



- (51) International Patent Classification:
C09K 5/10 (2006.01) *C09K 5/00* (2006.01)
- (21) International Application Number:
PCT/US2012/023208
- (22) International Filing Date:
31 January 2012 (31.01.2012)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
61/437,741 31 January 2011 (31.01.2011) US
61/451,761 11 March 2011 (11.03.2011) US
13/356,938 24 January 2012 (24.01.2012) US
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- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, 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) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, 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, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: NANOFUIDS FOR USE IN COOLING ELECTRONICS

(57) Abstract: A fluid composition or nanofluid is described that includes a dielectric base fluid, a chemical dispersant, and nanoparticles dispersed in the dielectric fluid. The chemical dispersant is used to facilitate the nanoparticle dispersing process and also to increase the stability of the nanofluid thus produced. The nanofluid is compatible with electronics and has enhanced thermal conductivity for use in cooling electronics. Techniques are described that can be used to efficiently disperse different forms of nanoparticles into a base fluid and produce a stable nanofluid which is compatible with electronic circuitry and components.

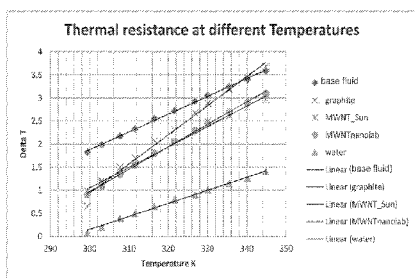


Figure 1





Published:

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

21 February 2013

- *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))*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/023208**A. CLASSIFICATION OF SUBJECT MATTER***C09K 5/10(2006.01)i, C09K 5/00(2006.01)i*

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)

C09K 5; C08K 3; E21B 43; F28F 9; C10M 125; C10M 169

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

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: nanofluid, cooling, electronics, thermal conductivity, dielectric*, base fluid, nanomaterial, carbon nanotube, hexagonal boron nitride.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004-0209782 A1 (ZHANG, ZHIGIANG et al.) 21 October 2004 See abstract; paragraphs [0022] - [0067]; examples 2 - 7.	1-7, 10-15, 18, 19
Y	See paragraph [0006].	16, 17, 20
A	See the whole document.	8, 9
X	XIE, H. et al. "Nanofluids containing multiwalled carbon nanotubes and their enhanced thermal conductivities", J. Appl. Phys., Vol. 94, No. 8, Pages 4967 - 4971, 15 October 2003 See abstract; pages 4968 - 4969; FIG. 7.	1, 2, 4-7, 10, 11, 13, 18, 19
Y	See pages 4968 - 4969.	16, 17, 20
A	See the whole document.	3, 8, 9, 12, 14, 15
X	HWANG, Y. et al. "Thermal conductivity and lubrication characteristics of anofluids", Current Appl. Phys., Vol. 6S1, No. 1, Pages e67 - e71, 13 March 2006 See abstract; pages e68 - e70; Table 1; FIG. 5.	1, 2, 4, 6, 7, 10, 11, 13, 18, 19
Y	See pages e68 - e70.	16, 17, 20
A	See the whole document.	3, 5, 8, 9, 12, 14, 15

 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 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 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

13 DECEMBER 2012 (13.12.2012)

Date of mailing of the international search report

14 DECEMBER 2012 (14.12.2012)

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2012/023208

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CHOI, C. et al. "Preparation and heat transfer properties of nanoparticle-in-transformer oil dispersions as advanced energy-efficient coolants", Current Appl. Phys., Vol. 8, No. 6, Pages 710 - 712, 18 October 2007 See abstract; Table 1; Fig. 1 and 2(a); Section 2. Experimental procedure.	8
A	See the whole document.	1-7,9-20
X	SHAIKH, S. et al. "Thermal conductivity improvement in carbon nanoparticle doped PAO oil: An experimental study", J. Appl. Phys., Vol. 101, No. 6, Page 064302(7 pages), 16 March 2007 See abstract; pages 2 - 5 of 064302.	10-15,18,19
Y	See pages 2 - 5 of 064302.	16,17,20
A	See the whole document.	1-9
Y	US 2009-0260777 A1 (ATTLESEY, CHAD DANIEL) 22 October 2009 See abstract; paragraphs [0032] - [0055] and [0072] - [0075]; FIG. 7.	16,17,20
A	CHOI, S. U. S. et al. "Anomalous thermal conductivity enhancement in nanotube suspensions", Appl. Phys. Lett., Vol. 79, No. 14, Pages 2252 - 2254, 01 October 2001 See the whole document.	1-20
A	WO 2010-085802 A2 (BAKER HUGHES INCORPORATED) 29 July 2010 See the whole document.	1-20
PX	LI, Y. et al. "Investigation on two abnormal phenomena about thermal conductivity enhancement of BN/EG nanofluids", Nanoscale Res. Lett., Vol. 6, No. 1, Page 443(7 pages), 09 July 2011 See abstract; pages 1 - 3 of 443; FIG. 2.	9
PA	See the whole document.	1-8,10-20
PX	TAHA-TIJERINA, J. et al. "Electrically insulating thermal nano-oils using 2D fillers", ACS Nano, Vol. 6 ,No. 2, Pages 1214 - 1220, 24 January 2012 See abstract; pages 1215 - 1217.	9
PA	See the whole document.	1-8,10-20

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2012/023208

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:

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 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.:

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

Information on patent family members

International application No.

PCT/US2012/023208

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2004-0209782 A1	21.10.2004	CA 2487340 A1	24.12.2003
		EP 1509585 A1	02.03.2005
		US 2009-0298725 A1	03.12.2009
		US 2010-0022422 A1	28.01.2010
		US 7348298 B2	25.03.2008
		WO 03-106600 A1	24.12.2003
US 2009-0260777 A1	22.10.2009	CN 102037426 A	27.04.2011
		EP 2271971 A2	12.01.2011
		JP 2011-518395 A	23.06.2011
		JP 4903295 B2	13.01.2012
		KR 10-1115711 B1	13.06.2012
		KR 10-2011-0004857 A	14.01.2011
		TW 200950687 A	01.12.2009
		US 2010-0246118 A1	30.09.2010
		US 2011-0134604 A1	09.06.2011
		US 7905106 B2	15.03.2011
		US 7911793 B2	22.03.2011
		US 8089764 B2	03.01.2012
		WO 2009-131810 A2	29.10.2009
WO 2009-131810 A3	30.12.2009		
WO 2010-085802 A2	29.07.2010	CA 2750658 A1	29.07.2010
		US 2010-0187925 A1	29.07.2010
		US 8076809 B2	13.12.2011
		WO 2010-085802 A3	18.11.2010

(Continuation of Box No. III.)

Group I: Claims 1 - 8 are directed to a fluid composition for cooling electronics comprising: a dielectric base fluid; about 0.001 to about 1 percent by weight of a nanomaterial having an aspect ratio of 500 - 2000 dispersed into the dielectric base fluid, the nanomaterial having a thermal conductivity greater than the predetermined thermal conductivity of the dielectric base fluid; and a chemical dispersing agent.

Group II: Claim 9 is directed to the fluid composition of claim 8 and claim 8 in turn is dependent on claim 1, wherein the oxide of claim 9 comprises hexagonal boron nitride. However, hexagonal boron nitride is not acknowledged to be an oxide material in a common sense of the inorganic material technology, even though it may contain boron trioxide as an unreacted impurity. Furthermore, the aspect ratio of hexagonal boron nitride used in the example cannot be defined because of non-available value of diameter (See Table 1 at page 9). In conclusion, the nanomaterial of claim 9 is neither an oxide nor nanomaterial having a specific aspect ratio, and thus claim 9 is treated as an independent claim directed to a fluid composition for cooling electronics comprising about 0.001 to about 1 percent by weight of a hexagonal boron nitride dispersed into the dielectric base fluid, the hexagonal boron nitride having a thermal conductivity greater than the predetermined thermal conductivity of the dielectric base fluid and a chemical dispersing agent.

Group III: Claims 10 - 19 are directed to a thermally enhanced fluid composition and a method for using or creating the composition of claim 10 wherein the thermally enhanced fluid composition comprises a dielectric base fluid; up to about 1 percent by weight of a nanomaterial dispersed into the dielectric base fluid, the nanomaterial having an aspect ratio of 500 - 20000, and the nanomaterial having a thermal conductivity greater than the predetermined thermal conductivity of the dielectric base fluid, and the nanomaterial having surfaces that are modified by a chemical wetting agent; and the fluid composition has an electric breakdown field that renders the fluid composition suitable for direct contact with an electronic component.

Group IV: Claim 20 is directed to a liquid submersion-cooled server computer characterized in the use of a dielectric cooling liquid comprising: a dielectric base fluid; and up to about 1 percent by weight of a nanomaterial dispersed into the dielectric base fluid, the nanomaterial having an aspect ratio of 500 - 20000, and the nanomaterial having a thermal conductivity greater than the predetermined thermal conductivity of the dielectric base fluid, and the nanomaterial having surfaces that are modified by a chemical wetting agent.

The only common technical feature among Group I - IV is: a fluid composition comprising: a dielectric base fluid; and up to about 1 percent by weight of a nanomaterial dispersed into the dielectric base fluid, and the nanomaterial having a thermal conductivity greater than the predetermined thermal conductivity of the dielectric base fluid.

However, this feature lacks novelty and/or inventive step with respect to the following documents:

(a) US 2004/0209782 A1, (b) Hwang, Y. et al., Current Applied Physics Vol. 6S1, e67 - e71, (c) Choi, S. U. S. et al., Applied Physics Letters Vol. 79, 2252 - 2254, (d) Xie, H. et al. Journal of Applied Physics Vol. 94, 4967 - 4971, (e) Shaikh, S. et al., Journal of Applied Physics Vol. 101, 064302 (f) Choi, C. et al., Current Applied Physics Vol. 8, 710 - 712

Thus there is no technical relationship left over the prior art among the claimed inventions, leaving the groups without a single general inventive concept.

Hence there is lack of unity "a posteriori"(PCT Rules 13.1 and 13.2).