*) and (*r*)). These results presented that PD-1 signal could take part in the exclusion of viruses by which the proliferation of effector T cells in virus infected tissue could be induced.

Example 12

P-815/PD-L1 cells compellingly expressing mouse PD-L1 were sown into culture flask and were cultured in usual medium including 5 μg/mL of puromycin (purchased from Sigma) (hereafter, abbreviated as selective medium) at 37° C. under 5% CO_2/95% air until to be 50%-90% confluent. Mouse cytotoxic T lymphocyte 2C cells were subcultured for several days in usual medium together with P-815 cells processed by MMC (Mitomycin C) and culture supernatant of ConA-stimulated rat splenic cells. The collected P-815/PD-L1 cells were cultured for 15 minutes after adding 3 μL of BATDA Reagent of DELFIA EuTDA Cytotoxicity Reagents (purchased from PerkinElmer). Then, they were washed with PBS. 2C cells subcultured for 5-8 days after adding P-815 cells were used.

As subject substrates, 20 μL (10 ng/mL) of anti-mouse PD-1 antibody (FIG. **17**, anti-mPD-1Ab(J43)), anti-mouse PD-L1 antibody (anti-mPD-L1Ab(1-111) in this figure), mouse PD-1 Fc (mPD-1 Fc in this figure), human PD-1 Fc (hPD-1 Fc in this figure), mouse IgG2ak (Control Ig in this figure), or PBS were dispensed into 96 well plate, and then 50 μL of P-815/PD-L1 cells or usual medium were added. Further, 50 μL of 2 C cells, usual medium, or usual medium including 1% Triton×100 were added. 50 μL of supernatants in wells which the usual medium were added were collected for background and other supernatants were preserved at 37° C. until being collected. The residual cells were cultured for 4 hours. The 96 well plates were centrifuged and the supernatants were collected. 200 μL of DELFIA Europium Solution of Cytotoxicity Reagents (purchased from PerkinElmer) were added to the collected supernatants, and were shaken for 15 minutes. After shaking, time resolved fluorescence measurement was executed with ARVOsx multi-label counter (WALLAC). The supernatants in wells that the usual medium including 1% Triton×100 was added were used as a high control, and the one in wells that the usual medium were used as a low control.

The evaluated group is composed of a subject substrate, P-815/PD-L1 cells, and 2C cells, the high control group is composed of PBS, P-815/PD-L1 cells, and usual medium including 1% Triton×100, and the low control group is composed of PBS, P-815/PD-L1 cells, and usual medium, the 2C cell control group is composed of PBS, usual medium, and 2C cells, and the background group is composed of PBS, P-815/PD-L1 cells, and usual medium. CTL activity (%) was calculated by the following formula. All values are the one that had been subtracted by the average of the background.

CTL activity (%)=([the measurement of the evaluation group]−[the measurement of the 2C cell control group]−[the measurement of the low control group])/([the measurement of the high control group]−[the measurement of the low control group])×100

Anti-PD-1 antibody, anti-PD-L1 antibody, and PD-1 Fc have significantly reinforced CTL activity (FIG. **17**(*a*)-(*d*), E:T ratio presents the mixing ratio of 2C cells and PD-L1/P815 cells).

Example 13

The inhibiting effect of anti-PD-1 antibody on cancer metastasis was evaluated by intraperitoneal administration of

anti-mouse PD-1 monoclonal antibody to C57BU6 mice to which B16 melanoma cells had been transferred at intervals of 2 days followed by measuring the liver weight on day 18 after transfer.

The increase in the liver weight of anti-PD-1 antibody administrated group was significantly suppressed than that in control IgG administrated control group (liver weight/carcinoma cell non-transferred group: 1.3 g, decrease from control group: 6.8 g to anti-PD-1 antibody administrated group: 3.5 g). The suppression of the increase in this weight presents that the metastasis of B16 melanoma cells is suppressed.

The invention claimed is:

1. A method for treatment of a tumor in a patient, comprising administering to the patient a pharmaceutically effective amount of an anti-PD-1 monoclonal antibody.

2. The method of claim **1**, wherein the anti-PD-1 monoclonal antibody binds to human PD-1 and is a chimeric, humanized, or human antibody.

3. The method of claim **2**, wherein the tumor is one or more selected from the group consisting of a carcinoma, squamous carcinoma, adenocarcinoma, sarcoma, leukemia, neuroma, melanoma, and lymphoma.

4. The method of claim **3**, wherein the squamous carcinoma is in the lung, cervical canal, eyelid, tunica conjunctiva, vagina, oral cavity, skin, urinary bladder, tongue, larynx, or gullet.

5. The method of claim **3**, wherein the adenocarcinoma is in the prostate, small intestine, endometrium, cervical canal, large intestine, lung, pancreas, gullet, intestinum rectum, uterus, stomach, mammary gland, or ovary.

6. The method of any one of claims **1** to **5**, wherein the pharmaceutically effective amount of the anti-PD-1 monoclonal antibody is administered to the patient in combination with a pharmaceutically effective amount of one or more chemotherapy drugs.

7. The method of claim **6**, wherein the one or more chemotherapy drugs are selected from the group consisting of an alkylating agent, a nitrosourea agent, an antimetabolite, an antitumor antibiotic, an alkaloid derived from a plant, a topoisomerase inhibitor, a hormone therapy medicine, a hormone antagonist, an aromatase inhibitor, a P-glycoprotein inhibitor and a platinum complex derivative.

8. A method for treatment of a melanoma in a patient, comprising administering to the patient a pharmaceutically effective amount of an anti-PD-1 monoclonal antibody.

9. The method of claim **8**, wherein the anti-PD-1 monoclonal antibody binds to human PD-1 and is a chimeric, humanized, or human antibody.

10. The method of claim **9**, wherein the pharmaceutically effective amount of the anti-human PD-1 monoclonal antibody is administered to the patient in combination with a pharmaceutically effective amount of one or more chemotherapy drugs.

11. The method of claim **10**, wherein the one or more chemotherapy drugs are selected from the group consisting of an alkylating agent, a nitrosourea agent, an antimetabolite, an antitumor antibiotic, an alkaloid derived from a plant, a topoisomerase inhibitor, a hormone therapy medicine, a hormone antagonist, an aromatase inhibitor, a P-glycoprotein inhibitor and a platinum complex derivative.

12. The method of claim **2** or **9**, wherein tumor proliferation is suppressed.

13. The method of claim **2** or **9**, wherein tumor metastasis is suppressed.

14. The method of claim **2** or **9**, wherein the anti-human PD-1 monoclonal antibody is administered to the patient in combination with interferon-alpha.

15. The method of claim **2** or **9**, wherein the anti-human PD-1 monoclonal antibody is administered to the patient in combination with an anti-CTLA-4 antibody.

16. The method of claim **2** or **9**, wherein the anti-human PD-1 monoclonal antibody is administered to the patient in combination with a tumor antigen.

17. The method of claim **16**, wherein the tumor antigen is selected from the group consisting of HLA-A1 or HLA-A2 restrictive peptide of malignant melanoma MAGE-1 or MAGE-3, MART-1, gp100, HER2/neu peptide of a mammary or ovarian carcinoma, MUC-1 peptide of an adenocarcinoma, and NY-ESO-1 of a metastatic carcinoma.

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