

GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, 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).

Published:

- *with international search report (Art. 21(3))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(88) Date of publication of the international search report:

21 March 2024 (21.03.2024)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 23/68933

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I: Claims 1-11 drawn to synaptic array.

Group II: Claims 12-20, drawn to a Fowler-Nordheim (FN) synapse.

--see extra sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-11

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 23/68933

A. CLASSIFICATION OF SUBJECT MATTER

IPC - INV. G11C 27/00, G11C 11/54, G06N 3/063, H01L 29/788 (2023.01)

ADD. G06N 3/04, G06N 3/08 (2023.01)

CPC - INV. G11C 27/005, G11C 11/54, G06N 3/063, H01L 29/788, H01L 29/7883

ADD. H01L 29/7885, G06N 3/04, G06N 3/08, Y02D 10/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y --- A	MEHTA et al., "An adaptive synaptic array using Fowler–Nordheim dynamic analog memory." Nature communications 13.1 (2022): 1670, published 29 March 2022 (29.03.2022), Fig 1c, 1d, 2c; pg 1-10; Supplemental Information pg 1-5 [online] < https://www.nature.com/articles/s41467-022-29320-6 >	1, 4, 5, 8, 9, 11 ----- 6, 7 ----- 2, 3, 10
Y --- A	US 5,627,392 A (DIORIO et al.) 06 May 1997 (06.05.1997), abstract; col 7, ln 5-24, 59-62; col 9, ln 45-52	6, 7 ----- 2, 3, 10
A	US 5,336,937 A (SRIDHAR et al.) 09 August 1994 (09.08.1994), entire document	1-11
A	TAO, et al., "Engineering complex synaptic behaviors in a single device: Emulating consolidation of short-term memory to long-term memory in artificial synapses via dielectric band engineering." Nano Letters 20.10 (2020): 7793-7801, entire document	1-11
A	US 5,256,911 A (HOLLER et al.) 26 October 1993 (26.10.1993), entire document	1-11
A	WO 2009/087109 A1 (UNIVERSITY OF ULSTER) 16 July 2009 (16.07.2009), entire document	1-11
A	US 2019/0164617 A1 (SILICON STORAGE TECHNOLOGY, INC.) 30 May 2019 (30.05.2019), entire document	1-11

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

30 October 2023

Date of mailing of the international search report

JAN 09 2024

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-8300

Authorized officer

Kari Rodriguez

Telephone No. PCT Helpdesk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 23/68933

Continuation of Box No. III – Observations where unity of invention is lacking

The inventions listed in the above-mentioned groups do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Special Technical Features

Group I includes the special technical feature of each FN synapse is operable to store a synaptic weight as a differential voltage across the floating gates of its FN tunneling devices and to implement synaptic memory consolidation, not included in the other group.

Group II includes the special technical feature of an input coupled to the first and second FN tunneling devices and operable to adjust a plasticity of the FN synapse in response to a signal applied to the input, not included in the other group.

Common Technical Features:

The only technical feature shared by Groups I and II that would otherwise unify the groups, is a Fowler-Nordheim (FN) synapse, that includes a pair of FN tunneling devices each including a floating gate. However, this shared technical feature does not represent a contribution over prior art, because the shared technical feature is disclosed by US 5,336,937 A to Sridhar et al. (hereinafter Sridhar).

Sridhar discloses a Fowler-Nordheim (FN) synapse, that includes a pair of FN tunneling devices each including a floating gate. (col 4, In 47-56: an improved programmable analog synapse or synaptic circuit in accordance with the invention uses two floating gate MOSFETs with tunneling injection, one of N-Type and the other P-Type, in an inverter structure. Each MOSFET has an associated weight value corresponding to a stored charge in its floating-gate, which causes a shift in its threshold voltage. This stored charge results from a charge injected into the MOSFET's floating gate by Fowler-Nordheim tunneling).

As the common technical feature was known in the art at the time of the invention, this cannot be considered a special technical feature that would otherwise unify the groups.

Therefore, Groups I-II lack unity under PCT Rule 13.