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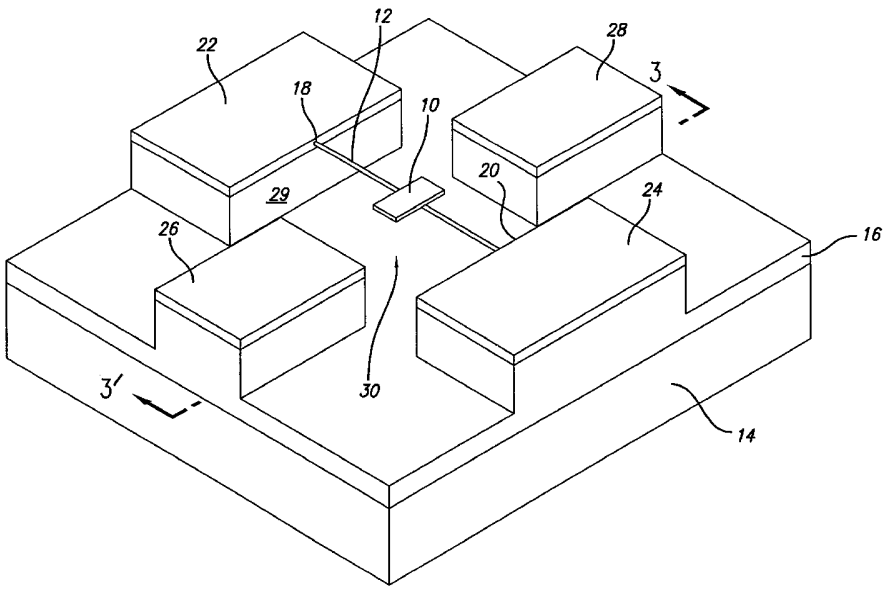
[Continued on next page]

(54) Title: ROTATIONAL ACTUATOR OR MOTOR BASED ON CARBON NANOTUBES



(57) Abstract: A rotational actuator/motor based on rotation of a carbon nanotube is disclosed. The carbon nanotube is provided with a rotor plate attached to an outer wall, which moves relative to an inner wall of the nanotube. After deposit of a nanotube on a silicon chip substrate, the entire structure may be fabricated by lithography using selected techniques adapted from silicon manufacturing technology. The structures to be fabricated may comprise a multiwall carbon nanotube (MWNT), two in plane stators (26, 28) and a gate stator (30) buried beneath the substrate surface. The MWNT is suspended between two anchor pads and comprises a rotator attached to an outer wall and arranged to move in response to electromagnetic inputs. The substrate is etched away to allow the rotor to freely rotate. Rotation may be either in a reciprocal or fully rotatable manner.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US04/22922

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : H02N 1/00; G02B 26/08, 26/10
US CL : 310/309
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)
U.S. : 310/309; 977/DIG. 1; 359/223, 226

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IEEE/GOOGLE: nanomotor, nanoscale, nanoactuator, nanomirror

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CLELAND et al, A Nanometre-scale Mechanical Electrometer, Nature Macmillan Publishers Ltd., Vol. 392, 12 March 1998 (12.03.1998), pages 160-162.	1, 2, 6-12, 15, 16
Y	WILLIAMS et al, Torsional Response and Stiffening of Individual Multiwalled Carbon Nanotubes, The Americaan Physical Society, Physical Review Letters, Vol. 89, No. 25, 16 December 2002 (16.12.2002), pages 1-4.	1, 2, 6-12, 15, 16
Y	US 2001/0050801 A1 (BEHIN et al) 13 December 2001 (13.12.2001), see entire document.	8-12
Y	US 2002/0070426 A1 (CUMINGS et al) 13 June 2002 (13.06.2002), see entire document.	16
A,P	JP 2003-211396 A (MURAKAMI) 29 July 2003 (29.07.2003), see entire document.	1-16

☐ 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

"E" earlier application or patent 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
31 March 2005 (31.03.2005)

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US04/22922

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:
Please See Continuation 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 an additional fee, this Authority did not invite payment of any additional fee.
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.: 1-16

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US04/22922

BOX III. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING

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 examined, the appropriate additional examination fees must be paid.

Group I, claims 1-16, drawn to a nanoscale actuator.
Group II, claims 17-23, drawn to a method of making a nanoscale actuator.
Group III, claims 24-31, drawn to a method of operating a nanoscale actuator.

The inventions listed as Groups I-III 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: The structure of the nanoscale actuator of Group I is not required for the method of making an actuator or the method of operating an actuator; and the method of making does not rely on the structure of the actuator or the method of operating the actuator, which shows the inventions lack a single inventive concept.