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Canadian Intellectual Property Office

CA 3060719 A1 2018/11/08

(21) 3 060 719

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(86) Date de dépôt PCT/PCT Filing Date: 2018/04/27
(87) Date publication PCT/PCT Publication Date: 2018/11/08
(85) Entrée phase nationale/National Entry: 2019/10/22
(86) N° demande PCT/PCT Application No.: JP 2018/017123
(87) N° publication PCT/PCT Publication No.: 2018/203517
(30) Priorité/Priority: 2017/05/02 (JP2017-091639)

(51) Cl.Int./Int.Cl. *C07K 16/36* (2006.01), *A61K 39/395* (2006.01), *A61P 35/00* (2006.01), *C07K 14/745* (2006.01), *C12N 15/13* (2006.01), *C12P 21/08* (2006.01)

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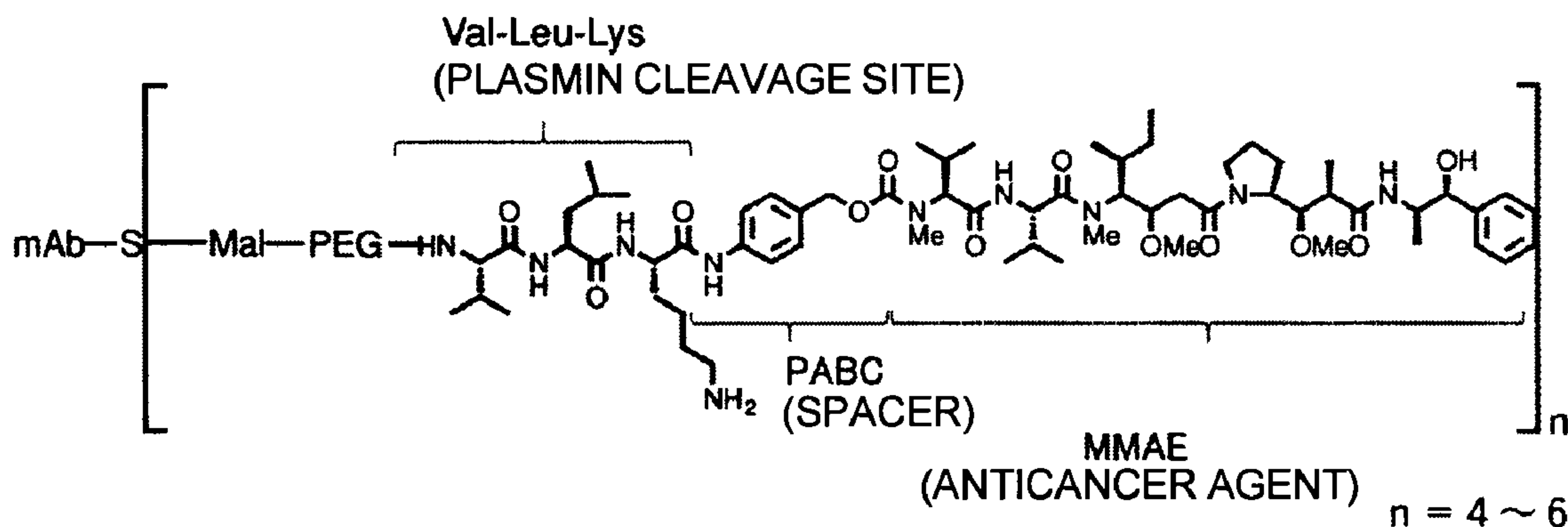
(54) Titre : CONJUGUE ANTICORPS-MEDICAMENT ANTI-FIBRINE INSOLUBLE POUVANT ETRE CLIVE PAR LA PLASMINE
(54) Title: PLASMIN-CLEAVABLE ANTI-INSOLUBLE FIBRIN ANTIBODY-DRUG CONJUGATE

FIG. 3



(57) Abrégé/Abstract:
The present invention relates to an antibody-drug conjugate (ADC) and to a composition containing this conjugate for use for the treatment of cancer. The present invention provides, with respect to an ADC between a drug and an antibody specific for insoluble fibrin, an ADC wherein the linker connecting the antibody and the drug has a plasmin cleavage site, and also provides a pharmaceutical composition containing this ADC for use for the treatment of cancer.

(12) 特許協力条約に基づいて公開された国際出願

(19) 世界知的所有権機関
国際事務局

(43) 国際公開日
2018年11月8日(08.11.2018)

(10) 国際公開番号
WO 2018/203517 A1

(51) 国際特許分類:
C07K 16/36 (2006.01) *C07K 14/745* (2006.01)
A61K 39/395 (2006.01) *C12N 15/13* (2006.01)
A61P 35/00 (2006.01) *C12P 21/08* (2006.01)

(21) 国際出願番号： PCT/JP2018/017123

(22) 国際出願日： 2018年4月27日(27.04.2018)

(25) 国際出願の言語： 日本語

(26) 国際公開の言語： 日本語

(30) 優先権データ：
特願 2017-091639 2017年5月2日(02.05.2017) JP

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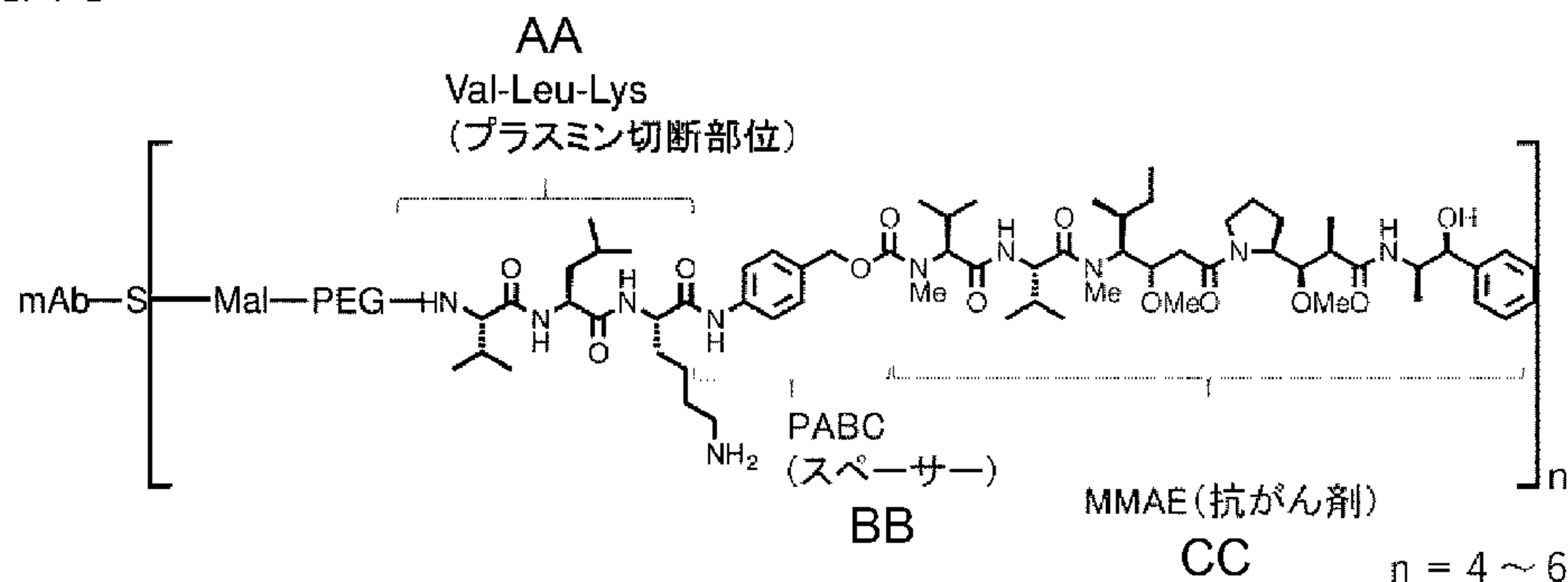
(81) 指定国(表示のない限り、全ての種類の国内保護が可能): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO,

(54) Title: PLASMIN-CLEAVABLE ANTI-INSOLUBLE FIBRIN ANTIBODY-DRUG CONJUGATE

(54) 発明の名称： プラスミンにより切断可能な抗不溶性フィブリン抗体と薬物とのコンジュゲート

［図3］



AA (Plasmin cleavage site)
BB (Spacer)
CC (Anticancer agent)

(57) Abstract: The present invention relates to an antibody-drug conjugate (ADC) and to a composition containing this conjugate for use for the treatment of cancer. The present invention provides, with respect to an ADC between a drug and an antibody specific for insoluble fibrin, an ADC wherein the linker connecting the antibody and the drug has a plasmin cleavage site, and also provides a pharmaceutical composition containing this ADC for use for the treatment of cancer.

(57) 要約： 本発明は、抗体薬物コンジュゲート（ＡＤＣ）および当該コンジュゲートを含む、がんを治療することに用いるための組成物に関する。本発明によれば、不溶性フィブリンに特異的な抗体と薬物とのＡＤＣにおいて、抗体と薬物とを連結するリンカーがプラスミン切断配列を有するＡＤＣおよび該ＡＤＣを含む癌を治療することに用いるための医薬組成物が提供される。

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DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) 指定国(表示のない限り、全ての種類の広域保護が可能): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), ユーラシア (AM, AZ, BY, KG, KZ, RU, TJ, TM), ヨーロッパ (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

添付公開書類:
— 国際調査報告(条約第21条(3))
— 明細書の別個の部分として表した配列リスト(規則5.2(a))

Description

Title of Invention:

PLASMIN-CLEAVABLE ANTI-INSOLUBLE FIBRIN ANTIBODY-DRUG CONJUGATE

Technical Field

[0001]

The present invention relates to an antibody-drug conjugate and a composition containing the conjugate for use in treating cancer.

Background Art

[0002]

It has been revealed that when a blood vessel is injured, if blood comes into contact with the damaged blood vessel wall or the blood vessel subendothelial tissue or a tissue factor flows into the bloodstream, a blood coagulation reaction starts, the fibrinogen in blood or pathological lesion changes into insoluble fibrin, and a net of fibrin functions as a strong hemostatic plug to harden the wound.

[0003]

It has long been suggested that blood coagulation is closely related to cancer (described in the "Plegmasia alba dolens" -by a French physician in 1800s, Trousseau). Recent clinical epidemiological data have also revealed

that most cancers, including pancreatic cancer, gastric cancer, and brain tumor, have a significantly higher frequency of thrombosis due to hypercoagulation than healthy individuals (Non-Patent Literature 1). In addition, it is considered that accumulation of insoluble fibrin, coagulative necrosis, and angiogenesis due to abnormal coagulation occur repeatedly also inside cancer tissues with the progress of the cancer.

[0004]

Insoluble fibrin is not present in tissues under normal physiological conditions, unlike fibrinogen, which is a precursor of fibrin, being widely present in the living body. Fibrinogen is cleaved by activated thrombin leaked to the outside of a blood vessel to form a fibrin monomer, and the fibrin monomer polymerizes and crosslinks to form fibrin fibers. Thus, insoluble fibrin is generated. Therefore, insoluble fibrin is specifically present in tissues in pathological conditions, such as bleeding and inflammation, and is formed when a pathologic state involving coagulation, such as cancer, myocardial infarction, or cerebral infarction, has occurred. Accordingly, insoluble fibrin is a marker molecule for such thrombus-related diseases. In particular, insoluble fibrin that is present in cancerous tissues not involving cerebral circulatory diseases such as myocardial infarction and cerebral infarction is exactly a cancer-specific molecule.

[0005]

Under such technical background, an antibody specific to insoluble fibrin and an antibody-drug conjugate (ADC) using the antibody have been proposed (Patent Literature 1).

Citation List

Patent Literature

[0006]

[Patent Literature 1]

WO 2014/133093

Summary of Invention

[0007]

The present inventors have developed an ADC of an antibody specific to insoluble fibrin and a drug, in which a linker linking the antibody and the drug has a plasmin cleavage sequence. The present inventors have found that the resulting ADC is delivered to insoluble fibrin and is cleaved by plasmin at the delivered site to release the drug at the site. Furthermore, the present inventors have found, using a tumor animal model, that the resulting ADC can target an insoluble fibrin accumulation site in the vicinity of a tumor and releases the drug at the site to show an anticancer activity against the tumor. In addition, the present inventors

have acquired a new insoluble fibrin-specific antibody. The present invention is based on these findings.

[0008]

That is, the present invention provides the followings:

(1) An antibody-drug conjugate (ADC), wherein

the antibody is an antibody that binds to fibrin and has affinity to insoluble fibrin higher than that to fibrinogen,

the drug is a cytotoxic agent, and

the antibody and the drug are linked to each other through a linker having a plasmin cleavage site that allows cleavage by plasmin;

(2) The ADC according to (1), wherein

the linker comprises a valine-leucine-lysine peptide sequence as the plasmin cleavage site;

(3) A pharmaceutical composition comprising the ADC according to (1) or (2) for use in treating cancer;

(4) The pharmaceutical composition according to (3), wherein the cancer is invasive cancer;

(5) An antibody that binds to fibrin, wherein the antibody has

a heavy chain variable region having CDR1 set forth in SEQ ID NO: 1, CDR2 set forth in SEQ ID NO: 2, and CDR3 set forth in SEQ ID NO: 3, and

a light chain variable region having CDR1 set forth in SEQ ID NO: 5, CDR2 set forth in SEQ ID NO: 6, and CDR3

set forth in SEQ ID NO: 7; an antibody that competes with the antibody for binding to fibrin; or an antigen-binding fragment thereof;

(6) An antibody that binds to fibrin, wherein the antibody has

a heavy chain variable region set forth in SEQ ID NO: 4 and a light chain variable region set forth in SEQ ID NO: 8; or

an antigen-binding fragment thereof;

(7) An antibody that binds to fibrin, wherein the antibody has

a heavy chain variable region having CDR1 set forth in SEQ ID NO: 9, CDR2 set forth in SEQ ID NO: 10, and CDR3 set forth in SEQ ID NO: 11, and

a light chain variable region having CDR1 set forth in SEQ ID NO: 13, CDR2 set forth in SEQ ID NO: 14, and CDR3 set forth in SEQ ID NO: 15;

an antibody that competes with the antibody for binding to fibrin; or an antigen-binding fragment thereof;

(8) An antibody that binds to fibrin, wherein the antibody has

a heavy chain variable region set forth in SEQ ID NO: 12 and a light chain variable region set forth in SEQ ID NO: 16; or

an antigen-binding fragment thereof;

(9) The ADC according to (1) or (2), wherein the antibody is the antibody according to any one of (5) to (8);

(10) A pharmaceutical composition comprising the ADC according to (9); and

(11) The pharmaceutical composition according to (10), for use in treating cancer.

Brief Description of Drawings

[0009]

[Figure 1] Figure 1 shows that antibodies obtained by the present invention are specific to insoluble fibrin.

[Figure 2] Figure 2 shows that monoclonal antibodies specific to insoluble fibrin obtained by the present invention accumulate at tumor-forming sites.

[Figure 3] Figure 3 shows especially a drug portion and a linker portion of an antibody-drug conjugate produced by the present invention.

[Figure 4] Figure 4 shows the results of verification of in vitro anticancer activity of the antibody-drug conjugate produced by the present invention.

[Figure 5] Figure 5 shows a Kaplan-Meier curve of an antibody-drug conjugate produced by the present invention for a spontaneous pancreatic cancer model.

[Figure 6A] Figure 6A shows an effect of suppressing an increase in tumor volume in tumor subcutaneous implantation mice by the antibody-drug conjugate produced by the present invention.

[Figure 6B] Figure 6B shows changes with time in weight of the mice observed in Figure 6A.

[Figure 7] Figure 7 shows cytostatic activities of an ADC having a plasmin linker having a plasmin cleavage site or an ADC having a cathepsin linker not having a plasmin cleavage site but having a cathepsin cleavage site instead.

[Figure 8] Figure 8 shows a presumed action mechanism of an antibody-drug conjugate produced by the present invention.

Description of Embodiments

[0010]

In the present invention, the term "subject" means a mammal, in particular a human.

[0011]

In the present specification, the term "treatment" is used to mean therapy (therapeutic treatment) and prevention (preventive treatment). In the present specification, the term "therapy" means therapy, cure, or prevention of a disease or a disorder; improvement of remission; or a reduction in the speed of progress of a disease or a disorder. In the present specification, the term "prevention" means a reduction in risk of onset of a disease or a pathologic state or a delay of onset of a disease or a pathologic state.

[0012]

In the present specification, the term "disease" means a symptom of which therapy is helpful. In the

present specification, the term "cancer" means a malignant tumor.

[0013]

In the present specification, the term "antibody" means an immunoglobulin and encompasses a polyclonal antibody and a monoclonal antibody. A preferred antibody is a monoclonal antibody. Although the origin of the antibody is not particularly limited, examples of the antibody include non-human animal antibodies, non-human mammal antibodies, and human antibodies. The antibody may be a chimera antibody, a humanized antibody, or a human antibody. In addition, the antibody may a bispecific antibody.

[0014]

In the present specification, the term "therapeutically effective amount" means an amount of a medicine effective for treating (prevention and therapy) of a disease or a condition. A therapeutically effective amount of a medicine can reduce the speed of worsening of a symptom of a disease or a condition, stop the worsening of the symptom, improve the symptom, cure the symptom, or suppress the onset or development of the symptom.

[0015]

In the present specification, the term "insoluble fibrin" means fibrin crosslinked by factor XIII. In a living body, for example, if bleeding occurs, fibrinogen is converted into a fibrin monomer by the action of

thrombin, the fibrinogen monomer polymerizes to form an insoluble fibrin polymer. The fibrin polymer is crosslinked by factor XIII into insoluble fibrin.

[0016]

In the present specification, the term "insoluble fibrin-specific antibody" is an antibody that binds to insoluble fibrin and has a higher affinity to insoluble fibrin than to fibrinogen. Such an insoluble fibrin-specific antibody can be easily obtained by screening with an affinity to insoluble fibrin and an affinity to fibrinogen. Fibrin has an epitope site that is exposed only when fibrin becomes insoluble by three-dimensional structural change into the insoluble fibrin. Accordingly, the "insoluble fibrin-specific antibody" can be obtained by immunization with the exposed domain, that is, D-domain as an immunogen. Alternatively, the antibody can also be obtained using a linear peptide. For example, an "insoluble fibrin-specific antibody" can be obtained by immunization with a fibrin Bβ chain partial peptide corresponding to positions 231 to 246 of the amino acid sequence of the fibrin Bβ chain (for example, human fibrin Bβ chain can have the amino acid sequence set forth in SEQ ID NO: 25). Alternatively, the "insoluble fibrin-specific antibody" can also be obtained by immunization using a peptide set forth in SEQ ID NO: 26 or SEQ ID NO: 27 as an immunogen. Such an insoluble fibrin-specific antibody can be an antibody having a

higher affinity to insoluble fibrin than to all of fibrinogen, fibrin monomers, and fibrin polymers. An antibody having a ratio of the affinity to insoluble fibrin to the affinity to fibrinogen of, for example, higher than 1, 1.5 or more, 2 or more, 3 or more, 4 or more, or 5 or more can be obtained as an insoluble fibrin-specific antibody. The affinity means binding affinity (KD) and can be determined by a known method, such as ELISA and kinetic exclusion assay.

[0017]

In the present specification, the term "compete" means scrambling with another binding antibody for binding to an antigen. Competition can occur when two antibodies have binding sites for the same antigen. Such antibodies can be obtained by immunization using an epitope described above and/or also by verifying by competitive assay whether binding of one antibody to an antigen is reduced by the other antibody or not.

[0018]

In the present specification, the term "antibody-drug conjugate" (hereinafter, also referred to as "ADC") means a substance in which an antibody and a cytotoxic agent are linked to each other. In the ADC, the antibody and the cytotoxic agent can be linked to each other via an appropriate linker. As the cytotoxic agent, a chemotherapeutic agent, a radioisotope, or a toxin can be

used. The term "ADC" encompasses a conjugate of an antigen-binding fragment of an antibody and a drug.

[0019]

In the present specification, the term "antigen-binding fragment" means a part of an antibody in which the affinity to an antigen is maintained. The antigen-binding fragment can comprise the heavy chain variable region, the light chain variable region, or the both in the antibody of the present invention. The antigen-binding fragment may be chimerized or humanized. Examples of the antigen-binding fragment include Fab, Fab', $F(ab')_2$, Fv, scFv (single-chain Fv), diabody, and $sc(Fv)_2$ (single-chain $(Fv)_2$). Such antibody fragments can be obtained by, but not particularly limited to, treating the antibody with an enzyme. For example, digestion of an antibody with papain gives Fab. Alternatively, digestion of an antibody with pepsin gives $F(ab')_2$, and Fab' can be obtained by further reduction of the $F(ab')_2$. In the present invention, such antigen-binding fragments of an antibody can be used.

[0020]

In the present invention, the antibody and the cytotoxic agent in an antibody-drug conjugate are linked to each other via a linker. Examples of the cytotoxic agent include chemotherapeutic agents (for example, anticancer agents such as commercially available anticancer agents, e.g., auristatin (auristatin E,

auristatin F phenylenediamine (AFP), monomethyl auristatin E, monomethyl auristatin F, and derivatives thereof), maytansinoids DM1 and DM4, and derivatives thereof), camptothecin (SN-38, irinotecan, Lurtotecan, DB67, BMP1350, ST1481, CKD602, topotecan, and exatecan, and derivatives thereof), DNA minor groove binding agents (enediyne, lexitropsin, and duocarmycin, and derivatives thereof), taxanes (paclitaxel and docetaxel, and derivatives thereof), polyketides (discodermolide and derivatives thereof), anthraquinones (mitoxantrone and derivatives thereof), benzodiazepine (pyrrolobenzodiazepine, indolinobenzodiazepine, and oxazolidinobenzodiazepine, and derivatives thereof), vinca alkaloids (vincristine, vinblastine, vindesine, and vinorelbine, and derivatives thereof), doxorubicins (doxorubicin, morpholino-doxorubicin, and cyanomorpholino-doxorubicin, and derivatives thereof), cardiac glycosides (digitoxin and derivatives thereof), calicheamicin, epothilone, cryptophycin, cemadotin, cemadotin, rhizoxin, netropsin, combrestatin, eluterobin, etoposide, T67 (tularik), and nocodazole); radioisotopes (for example, ^{32}P, ^{60}C, ^{90}Y, ^{111}In, ^{131}I, ^{125}I, ^{153}Sm, ^{186}Re, ^{188}Re, and ^{212}Bi); and toxins (for example, diphtheria toxin A, Pseudomonas endotoxin, ricin, and saporin), and they can be used as the cytotoxic agent in the ADC of the present invention. As the cytotoxic agent in the ADC of the present invention, preferably, for example,

camptothecin, in particular SN-38 or exatecan can be used. As the cytotoxic agent, any of those used for treatment of cancer can be used. The cytotoxic agent may be a pharmaceutically acceptable salt, a solvate (for example, hydrate), an ester, or a prodrug of the above-mentioned cytotoxic agents.

[0021]

In the present invention, the linker of the ADC comprises a plasmin cleavage sequence and can be cleaved in the presence of plasmin. In the present invention, the linker of the ADC, the parts other than the plasmin cleavage sequence comprise chemical bonds that are stable in the process from administration to delivery to insoluble fibrin. The ADC of the present invention in such a constitution is stable after administration until being delivered to insoluble fibrin and is cleaved by plasmin after binding to insoluble fibrin to release the cytotoxic agent in the vicinity of the insoluble fibrin. The plasmin cleavage sequence is an amino acid sequence and, specifically, can be a peptide chain comprising an amino acid sequence such as a plasmin cleavage sequence selected from the group consisting of valine-leucine-lysine, glycine-proline-lysine, glutamic acid-lysine-lysine, lysine-phenylalanine-lysine, norvaline-chlorohexylalanyl-lysine, and norleucine-hexahydrotyrosine-lysine. Such a linker can be appropriately selected in production of the ADC and

synthesized by a person skilled in the art. In a certain aspect, as the linker, for example, a first space may be inserted between the antibody and the plasmin cleavage sequence, where for example, polyethylene glycol (PEG), such as PEG with about 5 to 40 repeating units per molecule, can be used as the first spacer; and a second spacer may be inserted between the plasmin cleavage sequence and the cytotoxic agent, where for example, p-aminobenzyloxycarbonyl (PABC) can be used as the second spacer.

In a certain aspect, the linker comprises a first spacer and a plasmin cleavage sequence. In a certain aspect, the linker comprises a first spacer, a plasmin cleavage sequence, and a second spacer. In a certain subject, the linker comprises PEG, a plasmin cleavage sequence, and PABC.

In a certain aspect, the linker does not comprise cleavable moieties other than the plasmin cleavage sequence.

In the binding between an antibody and the linker, for example, the linker can be linked to a sulfhydryl group of the antibody via a maleimide group.

In a certain aspect, the antibody is linked to an anticancer agent via its sulfhydryl group through a linker having a maleimide-PEG-plasmin cleavage sequence. In a certain aspect, the antibody is linked to an anticancer agent via its sulfhydryl group through a

linker having maleimide-PEG-plasmin cleavage sequence-PABC.

In any case, in the ADC of the present invention, an anticancer agent is linked to an anticancer agent through a linker having a plasmin cleavage site that can be cleaved by plasmin, and when the ADC reached an insoluble fibrin accumulation site, the linker is cleaved at the plasmin cleavage site by plasmin present in the circumference thereof to release the anticancer agent to the vicinity of the insoluble fibrin. It is considered that in the vicinity of cancer tissue, there are many insoluble fibrin accumulation sites due to bleeding caused by cancer invasion (see Figure 8), and it is considered that the antibody of the present invention (i.e., insoluble fibrin-specific antibody) is useful for targeting to cancer in a drug delivery system, and the ADC of the present invention is useful as a therapeutic agent for cancer.

[0022]

The present invention provides the following antibodies:

an antibody that binds to fibrin, wherein the antibody has

a heavy chain variable region having CDR1 set forth in SEQ ID NO: 1, CDR2 set forth in SEQ ID NO: 2, and CDR3 set forth in SEQ ID NO: 3, and

a light chain variable region having CDR1 set forth in SEQ ID NO: 5, CDR2 set forth in SEQ ID NO: 6, and CDR3 set forth in SEQ ID NO: 7; and

an antibody that competes with the antibody for binding to fibrin. These antibodies can be used as the insoluble fibrin-specific antibody.

[0023]

The present invention also provides the following antibody:

an antibody that binds to fibrin, wherein the antibody has

a heavy chain variable region set forth in SEQ ID NO: 4 and a light chain variable region set forth in SEQ ID NO: 8. This antibody can be used as the insoluble fibrin-specific antibody.

This antibody is also recognized as an antibody having

a heavy chain variable region having CDR1 set forth in SEQ ID NO: 1, CDR2 set forth in SEQ ID NO: 2, and CDR3 set forth in SEQ ID NO: 3, and

a light chain variable region having CDR1 set forth in SEQ ID NO: 5, CDR2 set forth in SEQ ID NO: 6, and CDR3 set forth in SEQ ID NO: 7.

[0024]

The present invention provides the following antibodies:

an antibody that binds to fibrin, wherein the antibody has

a heavy chain variable region having CDR1 set forth in SEQ ID NO: 9, CDR2 set forth in SEQ ID NO: 10, and CDR3 set forth in SEQ ID NO: 11, and

a light chain variable region having CDR1 set forth in SEQ ID NO: 13, CDR2 set forth in SEQ ID NO: 14, and CDR3 set forth in SEQ ID NO: 15; and

an antibody that competes with the antibody for binding to fibrin. These antibodies can be used as the insoluble fibrin-specific antibody.

[0025]

The present invention also provides the following antibody:

an antibody that binds to fibrin, wherein the antibody has

a heavy chain variable region set forth in SEQ ID NO: 12 and a light chain variable region set forth in SEQ ID NO: 16. This antibody can be used as the insoluble fibrin-specific antibody.

This antibody is also recognized as an antibody having

a heavy chain variable region having CDR1 set forth in SEQ ID NO: 9, CDR2 set forth in SEQ ID NO: 10, and CDR3 set forth in SEQ ID NO: 11, and

a light chain variable region having CDR1 set forth in SEQ ID NO: 13, CDR2 set forth in SEQ ID NO: 14, and CDR3 set forth in SEQ ID NO: 15.

[0026]

The above-mentioned antibodies, insoluble fibrin-specific antibodies, and antigen-binding fragments thereof can be used as the antibody part in the ADC of the present invention.

[0027]

According to the present invention, a pharmaceutical composition comprising a therapeutically effective amount of the ADC (also referred to as "ADC of the present invention") is provided. According to the present invention, the ADC and the pharmaceutical composition of the present invention can each be used for treating cancer.

[0028]

The cancer as a subject to be treated by the ADC or the pharmaceutical composition of the present invention is not particularly limited, and examples thereof include lung cancer, pancreatic cancer, head and neck cancer, prostatic cancer, bladder cancer, breast cancer, esophageal cancer, stomach cancer, colon cancer, uterine cancer, ovarian cancer, skin cancer, thyroid cancer, thymic cancer, kidney cancer, testicular cancer, penile cancer, liver cancer, biliary tract cancer, brain tumor, bone and soft tissue tumor, retroperitoneal tumor, and

angiosarcoma/lymphangiosarcoma, and metastatic cancers thereof.

[0029]

The subject of the present invention can be a subject who does not suffer from a thrombotic disorder or a disease associated with a thrombotic disorder or a subject who is not diagnosed to have a thrombotic disorder or a disease associated with a thrombotic disorder. Consequently, it can be expected to reduce side effects at tissues other than cancer. Accordingly, whether a subject having cancer suffers from a thrombotic disorder or a disease associated with a thrombotic disorder or not may be determined, and then the ADC of the present invention may be administered to the subject not suffering from a thrombotic disorder or a disease associated with a thrombotic disorder. Whether a subject suffers from a thrombotic disorder or a disease associated with a thrombotic disorder or not can be appropriately determined by a medical doctor.

[0030]

In a certain aspect of the present invention, the pharmaceutical composition comprises the ADC of the present invention and an excipient. The pharmaceutical composition of the present invention can be administered by a method, such as intravenous administration, subcutaneous administration, intratumoral administration, intraperitoneal administration, intraventricular

administration, and intramuscular administration. The dose can be appropriately determined by a medical doctor in consideration with, for example, the age, sex, weight, and severity of a disease of a patient.

[0031]

The ADC of the present invention not only targets insoluble fibrin that accumulates in stroma of cancer and allows the cytotoxic agent to accumulate at the target site but also has a linker that can be cleaved by plasmin that is activated at the site where insoluble fibrin is present and causes liberation of the cytotoxic agent at the target site. Consequently, it is possible to site-specifically injure the cancer in the vicinity of the liberation site.

[0032]

According to the present invention, provided is use of the insoluble fibrin-specific antibody in the manufacture of a medicament for use in treating cancer. According to the present invention, provided is use of an ADC of an insoluble fibrin-specific antibody and a cytotoxic agent, wherein the antibody and cytotoxic agent has a plasmin cleavage site that can be cleaved by plasmin in the ADC, in the manufacture of medicament for use in treating cancer.

[0033]

According to the present invention, provided is a method for treating cancer in a subject in need thereof,

comprising administering a therapeutically effective amount of the ADC of the present invention to the subject. According to the present invention, provided is a method for treating cancer in a subject in need thereof, comprising determining whether a subject having cancer suffers from a thrombotic disorder or a disease associated with a thrombotic disorder or not, and then administering a therapeutically effective amount of the ADC of the present invention to the subject not suffering from a thrombotic disorder or a disease associated with a thrombotic disorder.

[0034]

According to the present invention, provided is use of the ADC of the present invention for use in a method for treating cancer.

Examples

[0035]

Example 1: Production of insoluble fibrin-specific antibody

In this example, an antibody that has a selectively higher affinity to insoluble fibrin than to fibrinogen (hereinafter, referred to as "insoluble fibrin-specific antibody") was produced.

[0036]

(1) Explanation of immunogen

In the example, antibodies were obtained by immunizing animals with a peptide having the amino acid sequence of SEQ ID NO: 26 or a peptide having the amino acid sequence of SEQ ID NO: 27 as immunogens.

[0037]

(2) Immunization method

Mice were immunized 6 times every 2 weeks as follows.

The immunogens for the first and the fourth immunization were prepared as follows. A peptide having the amino acid sequence of SEQ ID NO: 26 and a peptide having the amino acid sequence of SEQ ID NO: 27 were each used as immunogens. An immunogen adjusted to 0.5 mg/mL with sterilized PBS was put in a 1-mL syringe. Freund's Complete Adjuvant (Difco) in the same amount as that of the immunogen was put in another 1-mL syringe. The syringes were connected with an adaptor, and extrusion was performed until resistance was felt. In the first and fourth immunization, 200 μL of the immunogen were intraperitoneally administered.

The immunogen for second, third, fifth, and sixth immunization was prepared as follows. An immunogen adjusted to 0.5 mg/mL with sterilized PBS was mixed with GERBU ADJUVANT 100 (nacalai tesque) in the same amount of the immunogen in a 1.5-mL tube, and the mixture was put in a 1-mL syringe. In the second, third, fifth, and sixth immunization, 100 μL of the immunogen were intraperitoneally administered. In the final

immunization, an immunogen adjusted to 0.1 mg/mL with sterilized PBS was put in a 1-mL syringe, and 100 μL of the immunogen were first intraperitoneally administered, and after 10 minutes, 400 μL of the immunogen were administered from the tail vein.

[0038]

(3) Measurement of antibody titer

One week before the last immunization of each mouse, blood was collected from the tail vein. The blood was centrifuged at 4,000×g for 10 minutes at 4°C, and the supernatant was collected as a sample. The antibody titer was measured by ELISA using samples prepared by two-fold serial dilution from 100-fold to 12800-fold. In advance of the ELISA, an antigen-immobilized plate was prepared. Fibrinogen from human plasma (SIGMA) was dissolved in TBS (pH 8.5) to produce a 20 μg/mL fibrinogen solution. The solution was added to a 96-well immunoplate at 50 μL/well and was left to stand at 4°C overnight to prepare a fibrinogen plate. Thrombin diluted to 0.05 NIH U/mL with a thrombin diluent [7 mM L-cysteine (FUJIFILM Wako Pure Chemical Corporation), 1 mM $CaCl_2$ (FUJIFILM Wako Pure Chemical Corporation), TBS (pH 8.5)] was added to the fibrinogen plate at 100 μL/well and was incubated at 37°C for 2 hours to prepare an insoluble fibrin plate. The plate on which each antigen was immobilized was washed with 200 μL of PBS-T (PBS, 0.5% (v/v) Tween 20) three times, and 200 μL of a

blocking solution [PBS-T, 1% (w/v) BSA] were added to each well, followed by being left to stand at room temperature for 1 hour for blocking. The serially diluted samples were added to the plate at 50 μL/well and were left to stand at room temperature for 1 hour. The solutions were discarded, and the plate was washed with PBS-T three times. A secondary antibody diluted to 0.3 μg/mL with the blocking solution was added to the plate at 50 μL/well, followed by being left to stand at room temperature for 30 minutes. As the secondary antibody, polyclonal rabbit anti-mouse immunoglobulins/HRP (Dako) and polyclonal rabbit anti-rat immunoglobulins/HRP (Dako) were used properly according to the sample. The solutions were discarded, the plate was washed with PBS-T three times, and a chromogenic substrate solution (1-Step™ Slow TMB-ELISA Substrate Solution, Thermo Fisher Scientific, Inc.) was added to the plate at 100 μL/well, followed by a reaction at room temperature for 10 minutes. The reaction was stopped by adding 30 μL of 2N H_2SO_4 to each well. The absorbance at a wavelength of 450 nm was measured with a Spectra Max paradigm (Molecular Devices).

[0039]

(4) Preparation of hybridoma

The spleen was surgically removed from each mouse and immersed in an RPMI 1640 medium supplemented with 200 units/mL penicillin, 200 μg/mL streptomycin, and 500 ng/mL amphotericin B. RPMI 1640 was injected into the

spleen using a syringe 10-mL (TERUMO Corporation) and an injection needle 22G (TERUMO Corporation), and spleen cells were taken out and were passed through an EASY strainer 70-μm mesh (Greiner Bio-One). The collected cell suspension was centrifuged at 270×g for 5 minutes at room temperature, the supernatant was removed, and the precipitate was suspended in 10 mL of RPMI 1640. After repeating this washing with RPMI 1640 twice, the precipitate was suspended in 5 mL of RPMI 1640, followed by cell fusion as in cell fusion using mouse iliac lymph nodes.

[0040]

(5) Screening of hybridoma

Screening by ELISA was started 10 days after the cell fusion. In primary screening, 50 μL of the culture supernatant from each of all wells were dispensed to use as a primary antibody. Plates on which each of the peptides used for immunization was immobilized were prepared. A peptide was diluted to 20 μg/mL with a phosphate buffer and added to a 96-well immunoplate (MAXI BREAKAPART NUNC-IMMUNO MODULE, Nunc) at 50 μL/well, followed by being left to stand at room temperature for 1 hour for immobilization. After the immobilization, ELISA was performed as in the antibody titer measurement to verify wells containing cells producing antibodies.

In secondary screening, 50 μL of the culture supernatant from only the wells positive in the primary

screening were dispensed to use as a primary antibody. ELISA using the fibrin plate and the fibrinogen plate was performed as in the antibody titer measurement to verify wells containing cells producing insoluble fibrin-specific antibodies. The wells that were positive in the secondary screening were subjected to colony picking using 200 μL-scaled Tip Yellow (Watson). The tip was pressed to a colony, and 5 μL of the colony were sucked up and seeded in a fresh Costar 96-Well Cell Culture Plate.

In tertiary screening, 50 μL of the culture supernatant from the wells in which the colony was seeded were dispensed to use as a primary antibody. ELISA using the fibrin plate and the fibrinogen plate was performed as in the antibody titer measurement. The cells in the wells that were positive in the tertiary screening were subjected to limiting dilution.

In quaternary screening, 50 μL of the culture supernatant from only wells of a single cell were dispensed to use as a primary antibody. ELISA using the fibrin plate and the fibrinogen plate was performed as in the antibody titer measurement to select cells producing insoluble fibrin-specific antibodies.

Clone 99-5 was obtained from a mouse immunized with a peptide having the amino acid sequence of SEQ ID NO: 26. Clone 1101 was obtained from a mouse immunized with a

peptide having the amino acid sequence of SEQ ID NO: 27. The "clone 99-5" may be referred to as simply "clone 99".

[0041]

Example 2: Characteristic analysis of the resulting monoclonal antibodies

In this example, the affinity of an antibody was verified by ELISA and surface plasmon resonance (SPR).

[0042]

(1) Verification of affinity by ELISA

In advance of the ELISA, an antigen-immobilized plate was prepared. Fibrinogen from human plasma (SIGMA) was dissolved in TBS (pH 8.5) to produce a 20 μg/mL fibrinogen solution. The solution was added to a 96-well immunoplate at 50 μL/well and was left to stand at 4°C overnight to prepare a fibrinogen plate. Thrombin diluted to 0.05 NIH U/mL with a thrombin diluent [7 mM L-cysteine (FUJIFILM Wako Pure Chemical Corporation), 1 mM $CaCl_2$ (FUJIFILM Wako Pure Chemical Corporation), TBS (pH 8.5)] was added to the fibrinogen plate at 100 μL/well and was incubated at 37°C for 2 hours to prepare a fibrin plate. The plate on which each antigen was immobilized was washed with 200 μL of PBS-T (PBS, 0.5% (v/v) Tween 20) three times, and 200 μL of a blocking solution [PBS-T, 1% (w/v) BSA] were added to each well, followed by being left to stand at room temperature for 1 hour for blocking. The samples serially diluted with PBS were added to the plate at 50 μL/well and were left to stand at room

temperature for 1 hour. The solutions were discarded, and the plate was washed with PBS-T three times. A secondary antibody diluted to 0.3 μg/mL with the blocking solution was added to the plate at 50 μL/well, followed by being left to stand at room temperature for 30 minutes. As the secondary antibody, polyclonal rabbit anti-mouse immunoglobulins/HRP (Dako) and polyclonal rabbit anti-rat immunoglobulins/HRP (Dako) were used properly according to the sample. The solutions were discarded, the plate was washed with PBS-T three times, and a chromogenic substrate solution was added to the plate at 100 μL/well, followed by a reaction at room temperature for 10 minutes. The reaction was stopped by adding 30 μL of 2N H_2SO_4 to each well. The absorbance at a wavelength of 450 nm was measured with a Spectra Max paradigm (Molecular Devices).

[0043]

The results were as shown in Figure 1. As shown in Figure 1, the antibodies obtained from clone 99 and clone 1101, which were newly prepared in the above-described example, were insoluble fibrin-specific antibodies that bind more strongly to insoluble fibrin than to fibrinogen. In addition, the antibodies more strongly reacted with fibrin than the antibody obtained from clone 102-10 obtained in WO 2016/167227.

[0044]

(2) Verification of affinity by SPR

When an antigen is insoluble, although SPR is not suitable for verifying the affinity of the antigen, measurement by SPR was performed as reference for comparing relative affinity levels between antibodies.

The affinity of an antibody to insoluble fibrin was calculated based on analysis by surface plasmon resonance (SPR) using Biacore T200 (GE Healthcare) to evaluate the intermolecular interaction of the antibody. The buffer used in the flow channel was HBS-N buffer (GE Healthcare). The peptide of the epitope site of 102-10 (see WO 2016/167227) was diluted to 1 μg/mL with 10 mM sodium acetate, pH 5.5 (GE Healthcare) and was immobilized on a sensor chip (Biacore sensor chip CM5, GE Healthcare). The immobilization was performed using an amine coupling kit (BR-1000-50, GE Healthcare) and setting the immunization amount to 90 RU. Subsequently, an antigen-antibody reaction was performed using an antibody diluted to 48.875, 93.75, 187.5, 375, 750, and 1500 nM with 1 × HBS-N buffer by a multi cycle kinetics method under conditions shown in Table 1. After the measurement, analysis using BIA evaluation (GE Healthcare) was performed to determine the KD value, kd value, and ka value.

[0045]

[Table 1]

Table 1: Conditions for SPR

Conditions for measurement on sample	
contact time	120 sec

flow rate	30 μl/min
dissociation time	180 sec
Conditions for regeneration	
Reagent	10 mM Glycine-HCl pH 1.5
contact time	60 sec
flow rate	30 μl/min
stabilization period	30 sec

[0046]

The results were as shown in Table 2.

[0047]

[Table 2]

Table 2: Affinity of each clone-producing antibody to epitope by SPR

Clone No.	Binding rate constant ka (1/Ms)	Dissociation rate constant kd (1/s)	Affinity KD (M)
99-5	1.80×10^{4}	5.85×10^{-4}	3.26×10^{-8}
3435	1.63×10^{4}	3.68×10^{-4}	2.25×10^{-8}
1101	9.37×10^{4}	3.25×10^{-3}	6.68×10^{-8}
102-10	3.77×10^{4}	1.75×10^{-3}	4.64×10^{-8}

[0048]

Example 3: Verification of accumulation of antibody to cancer using pancreatic cancer subcutaneous implantation model

In this example, LSL-$Kras^{G12D/+}$ and Ptf1a-Cre provided by Y. Kawaguchi, C. Wright, and D. Tuveson and LSL-$Trp53^{R172H/+}$ provided by National Cancer Institute at

Frederick were crossed to produce p53/p48/K-Ras triple mutant mice (pancreatic cancer mouse model), and a triple mutant mouse-derived pancreatic cancer cell line was established. Accordingly, in vivo imaging was performed using the cell line. It has been reported that the triple mutant mice imitate development of human pancreatic cancer. The pancreatic cancer cell line was cultured in 500 mL of a RPMI 1640 (FUJIFILM Wako Pure Chemical Corporation) medium supplemented with 100 mL of inactivated fetal bovine serum (FBS, Gibco) and 10 mL of 100 units/mL Penicillin, 100 μg/mL Streptomycin, and 250 ng/mL Amphotericin B (FUJIFILM Wako Pure Chemical Corporation). The culture supernatant was then removed. The cells were washed with PBS (Invitrogen), and 2 mL of Trypsin-EDTA [0.25% (w/v) trypsin-1.0 mmol/L ethylenediaminetetraacetic acid-4Na Solution with Phenol Red, FUJIFILM Wako Pure Chemical Corporation] was added thereto. The cells were detached by pipetting and placed in a 15-mL tube (Corning Incorporated), followed by centrifugation with a centrifuge (Universal centrifuge 5800, KUBOTA Corporation Co., Ltd.) at 270×g for 3 minutes at 4°C. The supernatant was removed, and the precipitate was resuspended in 10 mL of PBS, followed by centrifugation at 270×g for 3 minutes at 4°C. After repeating this procedure three times, the concentration was adjusted to 2×10^6 cells/50 μL with PBS, and the cell solution was subcutaneously injected to 5-week old BALB/c

Slc nu/nu mice (Japan SLC, Inc.) at 50 μL per mouse from the left foot base. After one month, an Alexa 647-labeled anti-insoluble fibrin antibody or a control antibody was administered at 300 μg per mouse from the tail vein. The control used was InVivoMAb Mouse IgG1 Isotype control (Bio X Cell). The mice were photographed with an in vivo living-body observation system OV110 (Olympus Corporation) one hour after the administration and on the first, third, fifth, and seventh days after the administration.

[0049]

The results were as shown in Figure 2. As shown in Figure 2, it was revealed from the imaging that accumulation of the resulting insoluble anti-insoluble fibrin antibodies (in particular, 1101 and 99) to cancer is high.

[0050]

Subsequently, a surgically removed tumor was embedded in an OCT compound (Sakura Finetek Japan Co., Ltd.) and frozen to produce thin-layer sections of 6 μm. The thin-layer sections were air-dried with a dryer for 45 minutes and were then fixed with cooled acetone (FUJIFILM Wako Pure Chemical Corporation) for 10 minutes. After washing with PBS, nuclear staining with Mayer's Hematoxylin (Muto Pure Chemicals Co., Ltd.) was performed for 2 minutes. After washing with running water for 10 minutes, the cytoplasm was stained with eosin alcohol

(Muto Pure Chemicals Co., Ltd.) diluted three-fold with 100% ethanol. After washing with running water, immersion in 100% ethanol for 3 minutes and immersion in xylene (FUJIFILM Wako Pure Chemical Corporation) for 3 minutes were each repeated three times for dehydration and permeation. Finally, the sections were mounted with Mount-Quick (Daido Sangyo Co., Ltd.).

[0051]

Surgically removed tumor was embedded in an OCT compound (Sakura Finetek Japan Co., Ltd.) and frozen to produce thin-layer sections of 6 μm. The thin-layer sections were air-dried with a dryer for 45 minutes and were then fixed with cooled acetone (FUJIFILM Wako Pure Chemical Corporation) for 10 minutes. After washing with PBS, the sections were immersed in 0.3% (v/v) H_2O_2 for 20 minutes for endogenous peroxidase inhibition. After washing with PBS for 5 minutes three times, blocking with a blocking solution [5% (w/v) skimmed milk (Difco), PBS] was performed for 30 minutes. To the sections, 200 μL of a HRP-labeled antibody diluted to 1 μg/mL with the blocking solution was dropwise added, followed by a reaction at 4°C overnight. After washing with PBS for 5 minutes three times, an enzyme-substrate reaction with 3,3'-diaminobenzidine tetrahydrochloride (Dako) was performed. Subsequently, washing with sterile distilled water was performed for 3 minutes, and nuclear staining with Mayer's Hematoxylin (Muto Pure Chemicals Co., Ltd.)

was performed for 2 minutes. After washing with running water for 10 minutes, immersion in 100% ethanol for 3 minutes and immersion in xylene (FUJIFILM Wako Pure Chemical Corporation) for 3 minutes were each repeated three times for dehydration and permeation. Finally, the sections were mounted with Mount-Quick (Daido Sangyo Co., Ltd.).

[0052]

Example 4: In vitro anticancer activity

In this example, an antibody-drug conjugate (ADC) in which monomethyl auristatin E (MMAE) was linked to the resulting insoluble fibrin-specific antibody was produced, and the anticancer activity of the ADC was evaluated.

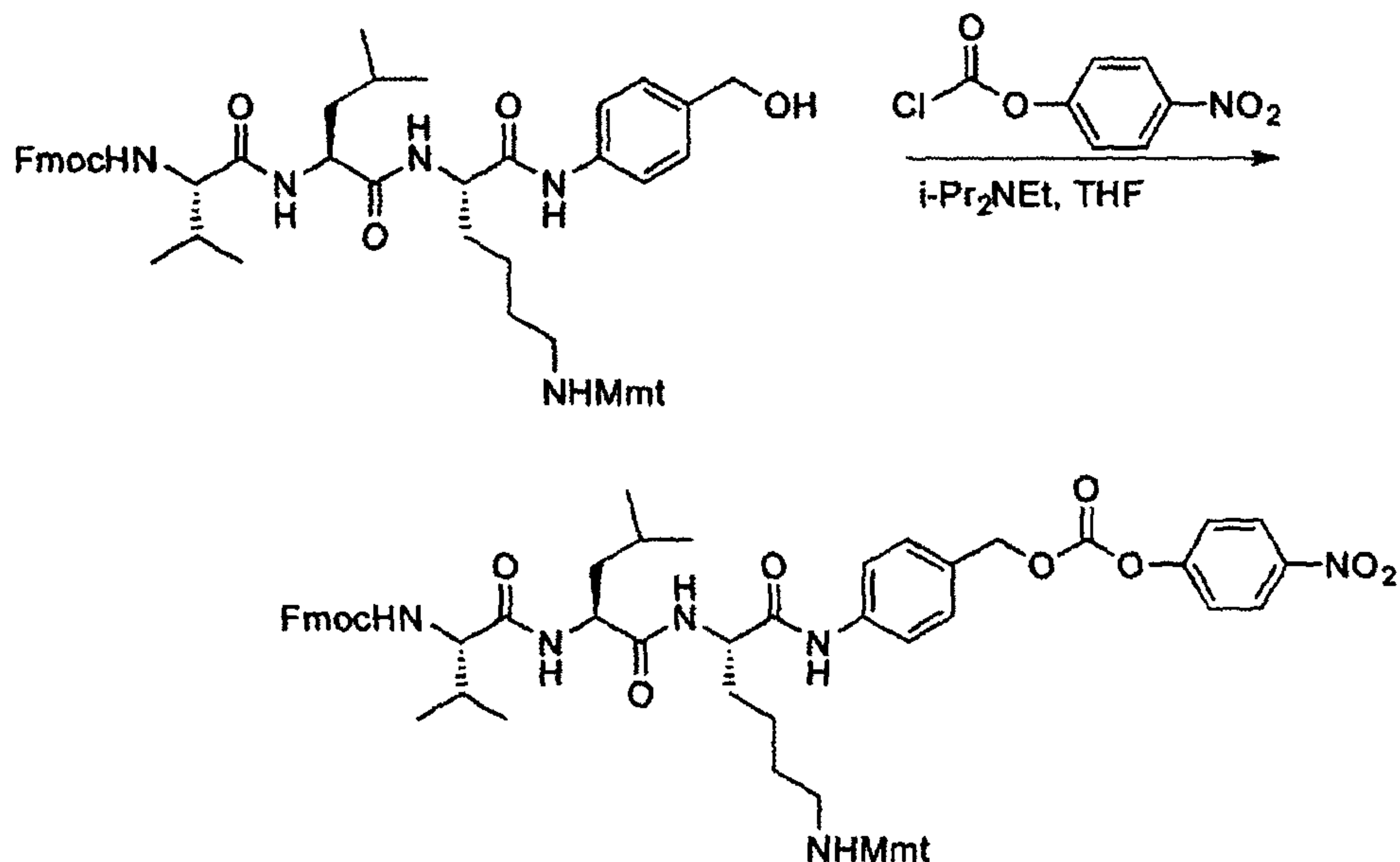
[0053]

As the ADC, an ADC having the structure shown in Figure 3 was synthesized. In this ADC, MMAE as the anticancer agent was linked to a monoclonal antibody (mAb). In the ADC, the antibody and MMAE were linked to each other via a polyethylene glycol (PEG) spacer and a plasmin cleavage site, Val-Leu-Lys. Accordingly, the ADC is cleaved in the presence of plasmin, and the MMAE is liberated from the antibody.

[0054]

The ADC was specifically synthesized as follows.

[Formula 1]



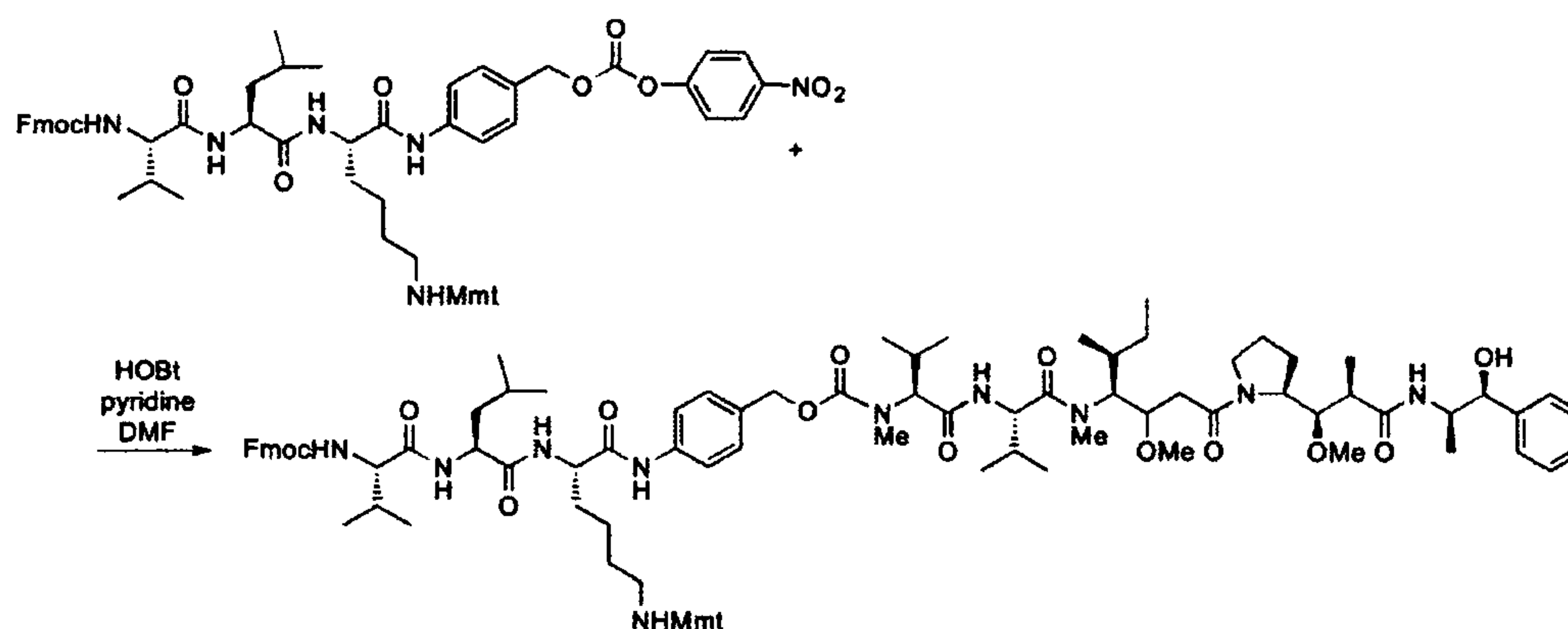
DIPEA (0.54 mL, 3.10 mmol) and p-nitrophenyl chloroformate (472 mg, 1.55 mmol) were added to a DMF (2 mL) solution containing Fmoc-Val-Leu-Lys(Mmt)-aminobenzyl alcohol (0.74 g, 0.773 mmol) at 0°C, followed by stirring at room temperature for 12 hours. The reaction solution was stopped with a saturated ammonium chloride aqueous solution, followed by extraction with chloroform. The extraction layer was washed with a saturated saline solution, dried over Na_2SO_4, and concentrated under reduced pressure. The residue was purified by silica gel chromatography ($CHCl_3$: MeOH = 95:5 to 9:1) to give Fmoc-Val-Leu-Lys(Mmt)-OPABC-p-nitrophenyl carbonate as a colorless amorphous product.

^{1}H NMR (400 MHz, $CDCl_3$): d 8.01 (br, 1H), 7.76 (br, 1H), 7.05-7.60 (m, 13H), 6.78 (d, J = 6.8 Hz, 2H), 5.49 (br, 1H), 5.25 (br, 1H), 4.94 (br, 1H), 4.77 (s, 2H), 4.04 (s,

3H), 4.00-4.85 (m, 3H), 3.75 (s, 3H), 3.55-3.90 (m, 2H), 3.26 (d, J =19.6 Hz, 1H), 3.00 (d, J = 19.6 Hz, 1H), 2.32 (br, 1H), 1.26 (s, 3H), 1.05-2.25(m, 15H), 0.70-1.05 (m, 12H); HRMS (ESI-MS) : calcd for $C_{72}H_{85}N_6O_{17}$: 1305.5971 $[M+H]^+$; found 1305.5935.

[0055]

[Formula 2]



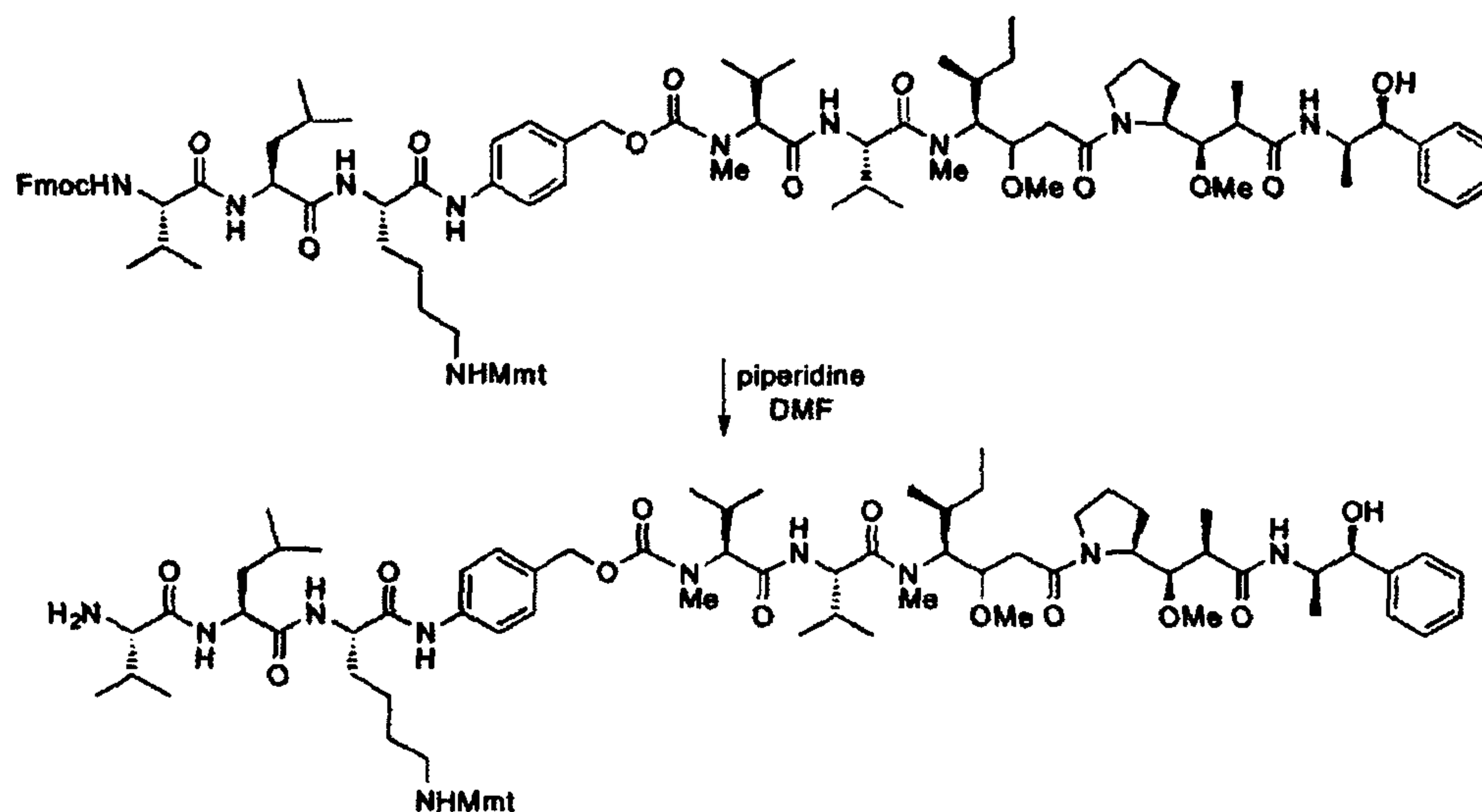
[0056]

MMAE (14.1 mg, 0.0197 mmol) was added to a pyridine (80 mL)/DMF (0.4 mL) solution containing p-nitrophenyl carbonate body (33.2 mg, 0.0296 mmol) and HOBt (0.5 mg, 0.0039 mmol) at 0°C. The reaction solution was stirred at room temperature for 10 hours and was then purified by direct LH20 (chloroform : methanol = 1:1) to give Fmoc-Val-Leu-Lys(Mmt)-OPABC-MMAE (22.7 mg, 68%) as a colorless amorphous product.

MS (MALDI-TOFMS) calcd for $[C_{99}H_{132}N_{10}O_{15}+K]^+$ 1739.95; found 1741.37.

[0057]

[Formula 3]



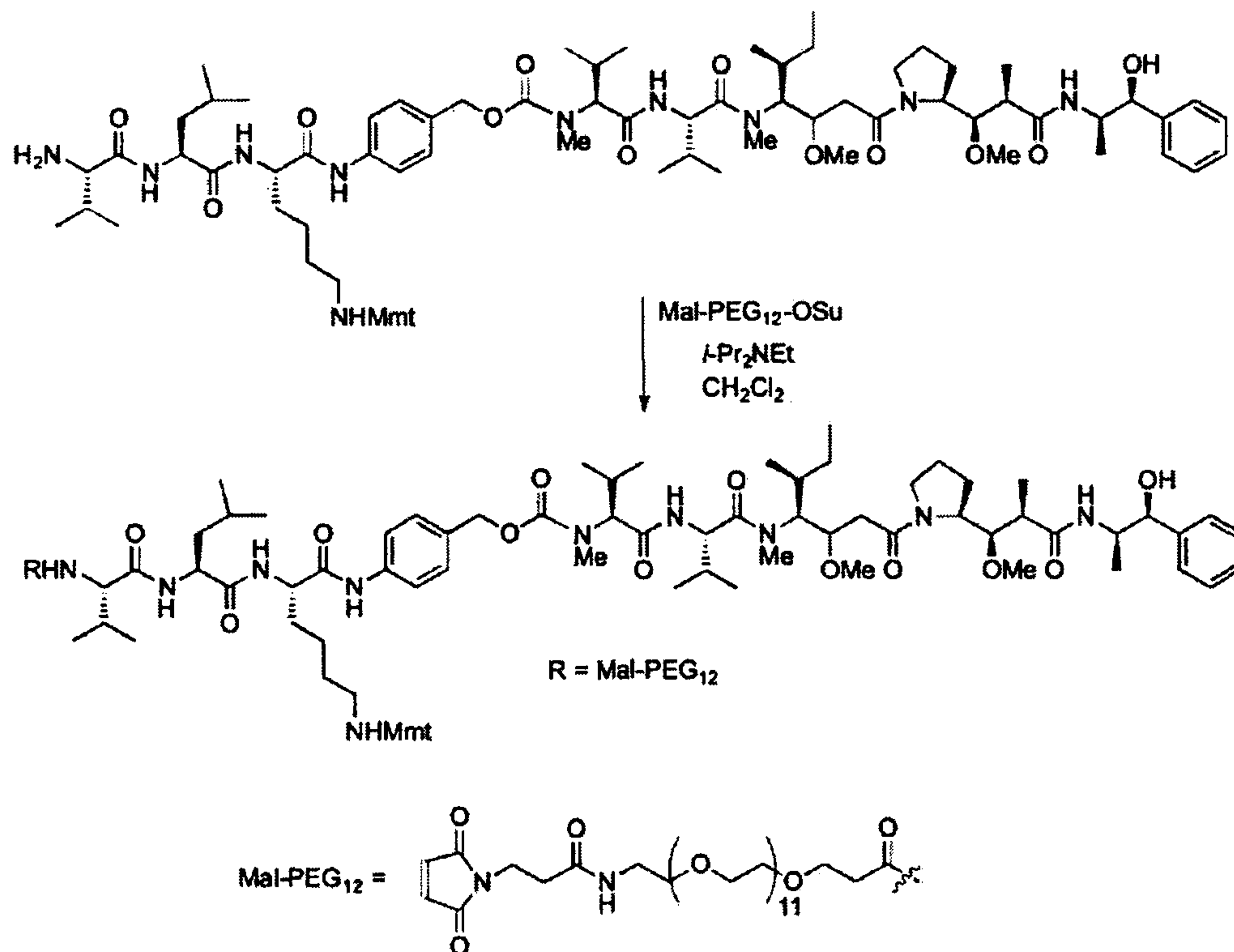
[0058]

Piperidine (110 mL, 1.10 mmol) was added to a DMF (3 mL) solution containing Fmoc-Val-Leu-Lys(Mmt)-OPABC-MMAE (626 mg, 0.368 mmol), followed by stirring at room temperature for 40 minutes. The reaction solution was purified by LH20 (chloroform : methanol = 1:1) and HPLC (YMC T4000 10.0 mL/min, $CHCl_3$: MeOH = 4:1, 254 nm) to give H-Val-Leu-Lys(Mmt)-OPABC-MMAE (458 mg, 84%) as a colorless amorphous product.

MS (MALDI-TOFMS) calcd for $[C_{94}H_{122}N_{10}O_{13}+K]^+$ 1519.02; found 1519.65.

[0059]

[Formula 4]



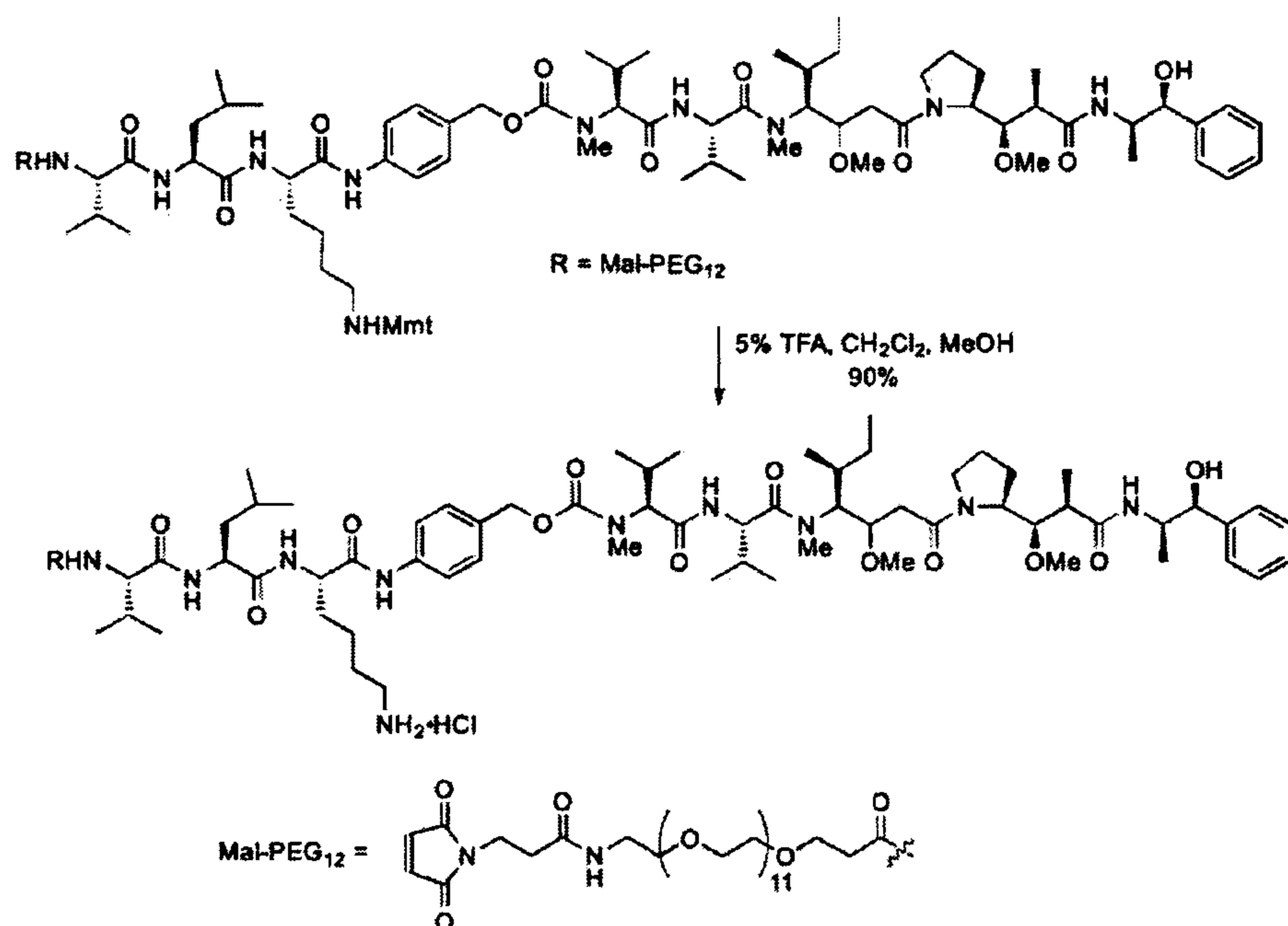
[0060]

A methylene chloride solution (1 mL) containing DIPEA (160 mL, 0.927 mmol) and Mal-PEG_{12}-OSu (295 mg, 0.340 mmol) was added to a methylene chloride solution (2 mL) containing H-Val-Leu-Lys(Mmt)-OPABC-MMAE (458 mg, 0.309 mmol) at 0°C. The reaction solution was stirred at room temperature for 22 hours, followed by purification by LH20 (chloroform : methanol = 1:1) and molecular sieve recycling HPLC (YMC T4000 10.0 mL/min, $CHCl_3$, 254 nm) to give Mal-PEG_{12}-Val-Leu-Lys(Mmt)-OPABC-MMAE (498 mg, 72%) as a colorless amorphous product.

MS (MALDI-TOFMS) calcd for $[C_{118}H_{180}N_{12}O_{29}+K\text{-}Mmt]^+$ 1997.51; found 1999.49.

[0061]

[Formula 5]



[0062]

Mal-PEG$_{12}$-Val-Leu-Lys(Mmt)-OPABC-MMAE (498 mg, 0.223 mmol) was dissolved in a 5% TFA methylene chloride solution (2 mL), and methanol (50 mL) was added thereto, followed by stirring at room temperature for 1 hour. The reaction solution was purified by direct LH20 (chloroform : methanol = 1:1) and then HPLC (YMC T4000, 10.0 mL/min, $CHCl_3$, 254 nm)) to give Mal-PEG$_{12}$-Val-Leu-Lys-OPABC-MMAE (440 mg, 90%) as a colorless amorphous product.

MS (MALDI-TOFMS) calcd for $[C_{98}H_{164}N_{12}O_{28}+K]^+$ 1997.51; found 1998.31.

[0063]

Subsequently, a fibrin plate was produced. A 25 mg/mL fibrinogen solution (5 μL) was added to a 96-well plate for cell culture along the wall surface. A thrombin solution (1 μL) was added to each well, followed by centrifugation at 40×g at 4°C for 1 minute. After a reaction at 37°C for 2 hours, the plate was stored at 4°C until use.

[0064]

5-11 Cell line (TG mouse-derived pancreatic cancer cells) was seeded on the resulting fibrin-coated plate at 2000 cells/well, followed by culturing at 37°C overnight. As the culture medium, a RPMI medium containing 10% FBS was used.

[0065]

A dilution series with final concentrations of 0 to 25 nM (in terms of MMAE) of the ADC was prepared.

[0066]

The final concentrations of plasminogen, tPA, and α2-antiplasmin were adjusted to approximately the same concentrations as those in normal plasma, i.e., about 1500 nM, about 0.3 nM, and about 1000 nM, respectively.

The culture solution was removed from the fibrin plate, and 90 μL of the solution containing plasminogen, tPA, and α2-antiplasmin were added thereto, and 10 μL of a dilution series of ADC (in the drawing, referred to as "Fbn-ADC") were then added thereto. As controls, an insoluble fibrin antibody alone (in the drawing, referred

to as "IgG") and an ADC (in the drawing, referred to as "Control-ADC") in which an anti-4M-Tag antibody (control IgG) was used as the antibody in Figure 3 were used. After incubation at 37°C for 72 hours, the culture solution was removed. A reaction solution prepared by mixing CCK-8 (Dojindo Laboratories) and a culture solution at a ratio of 1:10 was added to the plate, followed by incubation at 37°C for 3 hours. The IC_{50} was calculated from an optical density curve determined at A450.

[0067]

The results were as shown in Figure 4. The ADC of the insoluble fibrin-specific antibody showed a cancer cell proliferation inhibition effect, but in the control, no significant tumor proliferation inhibition effect was observed. This result demonstrates that the insoluble fibrin-specific antibody-ADC bound to the fibrin coated on a plate and that the linker is then cleaved by plasmin to release MMAE to kill tumor cells. The IC_{50} of the insoluble fibrin-specific antibody-ADC was 19 nM.

[0068]

Example 5: In vivo anticancer activity of the insoluble fibrin-specific antibody-ADC

The present inventors have set up a hypothesis that in vivo proliferation of cancer damages the blood vessels surrounding the cancer to cause bleeding and consequently insoluble fibrin accumulates near the tumor for arresting

the bleeding and that an anticancer agent can be delivered to the vicinity of the cancer by using an antibody that binds to the accumulated insoluble fibrin. The present inventors also have created a concept of a new anticancer agent in which a plasmin cleavage site is inserted into the linker of an ADC, and thereby the ADC reached insoluble fibrin is cleaved and further releases the anticancer agent insoluble fibrin dependently by plasmin activated on the insoluble fibrin. The present inventors have set up a hypothesis that the ADC consequently accumulates insoluble fibrin dependently and releases the anticancer agent to enhance cancer specificity.

[0069]

The therapeutic effect by the ADC against a model having spontaneous pancreatic cancer (spontaneous pancreatic cancer model) in the P53/K-ras/P48 triple mutant mice was verified. The insoluble fibrin-specific antibody-ADC (0.3 mg (in terms of MMAE)/kg weight/3 to 4 days (i.e., 20 mg (in terms of ADC)/kg weight/3 to 4 days) was administered to the model, and a Kaplan-Meier curve was determined. The significance level in a Logrank test was set to 0.05. As the control ADC (in the drawing, referred to as "Control-ADC"), anti-4M-Tag antibody was used.

[0070]

The results were as shown in Figure 5. As shown in Figure 5, the ADC (in the drawing, referred to as "αFbn-ADC") significantly improved the survival rate of the spontaneous pancreatic cancer model compared to the control. Consequently, it was proved that the above-described hypotheses are correct.

[0071]

Example 6: Anticancer activity of the insoluble fibrin-specific antibody-ADC in subcutaneous tumor model with fibrin deposition

In this example, a cell line was established from the triple mutant-derived spontaneous pancreatic cancer, and a subcutaneous tumor model obtained by subcutaneous implantation of the cell line was used for verification of the anticancer activity of the insoluble fibrin-specific antibody-ADC.

[0072]

The cell line established from the triple mutant-derived spontaneous pancreatic cancer was named as 5-11. 5×10^5 cells of 5-11 were subcutaneously implanted into BALB/C nude mice to produce a subcutaneous implantation model. This subcutaneous implantation model had fibrin deposition subcutaneously. The resulting subcutaneous tumor model was administered with the insoluble fibrin-specific antibody-ADC (0.3 mg (in terms of MMAE)/kg weight/3 to 4 days (i.e., 20 mg (in terms of ADC)/kg weight/3 to 4 days)), and the change in the tumor volume

increase rate was observed. The significance level in comparison by ANOVA was set 0.01.

[0073]

The results were as shown in Figure 6A. As shown in Figure 6A, the ADC (in the drawing, referred to as "αFbn-ADC") significantly suppressed the increase in tumor volume compared to the control.

[0074]

Changes in body weight over time in subcutaneous implantation model were as shown in Figure 6B. As shown in Figure 6B, there was no significant increase or decrease in weight, which revealed that the ADC of the present invention can be a therapeutic agent with few side effects.

[0075]

Subsequently, the antitumor effect was compared to the case of a linker not having the plasmin cleavage sequence.

44As3 was seeded on the resulting fibrin-coated plate and not coated plate at 3000 cells/well, followed by culturing at 37°C overnight. As the culture medium, a RPMI medium containing 10% FBS was used.

Dilution series with final concentrations of 0 to 3 nM (in terms of MMAE) of an ADC having a cathepsin linker (containing valine-citrulline) and an ADC having a plasmin linker were prepared.

The final concentrations of plasminogen, tPA, and α2-antiplasmin were adjusted to approximately the same concentration ratios as those in normal plasma, i.e., about 150 nM, about 0.03 nM, and about 100 nM, respectively.

The culture solution was removed from each plate, and 90 μL of the solution containing plasminogen, tPA, and α2-antiplasmin and then 10 μL of a dilution series of ADC were added to each plate. After incubation at 37°C for 72 hours, the culture solution was removed. A reaction solution prepared by mixing CCK-8 (Dojindo Laboratories) and a culture solution at a ratio of 1:10 was added to each plate, followed by incubation at 37°C for 2 hours. The IC_{50} was calculated from an optical density curve determined at A450.

[0076]

The results were as shown in Figure 7. As shown in Figure 7, the ADC having a plasmin cleavage site (in the drawing, referred to as "plasmin linker") clearly showed a cell proliferation inhibition effect on tumor cells, but the ADC in which the linker having a plasmin cleavage site was replaced by a linker having a cathepsin cleavage site (in the drawing, referred to as "cathepsin linker") showed almost no cell proliferation inhibition effect on tumor cells.

[0077]

From the above-described results, as shown in Figure 8, the action mechanism of the ADC of the present invention is inferred as follows: an anti-insoluble fibrin antibody-cytotoxic agent conjugate including a linker having a plasmin cleavage site is delivered by blood circulation to the vicinity of cancer where insoluble fibrin accumulates, the linker site is cleaved by plasmin near fibrin, and the cytotoxic agent is released to the vicinity of the cancer. Consequently, the cancer comes into contact with the cytotoxic agent.

[0078]

Cancer with a higher degree of malignancy is more invasive to tissues. When cancer invades a blood vessel, bleeding occurs, and insoluble fibrin is then formed at the bleeding site. The ADC of the present invention is inferred to have especially high effectiveness on such cancer with a high degree of malignancy. In addition, it is inferred that the ADC similarly shows an anticancer activity even if another insoluble fibrin-specific antibody is used.

[0079]

Example 7: Sequence analysis of antibody

5×10^5 cells were transferred from a 100-mm dish (Corning Incorporated) to a 15-mL tube, followed by centrifugation at 270×g for 3 minutes at 4°C. After removing the supernatant, 1 mL of RNAiso Plus (Takara Bio Inc.) was added to the tube. The cells were transferred

to an Eppendorf and were vortexed. Subsequently, the cell suspension was left to stand at room temperature for 5 minutes, followed by extraction of total RNA with an RNeasy Mini Kit (Qiagen). Chloroform (200 μL, FUJIFILM Wako Pure Chemical Corporation) was added to the cell suspension, vortexed for 30 seconds, and left to stand for 3 minutes. Subsequently, centrifugation was performed at 20,400×g for 15 minutes at 4°C, and 500 μL of the supernatant was collected. To the collected supernatant, 500 μL of 70% EtOH was added. The solution was transferred to an RNeasy Mini spin column and centrifuged at 15,000×g for 1 minute at room temperature. The flow through was discarded, and 700 μL of Buffer RW1 (Qiagen) was added to the column, followed by centrifugation at 8,000×g for 1 minute at room temperature. The flow through was discarded, and 500 μL of Buffer RPE (Qiagen) was added to the column, followed by centrifugation at 8,000×g for 1 minute at room temperature. This washing was repeated three times, and finally 50 μL of sterile distilled water was added to the column, followed by centrifugation at 20,400×g for 1 minute at room temperature to extract RNA.

Complementary DNA was synthesized from the extracted RNA using a SMARTer RACE cDNA Amplification Kit (Takara Bio Inc.). Buffer Mix (5 × First-Strand buffer 2 μL, 20 mM DTT 1 μL, 10 mM dNTP Mix 1 μL) was adjusted in advance and was left at room temperature. One microliter of 5'-

CDS primer-A was taken in a PCR 8-tube strip (Thermo Fisher Scientific, Inc.), 300 ng of total RNA was added thereto, and the total volume was adjusted to 3.75 μL with Nuclease-free Water. The sample was reacted at 72°C for 3 minutes and then at 42°C for 2 minutes using a ProFlex PCR system. After spinning down, 1 μL of SMARTerIIA oligo was added thereto. A solution prepared by mixing 4 μL of Buffer Mix, 0.25 μL of RNase inhibitor, and 1 μL of SMART Scribe Reverse Transcriptase was added to the sample. The sample was reacted at 42°C for 90 minutes and then at 72°C for 10 minutes using a ProFlex PCR system to synthesize cDNA. The sequence of the cDNA was then analyzed. The sequences of the resulting antibodies were as follows.

[0080]

The heavy chain variable region of mAb (mouse IgG1) obtained from clone 99 (clone 99-5)

[Formula 6]

```
  1  ATG GAT TGG CTG TGG AAC TTG CTA TTC CTG ATG GCA GCT GCC CAA AGT ATC CAA GCA CAG   60
     M   D   W   L   W   N   L   L   F   L   M   A   A   A   Q   S   I   Q   A   Q

 61  ATC CAG TTG GTG CAG TCT GGA CCT GAG CTG AAG AAG CCT GGA GAG ACA GTC AAG ATC TCC  120
     I   Q   L   V   Q   S   G   P   E   L   K   K   P   G   E   T   V   K   I   S
                                         CDR1
121  TGC AAG GCT TCT GGG TAT ACC TTC ACA AAC TAT GGA ATG AAC TGG GTG AAG CAG GCT CCA  180
     C   K   A   S   G   Y   T   F   T   N   Y   G   M   N   W   V   K   Q   A   P
                                     CDR2
181  GGA AAG GGT TTA AAG TGG ATG GGC TGG ATA AAC ACC AAA ATT GGA GAG CCA ACA TAT GCT  240
     G   K   G   L   K   W   M   G   W   I   N   T   K   I   G   E   P   T   Y   A

241  GAA GAG TTC AAG GGA CGG TTT GCC TTC TCT TTG GAA ACC TCT GCC AGC ACT GCC TAT TTG  300
     E   E   F   K   G   R   F   A   F   S   L   E   T   S   A   S   T   A   Y   L
                                                                         CDR3
301  CAG ATC AAC AAC CTC AAA AAT GAG GAC ACG GCT ACA TAT TTC TGT GCA AGA CTC CTT GAC  360
     Q   I   N   N   L   K   N   E   D   T   A   T   Y   F   C   A   R   L   L   D

361  TAC TGG GGC CAA GGC ACC ACT CTC ACA GTC TCC TCA GCC AAA ACG ACA CCC CCA TCT GTC  420
     Y   W   G   Q   G   T   T   L   T   V   S   S   A   K   T   T   P   P   S   V
```

[0081]

The light chain variable region of mAb (mouse IgG1) obtained from clone 99 (clone 99-5)

[Formula 7]

```
  1  ATG GAG ACA GAC ACA CTC CTG CTA TGG GTG CTG CTG CTC TGG GTT CCA GGT TCC ACA GGT   60
     M   E   T   D   T   L   L   L   W   V   L   L   L   W   V   P   G   S   T   G

 61  GAC ATT GTG CTG ACC CAA TCT CCA GCT TCT TTG GCT GTG TCT CTA GGG CAG AGG GCC ACC  120
     D   I   V   L   T   Q   S   P   A   S   L   A   V   S   L   G   Q   R   A   T
             CDR1
121  ATA TCC TGC AGA GCC AGT GAA AGT GTT GAT AGT TAT GGC AAT AGT TTT ATG CAC TGG TAC  180
     I   S   C   R   A   S   E   S   V   D   S   Y   G   N   S   F   M   H   W   Y
                                                         CDR2
181  CAG CAG AAA CCA GGA CAG CCA CCC AAA CTC CTC ATC TAT CGT GCA TCC AAC CTA GAA TCT  240
     Q   Q   K   P   G   Q   P   P   K   L   L   I   Y   R   A   S   N   L   E   S

241  GGG ATC CCT GCC AGG TTC AGT GGC AGT GGG TCT AGG ACA GAC TTC ACC CTC ACC ATT AAT  300
     G   I   P   A   R   F   S   G   S   G   S   R   T   D   F   T   L   T   I   N
                                                     CDR3
301  CCT GTG GAG GCT GAT GAT GTT GCA ACC TAT TAC TGT CAG CAA AGT AAT GAG GAT CCT CGG  360
     P   V   E   A   D   D   V   A   T   Y   Y   C   Q   Q   S   N   E   D   P   R

361  ACG TTC GGT GGA GGC ACC AAG CTG GAA ATC AAA CGG GCT GAT GCT GCA CCA ACT GTA TCC  420
     T   F   G   G   G   T   K   L   E   I   K   R   A   D   A   A   P   T   V   S
```

[0082]

The heavy chain variable region of mAb (mouse IgG1) obtained from clone 1101

[Formula 8]

```
1    ATG GAA TGT AAC TGG ATA CTT CCT TTT ATT CTG TCG GTA ATT TCA GGG GTC TAC TCA GAG   60
     M   E   C   N   W   I   L   P   F   I   L   S   V   I   S   G   V   Y   S   E

61   GTT CAG CTC CAG CAG TCT GGG ACT GTG CTG GCA AGG CCT GGG GCT TCC GTG AAA ATG TCC   120
     V   Q   L   Q   Q   S   G   T   V   L   A   R   P   G   A   S   V   K   M   S
                                             CDR1
121  TGC AAG GCT TCT GGC TTC AGC TTT ACC AGC TAC TGG ATG CAC TGG GTA AAA CAG AGG CCT   180
     C   K   A   S   G   F   S   F   T   S   Y   W   M   H   W   V   K   Q   R   P
                                     CDR2
181  GGA CAG GGT CTA GAA TGG ATT GGT GCT ATT TAT CCT GGA AAT AGT GAT ACT AGA AAC AAC   240
     G   Q   G   L   E   W   I   G   A   I   Y   P   G   N   S   D   T   R   N   N

241  CAG AAG TTC AAG GGC AAG GCC AAA CTG ACT GCA GTC ACA TCC GCC AAC ACT GCC TAC ATG   300
     Q   K   F   K   G   K   A   K   L   T   A   V   T   S   A   N   T   A   Y   M
                                                                         CDR3
301  GAG CTC AGC AGC CTG ACA AAT GAG GAC TCT GCG GTC TAT TAT TGT ACA AGA AAG GCC CAC   360
     E   L   S   S   L   T   N   E   D   S   A   V   Y   Y   C   T   R   K   A   H

361  TAT GGT AAC TAC GGG TTT GCT TAC TGG GGC CAA GGG ACT CTG GTC ACT GTC TCT GCA GCC   420
     Y   G   N   Y   G   F   A   Y   W   G   Q   G   T   L   V   T   V   S   A   A
```

[0083]

The light chain variable region of mAb (mouse IgG1) obtained from clone 1101

[Formula 9]

```
1    ATG TCA GGT CAC AGC AGA AAC ATG AAG TTT CCT TCT CAA CTT CTG CTC TTC CTG CTG TTC   60
     M   S   G   H   S   R   N   M   K   F   P   S   Q   L   L   L   F   L   L   F

61   AGA ATC ACA GGC ATA ATA TGT GAC ATC CAG ATG ACA CAA TCT TCA TCC TAC TTG TCT GTA   120
     R   I   T   G   I   I   C   D   I   Q   M   T   Q   S   S   S   Y   L   S   V
                                             CDR1
121  TCT CTA GGA GGC AGA GTC ACC ATT ACT TGC AAG GCA AGT GAC CAC ATT AAT AAT TGG TTA   180
     S   L   G   G   R   V   T   I   T   C   K   A   S   D   H   I   N   N   W   L
                                                                         CDR2
181  GCC TGG TAT CAG CAG AAA CCA GGA AAT GCT CCT AGG CTC TTA ATA TCT GGT GCA ACC AGT   240
     A   W   Y   Q   Q   K   P   G   N   A   P   R   L   L   I   S   G   A   T   S

241  TTG GAA ACT GGG GTT CCT TCA AGA TTC AGT GGC AGT GGA TCT GGA AAG GAT TAC ACT CTC   300
     L   E   T   G   V   P   S   R   F   S   G   S   G   S   G   K   D   Y   T   L
                                                                 CDR3
301  AGC ATT ACC AGT CTT CAG ACT GAA GAT GTT GCT ACT TAT TAC TGT CAA CAG TAT TGG AGT   360
     S   I   T   S   L   Q   T   E   D   V   A   T   Y   Y   C   Q   Q   Y   W   S

361  ACT CCG CTC ACG TTC GGT GCT GGG ACC AAG CTG GAG CTG AAA CGG GCT GAT GCT GCA CCA   420
     T   P   L   T   F   G   A   G   T   K   L   E   L   K   R   A   D   A   A   P
```

[0084]

The heavy chain variable region of mAb (mouse IgG2b) obtained from clone 0211

[Formula 10]

```
1    ATG AAC TTC GGG TTC AGC TTG ATT TTC CTT GTC CTT GTT TTA AAA GGT GTC CAG TGT GAA   60
     M   N   F   G   F   S   L   I   F   L   V   L   V   L   K   G   V   Q   C   E

61   GTG AAG CTG GTG GAG TCT GGG GGA GGC TTA GTG AAG CCT GGA GGG TCC CTG AAA CTC TCC   120
     V   K   L   V   E   S   G   G   G   L   V   K   P   G   G   S   L   K   L   S
                                         CDR1
121  TGT GCA GCC TCT GGA TTC ACT TTC AGT AGC TAT GCC ATG TCT TGG GTT CGC CAG ACT CCA   180
     C   A   A   S   G   F   T   F   S   S   Y   A   M   S   W   V   R   Q   T   P
                                     CDR2
181  GAG AAG AGG CTG GAG TGG GTC GCA GCC ATT AGT AGT GGT GGT ACC ACC TAC TAT CCA GAC   240
     E   K   R   L   E   W   V   A   A   I   S   S   G   G   T   T   Y   Y   P   D

241  AGT GTG AAG GGC CGA TTC ACC ATC TCC AGA GAT AAT GCC AGG AAC ATC CTG TAC CTG CAA   300
     S   V   K   G   R   F   T   I   S   R   D   N   A   R   N   I   L   Y   L   Q
                                                                     CDR3
301  ATG AGC AGT CTG AGG TCT GAG GAC ACG GCC ATG TAT TAC TGT GTA AGA GGC GGT ACG ATA   360
     M   S   S   L   R   S   E   D   T   A   M   Y   Y   C   V   R   G   G   T   I

361  GGG GCT TAC TGG GGC CAA GGG ACT CTG GTC ACT GTC TCT GCA                           402
     G   A   Y   W   G   Q   G   T   L   V   T   V   S   A
```

[0085]

The light chain variable region of mAb (mouse IgG2b) obtained from clone 0211

[Formula 11]

```
1    ATG GAA TCA CAG ACT CAG GTC TTC CTC TCC CTG CTG CTC TGG GTA TCT GGT ACC TGT GGG   60
     M   E   S   Q   T   Q   V   F   L   S   L   L   L   W   V   S   G   T   C   G

61   AAC ATT ATG ATG ACA CAG TCG CCA TCA TCT CTG GCT GTG TCT GCA GGA GAA AAG GTC ACT   120
     N   I   M   M   T   Q   S   P   S   S   L   A   V   S   A   G   E   K   V   T
                 CDR1
121  ATG AGC TGT AAG TCC AGT CAA AGT GTT TTA TAC AGT TCA AAT CAG AAG AAC TAC TTG GCC   180
     M   S   C   K   S   S   Q   S   V   L   Y   S   S   N   Q   K   N   Y   L   A
                                                                 CDR2
181  TGG TAC CAG CAG AAA CCA GGG CAG TCT CCT AAA CTG CTG ATC TAC TGG GCA TCC ACT AGG   240
     W   Y   Q   Q   K   P   G   Q   S   P   K   L   L   I   Y   W   A   S   T   R

241  GAA TCT GGT GTC CCT GAT CGC TTC ACA GGC AGT GGA TCT GGG ACA GAT TTT ACT CTT ACC   300
     E   S   G   V   P   D   R   F   T   G   S   G   S   G   T   D   F   T   L   T
                                                             CDR3
301  ATC AGC AGT GTA CAA GCT GAA GAC CTG GCA GTT TAT TAC TGT CAT CAA TAC CTC TCC TCG   360
     I   S   S   V   Q   A   E   D   L   A   V   Y   Y   C   H   Q   Y   L   S   S

361  TGG ACG TTC GGT GGA GGC ACC AAG CTG GAA ATC AAA                                   396
     W   T   F   G   G   G   T   K   L   E   I   K
```

[0086]

Sequence Listing

SEQ ID NOs: 1 to 3: corresponding to the heavy chain CDR1 to CDR3, respectively, of antibody 99

SEQ ID NO: 4: corresponding to the heavy chain variable region of antibody 99 (amino acid positions 1 to 19 are the signal sequence)

SEQ ID NOs: 5 to 7: corresponding to the light chain CDR1 to CDR3, respectively, of antibody 99

SEQ ID NO: 8: corresponding to the light chain variable region of antibody 99 (amino acid positions 1 to 19 are the signal sequence)

SEQ ID NOs: 9 to 11: corresponding to the heavy chain CDR1 to CDR3, respectively, of antibody 1101

SEQ ID NO: 12: corresponding to the heavy chain variable region of antibody 1101 (amino acid positions. 1 to 19 are the signal sequence)

SEQ ID NOs: 13 to 15: corresponding to the light chain CDR1 to CDR3, respectively, of antibody 1101

SEQ ID NO: 16: corresponding to the light chain variable region of antibody 1101 (amino acid positions 1 to 27 are the signal sequence)

SEQ ID NOs: 17 to 19: corresponding to the heavy chain CDR1 to CDR3, respectively, of antibody 0211

SEQ ID NO: 20: corresponding to the heavy chain variable region of antibody 0211 (amino acid positions 1 to 19 are the signal sequence)

SEQ ID NOs: 21 to 23: corresponding to the light chain CDR1 to CDR3, respectively, of antibody 0211

SEQ ID NO: 24: corresponding to the light chain variable region of antibody 0211 (amino acid positions 1 to 20 are the signal sequence)

SEQ ID NO: 25: human fibrin Bβ chain

SEQ ID NO: 26: human fibrin Bβ chain fragment used as the immunogen of 99

SEQ ID NO: 27: human fibrin Bβ chain fragment used as the immunogen of 1101

SEQ ID NO: 28: human fibrin Bβ chain fragment (No. 2 peptide) that can be used as an immunogen

Claims

[Claim 1]

An antibody-drug conjugate (ADC), wherein

the antibody is an antibody that binds to fibrin and has affinity to insoluble fibrin higher than that to fibrinogen,

the drug is a cytotoxic agent, and

the antibody and the drug are linked to each other through a linker having a plasmin cleavage site that allows cleavage by plasmin.

[Claim 2]

The ADC according to claim 1, wherein

the linker has a valine-leucine-lysine peptide sequence as the plasmin cleavage site.

[Claim 3]

A pharmaceutical composition comprising the ADC according to claim 1 or 2 for use in treating cancer.

[Claim 4]

The pharmaceutical composition according to claim 3, wherein the cancer is invasive cancer.

[Claim 5]

An antibody that binds to fibrin, wherein the antibody has

a heavy chain variable region having CDR1 set forth in SEQ ID NO: 1, CDR2 set forth in SEQ ID NO: 2, and CDR3 set forth in SEQ ID NO: 3, and

a light chain variable region having CDR1 set forth in SEQ ID NO: 5, CDR2 set forth in SEQ ID NO: 6, and CDR3 set forth in SEQ ID NO: 7;
an antibody that competes with the antibody for binding to fibrin; or an antigen-binding fragment thereof.
[Claim 6]

An antibody that binds to fibrin, wherein the antibody has

a heavy chain variable region set forth in SEQ ID NO: 4 and a light chain variable region set forth in SEQ ID NO: 8; or
an antigen-binding fragment thereof.
[Claim 7]

An antibody that binds to fibrin, wherein the antibody has

a heavy chain variable region having CDR1 set forth in SEQ ID NO: 9, CDR2 set forth in SEQ ID NO: 10, and CDR3 set forth in SEQ ID NO: 11, and

a light chain variable region having CDR1 set forth in SEQ ID NO: 13, CDR2 set forth in SEQ ID NO: 14, and CDR3 set forth in SEQ ID NO: 15;
an antibody that competes with the antibody for binding to fibrin; or an antigen-binding fragment thereof.
[Claim 8]

An antibody that binds to fibrin, wherein the antibody has

a heavy chain variable region set forth in SEQ ID NO: 12 and a light chain variable region set forth in SEQ ID NO: 16; or

an antigen-binding fragment thereof.

[Claim 9]

The ADC according to claim 1 or 2, wherein the antibody is the antibody according to any one of claims 5 to 8.

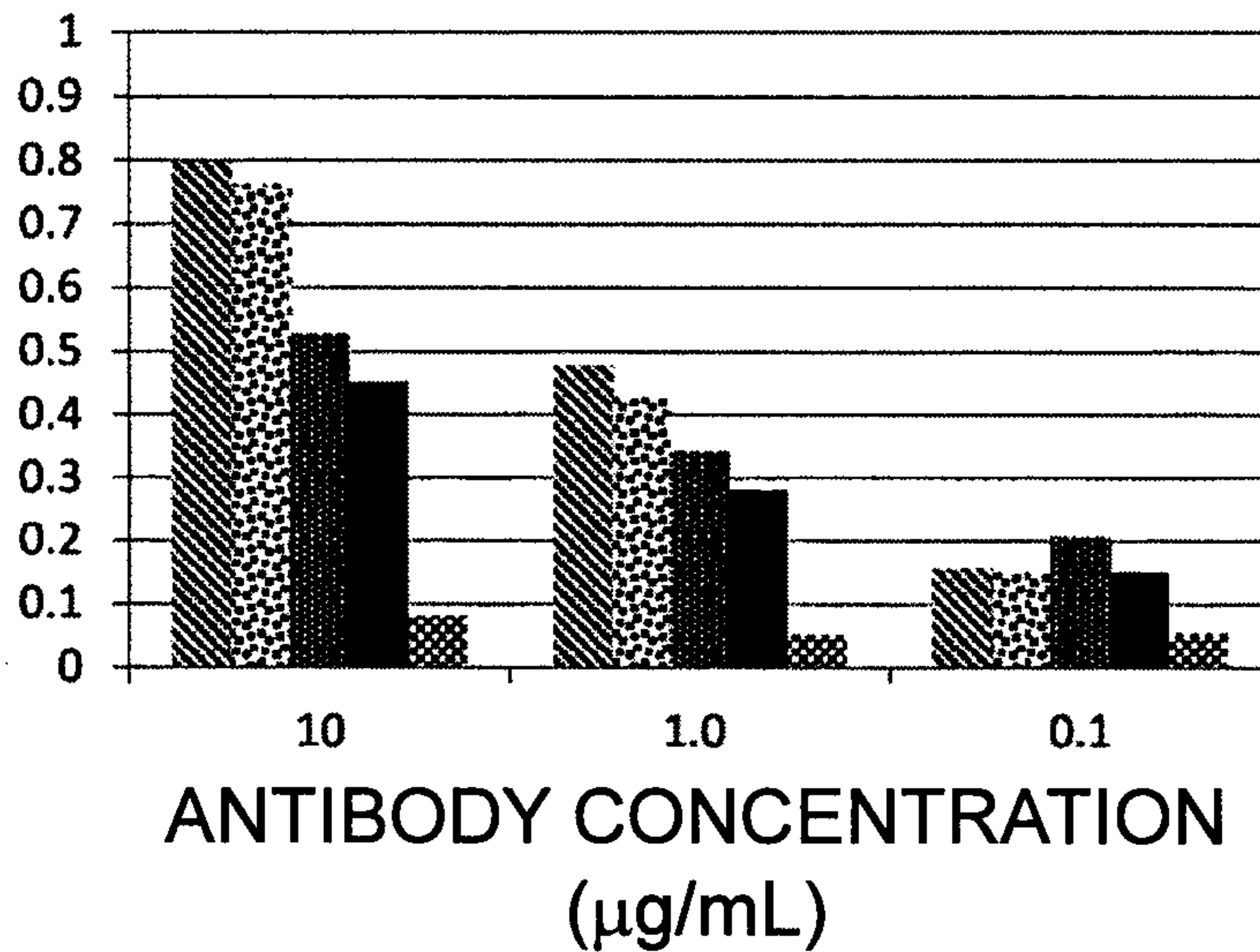
[Claim 10]

A pharmaceutical composition comprising the ADC according to claim 9.

[Claim 11]

The pharmaceutical composition according to claim 10, for use in treating cancer.

FIG. 1



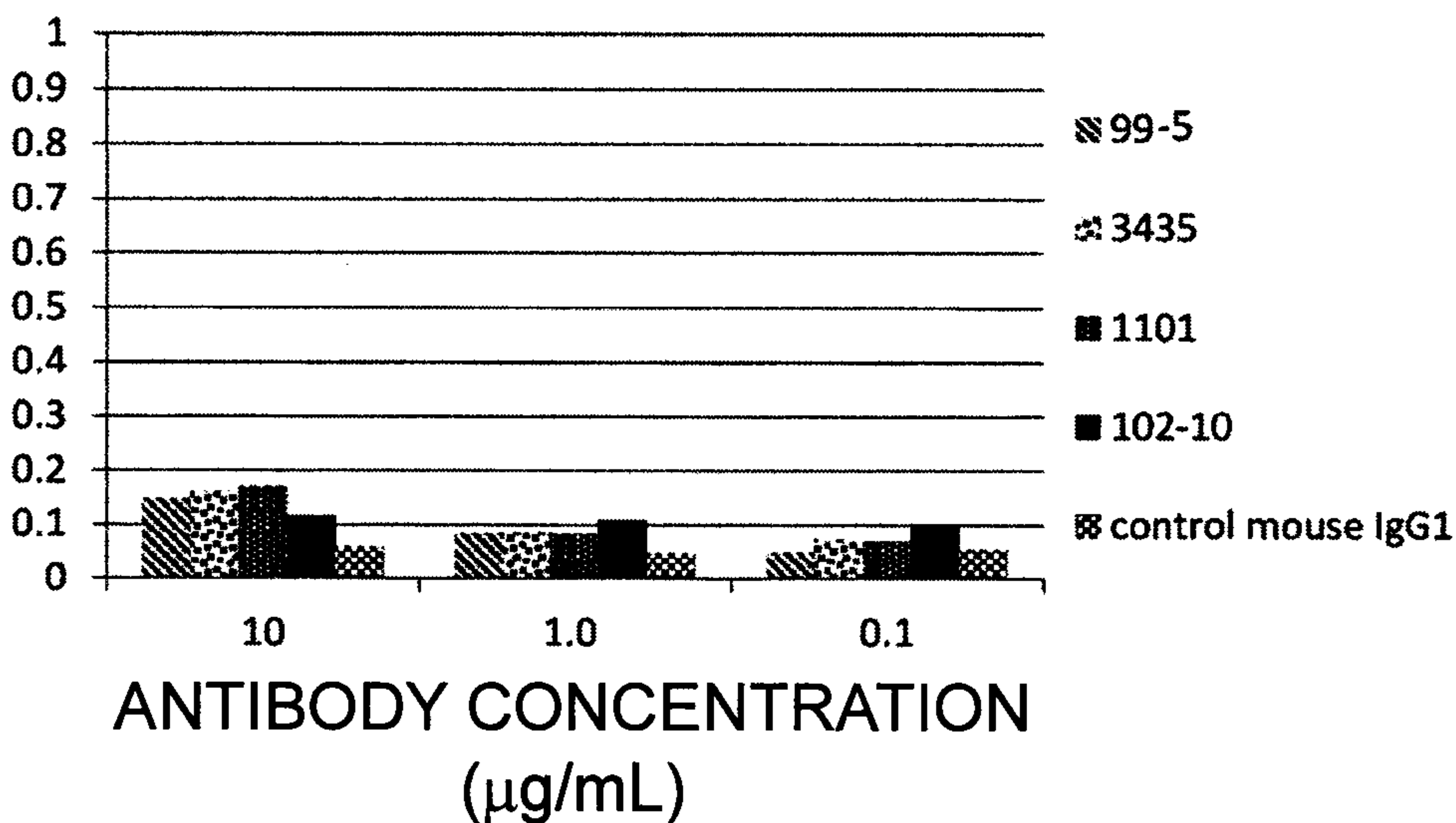
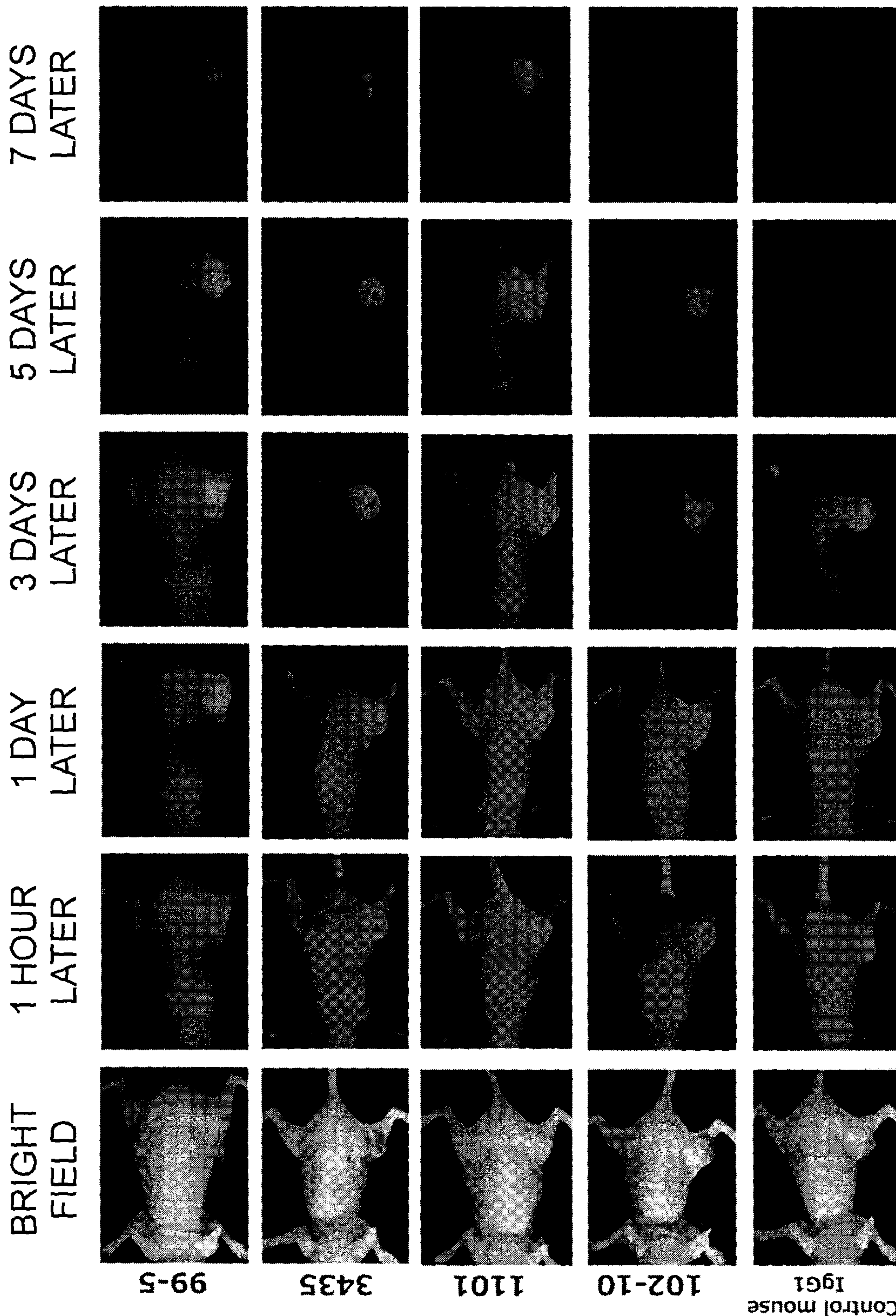


FIG. 2



ALEXA FLUOR 647-LABELED ANTIBODY, 300 ug i.v.

FIG. 3

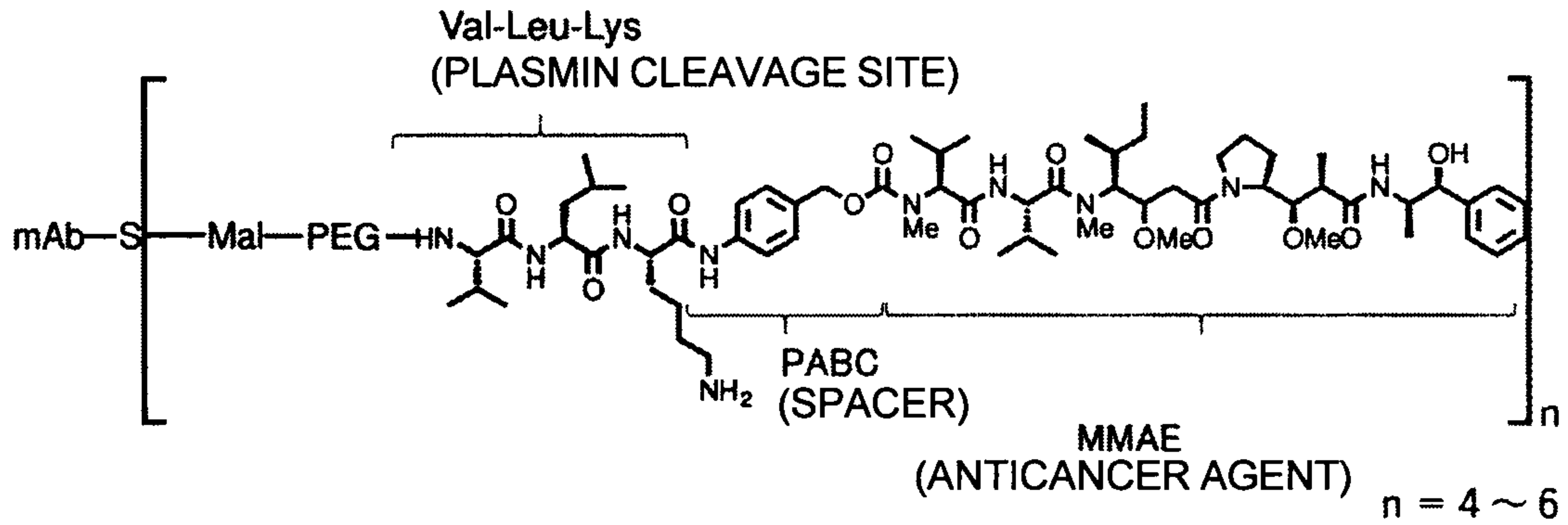


FIG. 4

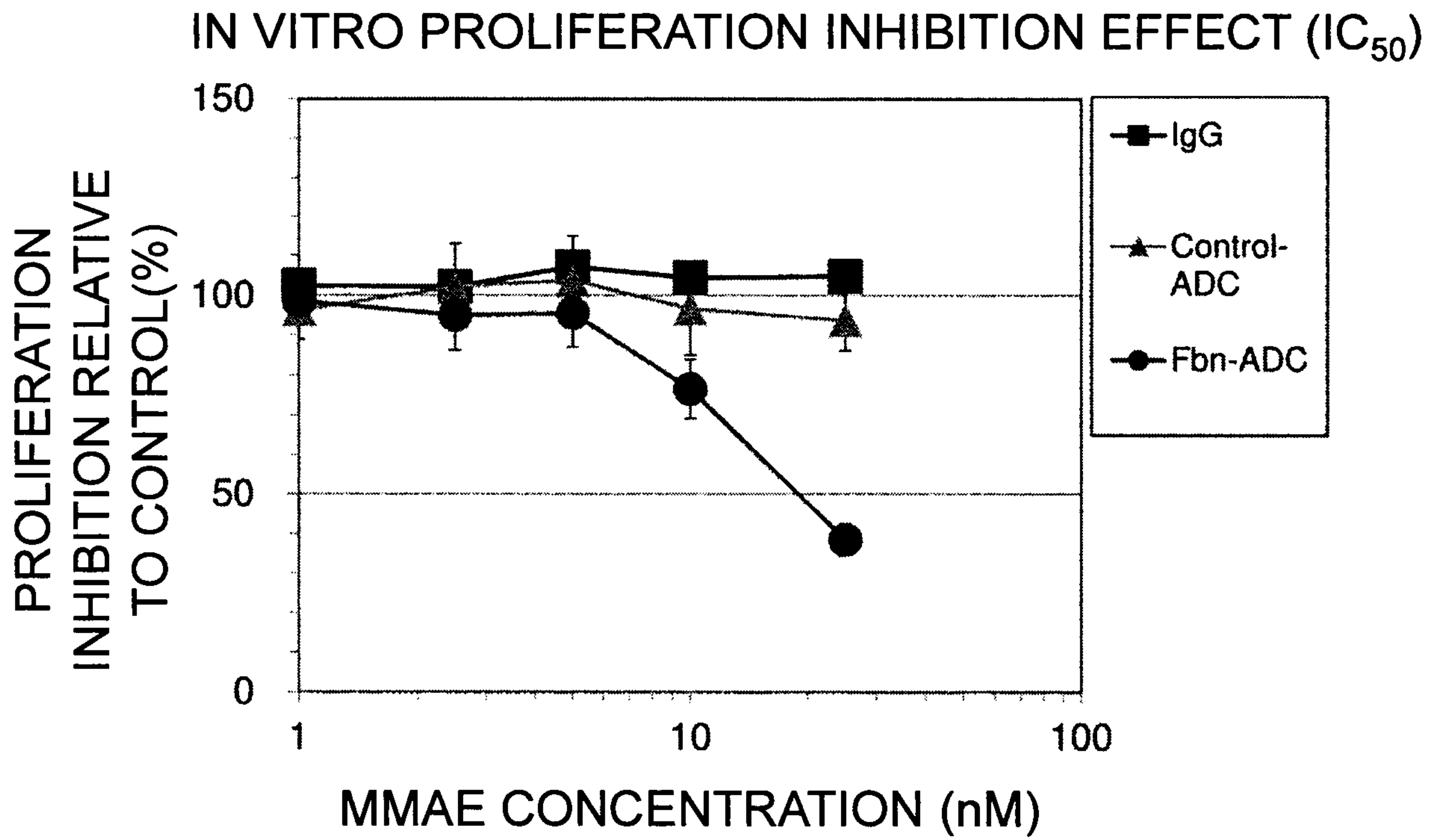


FIG. 5

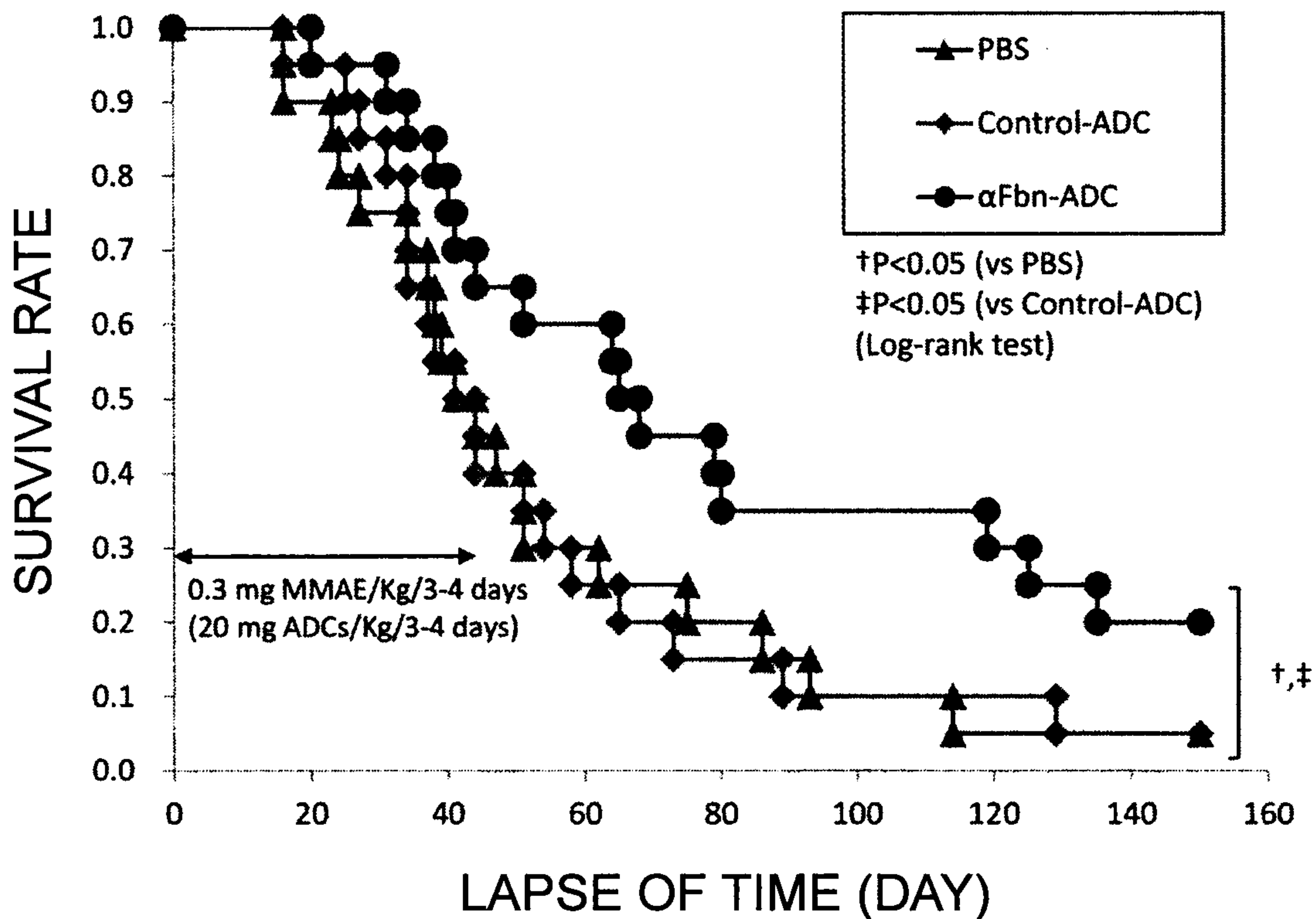


FIG. 6A

ANTITUMOR EFFECT

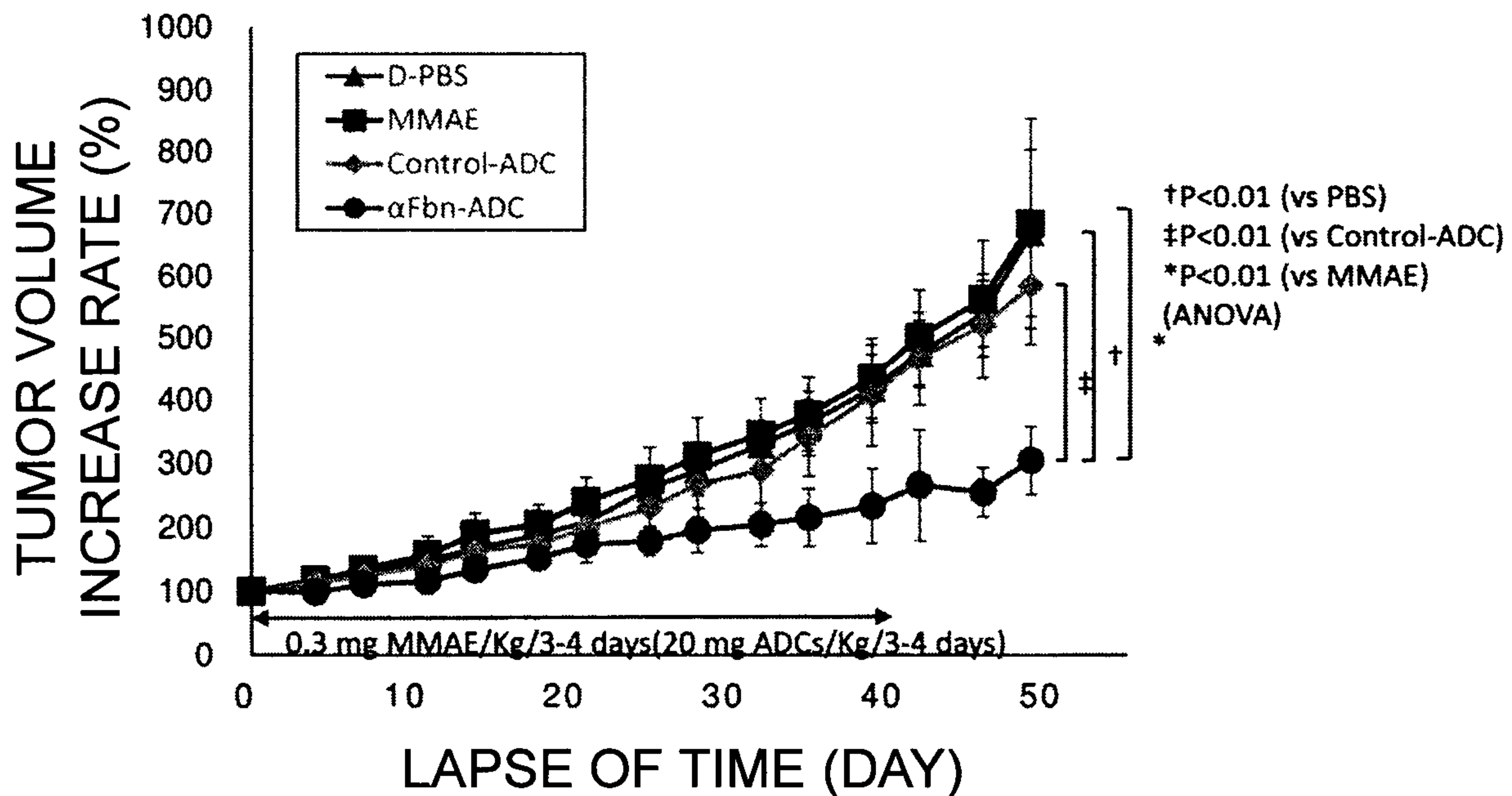


FIG. 6B

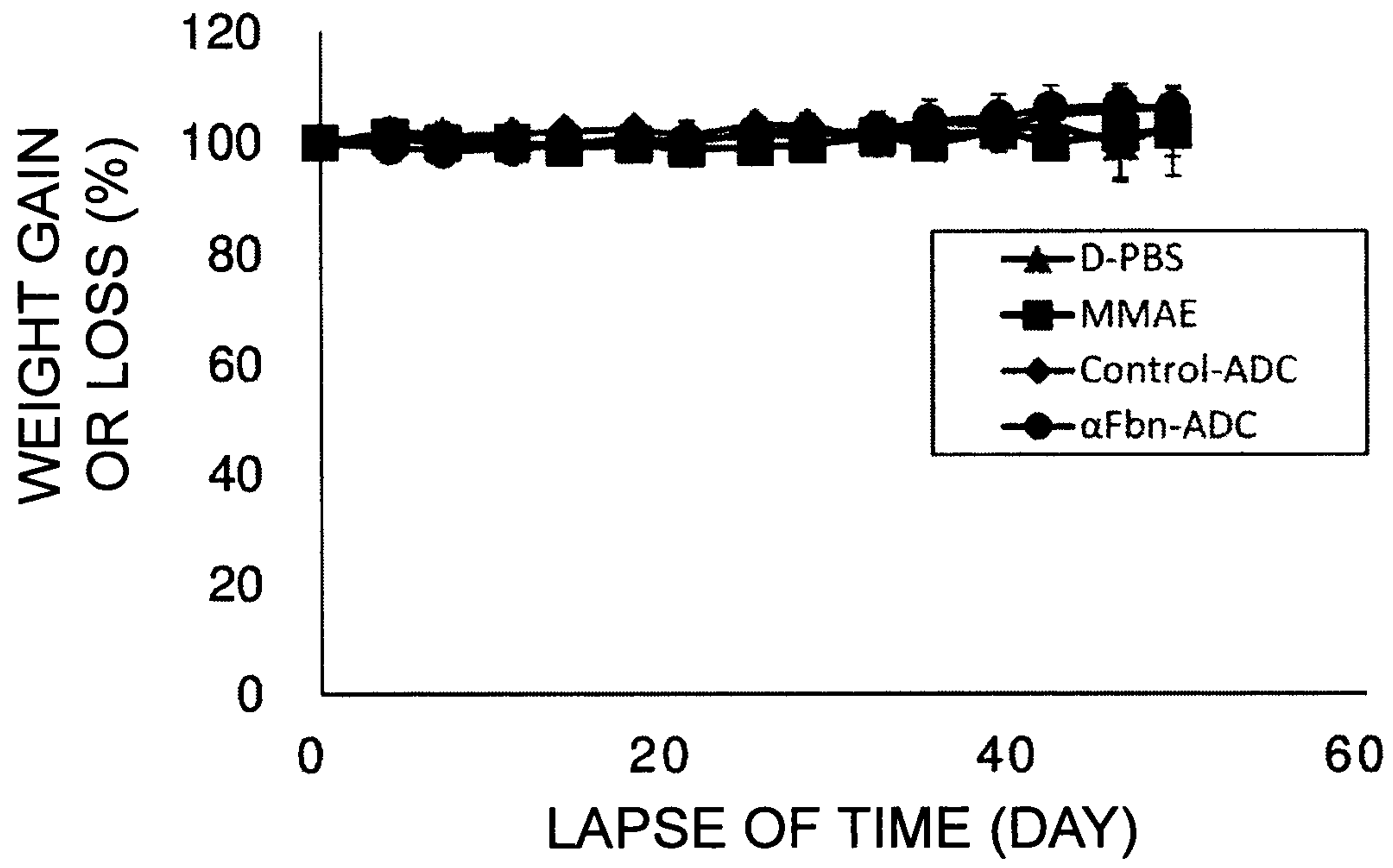
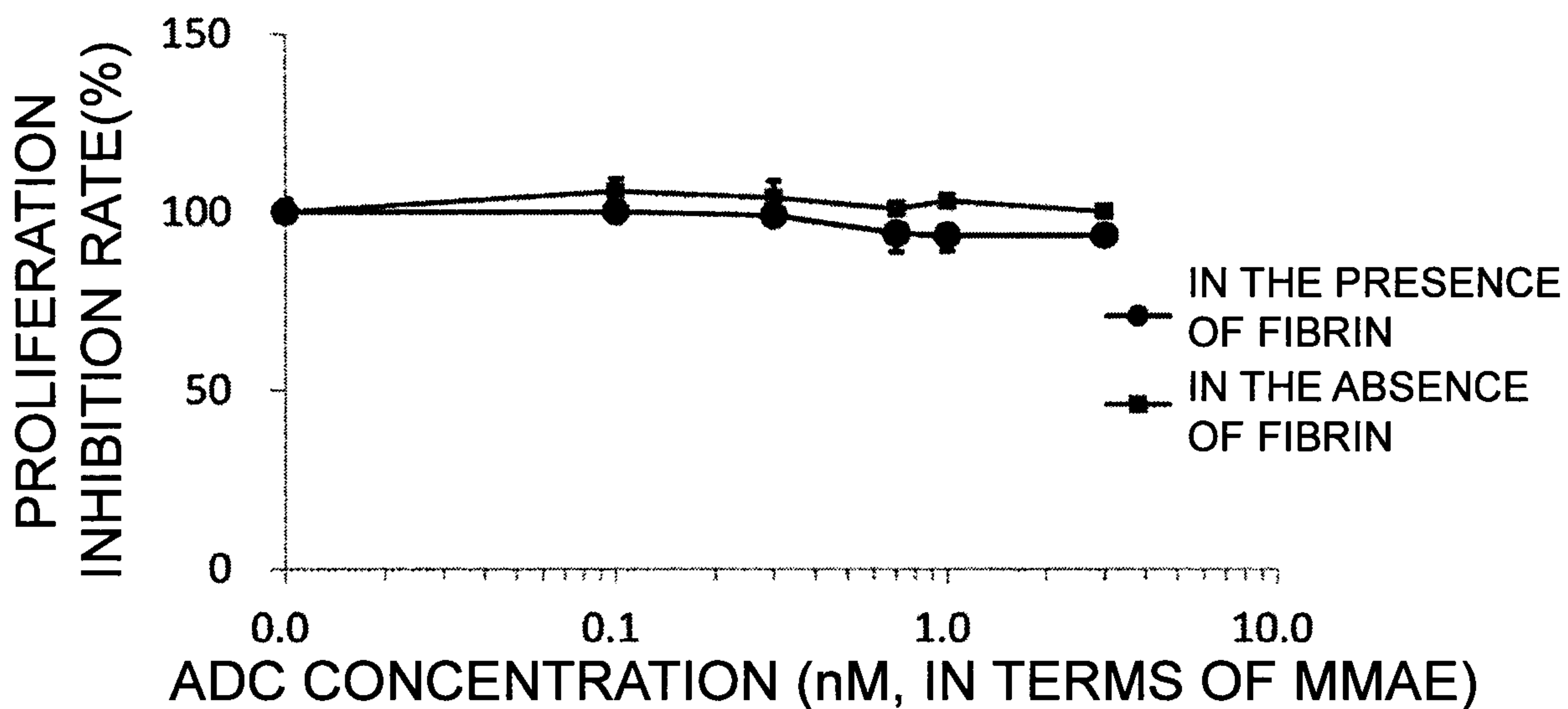


FIG. 7



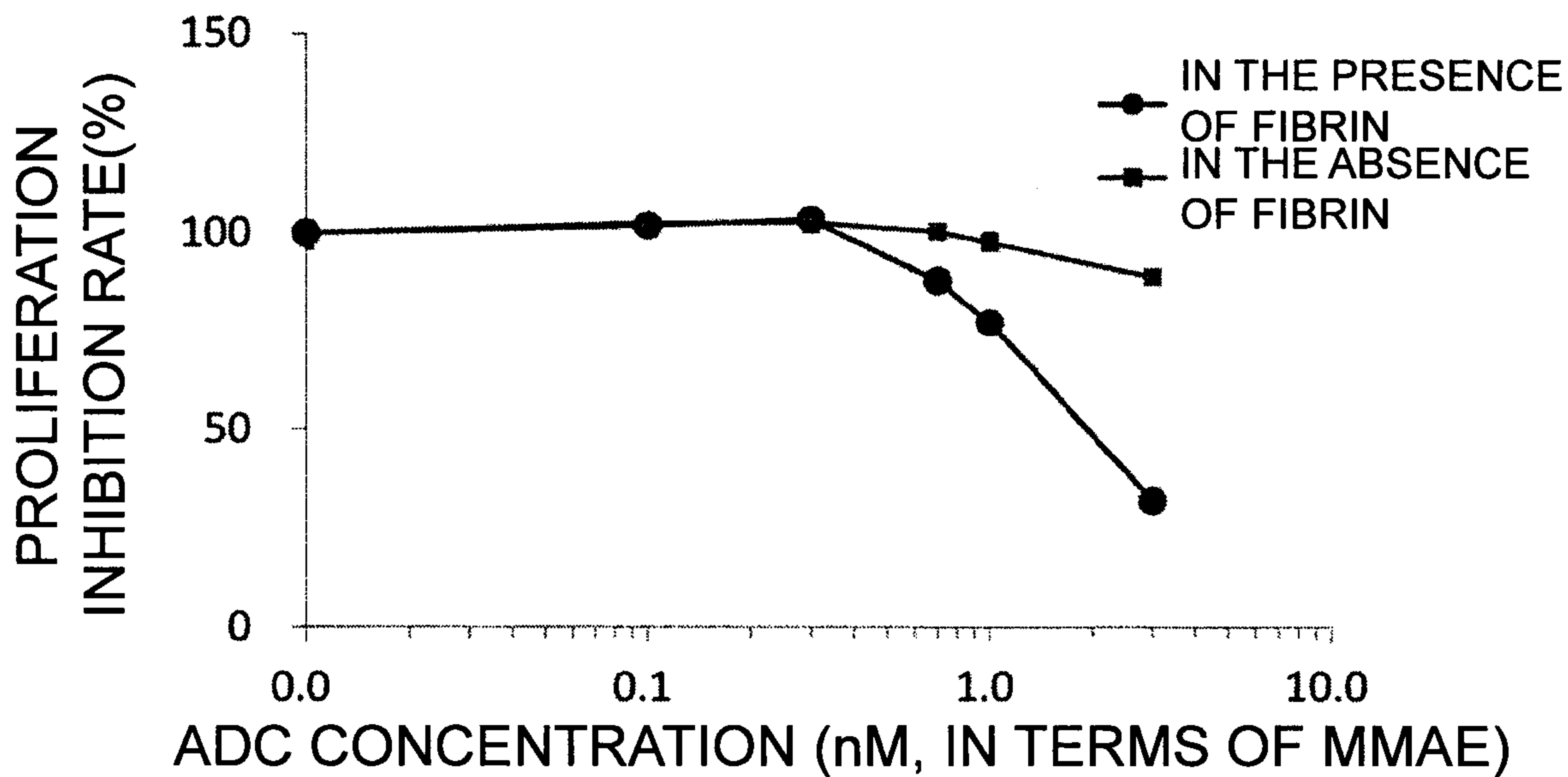
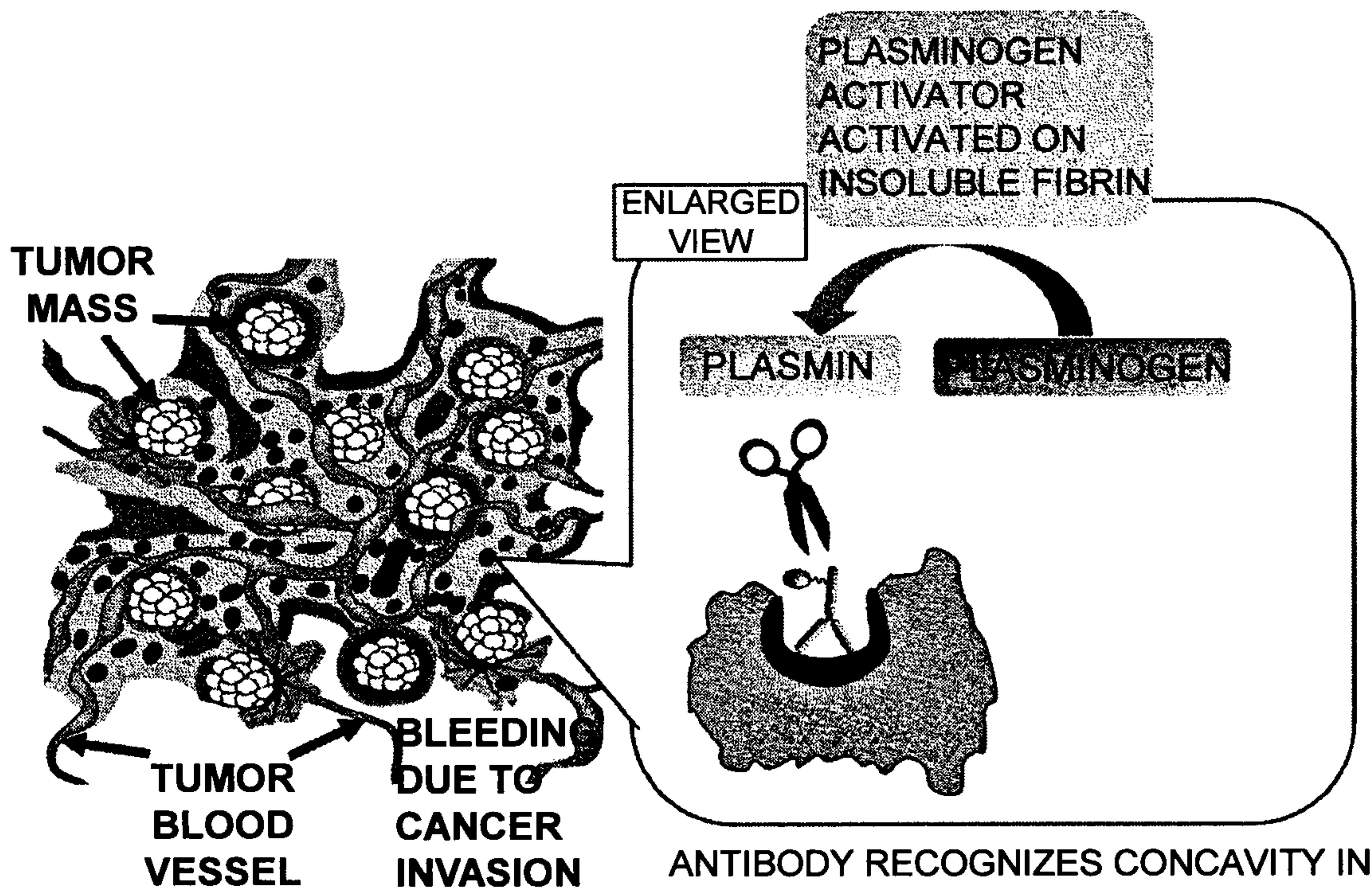


FIG. 8



ANTIBODY RECOGNIZES CONCAVITY IN FIBRIN MASS, AND LINKER IS CLEAVED BY PLASMINOGEN ACTIVATOR ACTIVATED ON INSOLUBLE FIBRIN TO RELEASE ANTITUMOR AGENT.

[図3]

AA

Val-Leu-Lys
(プラスミン切断部位)

mAb—S—Mal—PEG—HN ... NH2

PABC
(スペーサー)

BB

MMAE(抗がん剤)

CC

$n = 4 \sim 6$

AA (Plasmin cleavage site)

BB (Spacer)

CC (Anticancer agent)