様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

科学研究費助成事業　　研究成果報告書

令和　元 年　 ６ 月 １５ 日現在

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研究期間：2016～2018
課題番号：１６Ｈ０４５２１

研究課題名（和文）セラミック半導体の光応答を利用した細胞培養デバイスの開発

研究課題名（英文）Development of cell culture device utilising light response of ceramic semiconductor

研究代表者
上田　正人（Ueda, Masato）

関西大学・化学生命工学部・教授

研究者番号：４０３６２６６０

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研究成果の概要（和文）：光応答セラミックスを利用して，細胞の基盤への接着を酵素処理フリーで制御することを目的とした。TiO2とSrTiO3は，バンドギャップが3.0-3.2 eVのn型半導体であり，紫外光（UV）照射で光触媒反応を呈する。そのセラミックスをSiO2上にRFスパッタリングで成膜した。その表面では暗所下で細胞が単調に増殖した。その表面にUV予備照射を施すと細胞接着が促進された。逆に連続照射を行うとその接着は抑制された。なお，UVは同膜で完全に吸収されるため，細胞はUVに曝されない。これらは，細胞の接着・増殖・剥離挙動をこの細胞培養器で制御できることを示している。さらに，細胞の2次元配置も可能となった。

研究成果の学術的意義や社会的意義
紫外線（UV）に応答するTiO2とSrTiO3をSiO2基盤上に成膜したシンプルな構造を有する細胞培養器を開発し，光照射によって細胞接着の促進や抑制を制御できることを実験的に示した。なお，UV照射は培養器背面から行い，細胞はUVに曝されない構造とした。これは，細胞にダメージを与えてしまう従来の酵素処理を用いた細胞制御に代わる有効な手法である。さらに，細胞の2次元配置も可能となった。本技術を利用すれば，複数の細胞を任意に配置した細胞シートを作製することが可能となる。

研究成果の概要（英文）：Attachment/detachment of cells to/from substrates was tried to control without enzyme treatments by using photo-responsible ceramic films and light irradiation. TiO2 and SrTiO3 are n-type semiconductors with an energy band gap of 3.0-3.2 eV, which display photocatalytic reactions under ultraviolet (UV). Such films were prepared on SiO2 by a RF sputtering. Basically the number of cells monotonically increased with incubation periods under darkness. Previous UV irradiation promoted the cell adhesion. In contrast, the cells decreased under continuous UV irradiation. The cells were not exposed to UV in the vessels since it was completely absorbed by the ceramics layer. These results indicate that the adhesion/proliferation/detachment behaviours of cells can be controlled by the photocatalytic reactions of ceramic films and the irradiation patterns. Furthermore, two-dimensional patterning of attached cells by light irradiation could be performed in the vessels with simple structure.

研究分野：材料物性学

キーワード：生体材料　セラミックス　光化学反応

[illegible]

[illegible] 37°C [illegible] 20 [illegible] 25°C [illegible]

[illegible] 2, 2004, 83-92 [illegible]

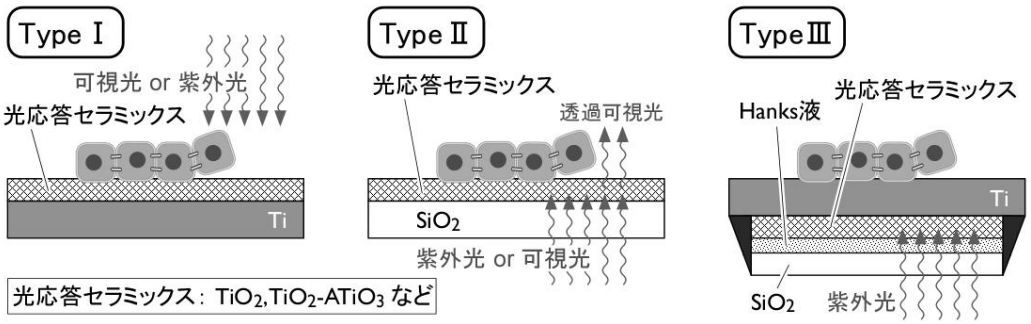
[illegible]

[illegible]

[illegible]

[illegible]

[illegible] (i) [illegible] (ii) [illegible] (iii) [illegible] m2 [illegible]



[illegible]

[illegible]

3.1 [illegible]

[illegible] TiO_2 [illegible] Ti [illegible] 80°C [illegible] 5 M H_2O_2/0.1 M HNO_3 [illegible] 20 min [illegible] 1 M NH_3 [illegible] 180°C-12 h [illegible]

[illegible] TiO_2 [illegible] $Ti(OC_3H_7^i)_4$ [illegible] Sol-gel [illegible] Ti [illegible] Ar-O_2 [illegible] 8:5 [illegible] 673 [illegible] 873 K [illegible]

3.2 [illegible]

3.2.1 [illegible]

[illegible] Ti [illegible] Nb [illegible] 2 [illegible] $(Ti_{1-x}Nb_x)O_{2-\delta}$ [illegible] Ti : Nb = 1 : 1 [illegible] 0.25 [illegible]

3.2.2 [illegible]

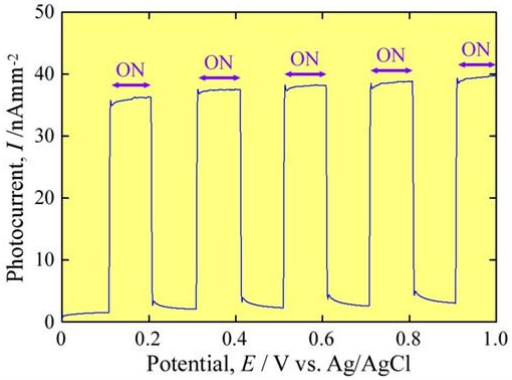
[illegible] Ti [illegible] 5 M H_2O_2/0.1 M HNO_3 [illegible] TiO_2 gel [illegible] $Sr(OH)_2$ [illegible] 673 [illegible] 873 K [illegible] 1 M HNO_3 [illegible] Sr [illegible]

3.3 [illegible]

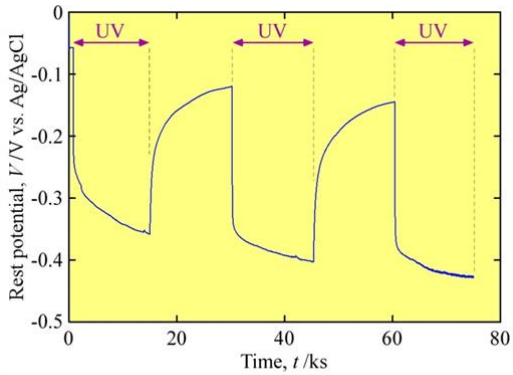
[illegible] Type [illegible] Type [illegible] Type [illegible]

4.1 [illegible]

W 1 &gM 3 b (ý [illegible] (ÿ & UV> B([illegible] LM• * Type é * Type [illegible] 2s7Ã @ [illegible] * Type [illegible] V‰ Type é * Type [illegible] W [illegible] KS [illegible] Typeé * Typeê [illegible] 2(a)* (b) [illegible] &gM Type [illegible] * [illegible] WS M‰ Type [illegible] * [illegible])† x ? _ [illegible] 2s7 [illegible]



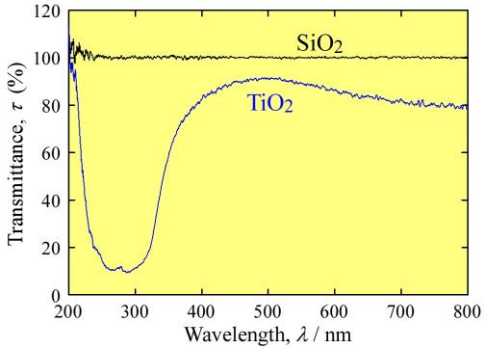
(a)



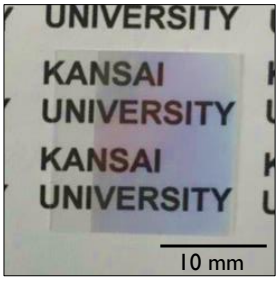
(b)

W 2 Typeé & Sol-gel 2> [illegible] (a)\ Type [illegible] 2s7Ã (b)

TypeII Sol-gel 2 > [illegible] †
W 3 &gM [illegible] TiO$_2$ [illegible]
[illegible]
[illegible] TiO$_2$ b [illegible]
O [illegible] UV B([illegible]
[illegible]
[illegible] TypeII 4 &g
M [illegible] TiO$_2$
[illegible]
[illegible] 48 h [illegible] 120 nm [illegible] Gb TiO$_2$ [illegible]
[illegible] 50-60 nm [illegible] UV B([illegible]
[illegible]
[illegible] 24 h [illegible]
[illegible] 5 [illegible] TEM [illegible]
[illegible] UV& λ=375 nm [illegible] KFM
[illegible]
[illegible] 70μm [illegible]
[illegible] SrS [illegible]
[illegible] 200mV [illegible]



W 3 TypeII& Sol-gel 2 > [illegible]•
[illegible]



W 4 TypeII& [illegible]

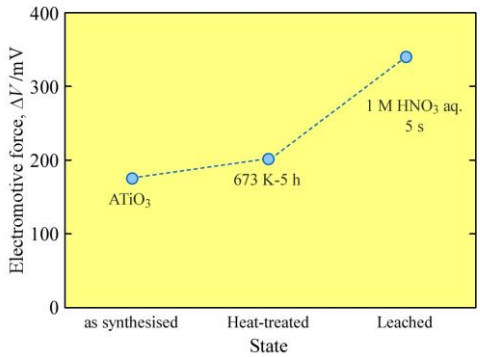
4.2 [illegible]

4.2.1 [illegible]

(ç Ti (ç Nb [illegible]
[illegible] XRD [illegible]
&gKS [illegible] Ti: Nb = 1: 1 b [illegible]
Nb$_2$O$_5$ [illegible] Ti: Nb = 1: 0.2 b [illegible]
TiO$_2$ [illegible]
[illegible] Nb [illegible]
[illegible] r S* [illegible]
[illegible] x † 0.04> 0.30 b(
[illegible]

4.2.2 [illegible]

(ç Ti _ 3.2.2 [illegible] &gKS [illegible]
[illegible] SrTiO$_3$ [illegible]
[illegible] UV& λ= 365
nm [illegible] 100 s [illegible]
[illegible]
S UV [illegible] 400 s [illegible] 2s



W 5 (ç Ti V [illegible] KS SrTiO$_3$ b [illegible]
[illegible] Sr [illegible]

TiO$_2$ ѡ[Ù 150 mV ƃ~ * Gb SrTiO$_3$ ѡ8Žop ¼ b4¥
&gKSb2s7ĂMG¥M4¥ @1u$& W 5@
9× 6×6bĐ@W@$G:Õ #@
G&g6IM2s7ĂVKS& W 5> SrTiO$_3$ b/²
8@ TiO$_2$ &6ğÂSN9KŽ•

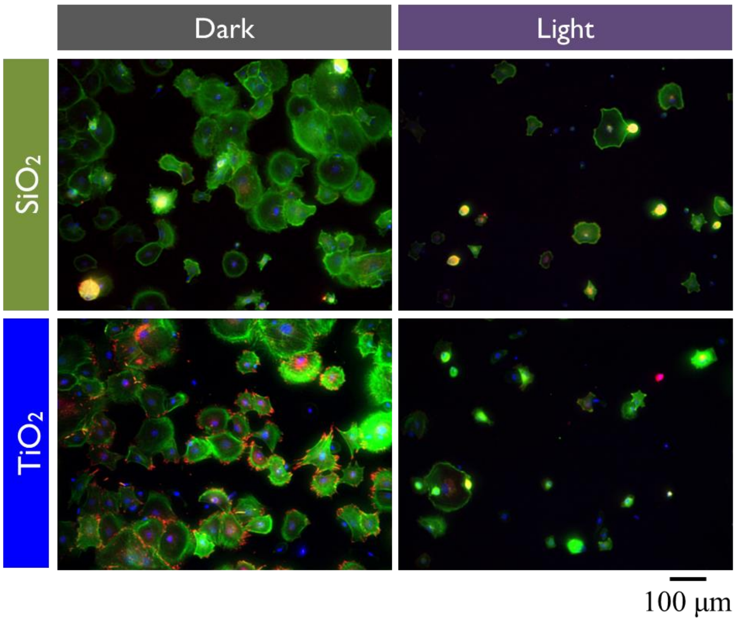
4.3

4.3.1 Typeè

Typeè _ (* 4 h 6KS b4&* UV Û 1 h TEU*c 4 h
4)FUKK%T(0ûKS 6b UV UcV%S TiO$_2$ Û 1 h b %·
6ë U /œ K%T(XcKS UV U TiO$_2$ /8b&K *
(K%T@SM%_ UV 4)FUMK%T(
Xc/dWb@ KS Ti V[b8WSG(XcÂ
öKS@Wb6ü}c8&WS6_ UV b%KUc
(@ TiO$_2$ V[6S@KS
SuK%T(Xb--K8ä)WS•

4.3.2 Typeé

Type& Sol-gel 2[K8? UV 4)FUKSğÂ 4 h 6KS Q
b@ 6 &gM /dW8Ž* SiO$_2$& TiO$_2$ [@ K%TK
Z@I€ S UV UMg0K%T@I6#L[
6@ • SiO$_2$ [UV @ S SuM%‰
TiO$_2$& TypeW 3 [
&gKS3 UV B(c TiO$_2$
[™ ë1€
TiO$_2$ _ UV @I€
2s7Ă7Ú
Gb
WK%T
@I6•
6 Type& Sol-gel 2>
[* /dW[6K*
8ô)6b 0.5 h* 2 h bs
UV †U M • d7³ 0y
/WS *)r6ë*
8N€ 24 h KS /d
W 6K S(_ 8?
} UV U/œ* K%T(ý
Xc!U6ä
KSG K%TKS(ý
@7KSGM•
TiO$_2$ bW
bd7†ÂS@
mœ 2 h U 23%$
rWS



W 6 TypeII& Sol-gel 2ĞK8? UV †
4)FUKSğÂ 4 h 6KS(@

Type& Â 2 * Bѡb8 24 h* 18 mm×18 mm* 400°C
TEM » * φ3 mm* 9 Û 2K8? UV UKSğÂ 4 h
b(K%T0/WS 5 "& bs * œ @WS8(@_
K%TK3@I68(K%T@I6/KŽ 2K S 5 "ç
& bgğ4@%T(W K%T(@0K
SG@K%T@I68K%TĂ Vinculin>
@I6(K%T0èS@ 6G&g@Ž•
400°C
TiO$_2$ [MG@
MG&bd$(K%Tc* TiO$_2$ bsI KŽ
• 0«

4.3.3 Typeê

TypeK8? UV 4)FUKSğÂ 4 h 6KS
KŽ TiO$_2$ BѡONbS4ѡM(b(9/WS (@
K%TM/8c* Typeêb68%&KS(ç Ti KK@
W8Ž* Typeê V bK%T(XcK@waWS Type
êb TiO$_2$ ѡ[PK0M/83@ Su?
@8j@ Ti /8b(K%TvS8jKS•
rS8? UV UKSğÂMK(@

[illegible] Type [illegible] 2(b) [illegible] UV [illegible] Type [illegible] UV [illegible] 48 h [illegible] 4 h [illegible] 35% [illegible]

4.4 [illegible]

[illegible] Type [illegible] UV B [illegible]

[illegible]

[illegible] 7 [illegible]

- M. Ueda, M. Ikeda, S. Mori, K. Doi, H. Kitagaki, S. Terauchi, Mechanical Properties of Additively Manufactured Porous Titanium with Sub-Millimetre Structural Units, Mater. Trans., 2019, in press, 1w [illegible].
- D M. Ueda, R. Yamaguchi, C. Fujita, M. Ikeda, Control of Cell Adhesion on Titanium Dioxide by Light Irradiation, Materials Science Forum, 941, 2018, 2507-2512, 1w [illegible].
- D! I. Suzuki, A. Kakinuma, M. Ueda, T. Omata, Flux growth of β-$NaGaO_2$ single crystals, J. Crystal Growth, 504, 2018, 26-30, 1w [illegible].
- D" [illegible], [illegible], [illegible], [illegible] 65, 2018, 1-3, 1w [illegible].
- D# [illegible], [illegible], [illegible], [illegible], [illegible], [illegible], [illegible] 75, 2018, 69-74, 1w [illegible].
- D$ M. Ueda, N. Hayashi, Y. Nakano, M. Ikeda, K. Doi, S. Mori, H. Kitagaki, S. Terauchi, A. Seki, Preparation and In vivo Study of Porous Titanium–Polyglycolide Composite, Mater. Trans., 57, 2016, 2002-2007, 1w [illegible].
- D% M. Tane, K. Hagihara, M. Ueda, T. Nakano, Y. Okuda, Elastic-modulus Enhancement during Room-temperature Aging and its Suppression in Metastable Ti-Nb-Based Alloys with Low Body-centered Cubic Phase Stability, Acta Mater., 102, 2016, 373-384, 1w [illegible].

[illegible] 22 [illegible]

- [illegible] 2019 [illegible] 164 [illegible] 2019.3.21.
- D [illegible] 2018 [illegible] 163 [illegible] 2018.9.19.
- D! [illegible] 2018 [illegible] 163 [illegible] 2018.9.19.
- D" [illegible] 13 [illegible] 2018.8.31.
- D# M. Ueda, R. Yamaguchi, C. Fujita, M. Ikeda, Control of Cell Adhesion on Titanium Dioxide by Light Irradiation, THERMEC'2018, Cité des Sciences et de'lindustrie, Paris, France, 2018.7.12.
- D$ [illegible] 38 [illegible] 2018.6.23.
- D% M. Ueda, 2D Patterning of Cells by Light Irradiation, Finland-Japan Workshop: The next generation medical engineering in biomaterials, Joint with 3rd Bone and Biomaterials Workshop, Oulu University, Oulu, Finland, 2018.6.18.
- D& M. Ueda, T. Sakamoto, M. Ikeda, Detection of Lattice Defects in Pure Titanium by Resistivity Measurement, The 16th Korea/Japan International Symposium on Recourses Recycling and Materials Science, The K Hotel, Seoul, Korea, 2018.5.17.
- D' S. Matsumura, M. Ueda, M. Ikeda, Preparation of $SrTiO_3$ Thin Film for Cell Culture Vessel by RF Magnetron Sputtering, The 16th Korea/Japan International Symposium on Recourses Recycling and Materials Science, The K Hotel, Seoul, Korea, 2018.5.17.
- D([illegible] 2018 [illegible] 162 [illegible] 2018.3.19-21.
- D) M. Ueda, C. Fujita, M. Ikeda, Fabrication of Photo-Responsible Cell Culture Vessels using Titanium Oxide films, 2017 MRS Fall Meeting & Exhibit, Boston, USA, 2017.11.27-12.1.

[illegible]
[illegible] 39 [illegible] 2017.11.20-21.

D+ [illegible] 2017.9.6-8.

D, [illegible] Ti/TiO_2/Hanks ® /SiO_2 [illegible] 2017 [illegible] 161 [illegible] 2017.9.6-8.

D- [illegible] Ti/TiO_2/Hanks ® /SiO_2 [illegible] 12 [illegible] 2017.8.31.

D. [illegible] TiO_2/SiO_2 [illegible] 12 [illegible] 2017.8.31.

D/ [illegible] 37 [illegible] 2017.6.24.

D0 C. Fujita, M. Ueda, M. Ikeda, Fabrication of Photo-Responsible Cell Culture Vessels using Titanium Dioxide, The 15th Japan/Korea International Symposium on Recourses Recycling and Materials Science, Kansai University, Suita, Japan, 2017.4.17-19.

D1 M. Ueda, C. Fujita, M. Ikeda, Sensitization of Photo-Response in Cell Culture Vessels, The 15th Japan/Korea International Symposium on Recourses Recycling and Materials Science, Kansai University, Suita, Japan, 2017.4.17-19.

D2 [illegible] Ti/TiO_2/[illegible] /SiO_2 [illegible] 2017 [illegible] 160 [illegible] 2017.3.15.

G¡ [illegible] 2017 [illegible] 160 [illegible] 2017.3.15-17.

G¢ M. Ueda, Control of bone adhesion on titanium by surface modification, 2nd Bone and Biomaterials Workshop, Inari, Finland, 2016.8.9.

[illegible]

http://www.chemmater.kansai-u.ac.jp/ecmate/index.html

[illegible]

(1) [illegible]

(IKEDA, masahiko)

[illegible] 20184434

(2) [illegible]

(MATSUGAKI, aira)

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