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APPENDICES

APPENDIX A

Publications Resulting from This Research Work

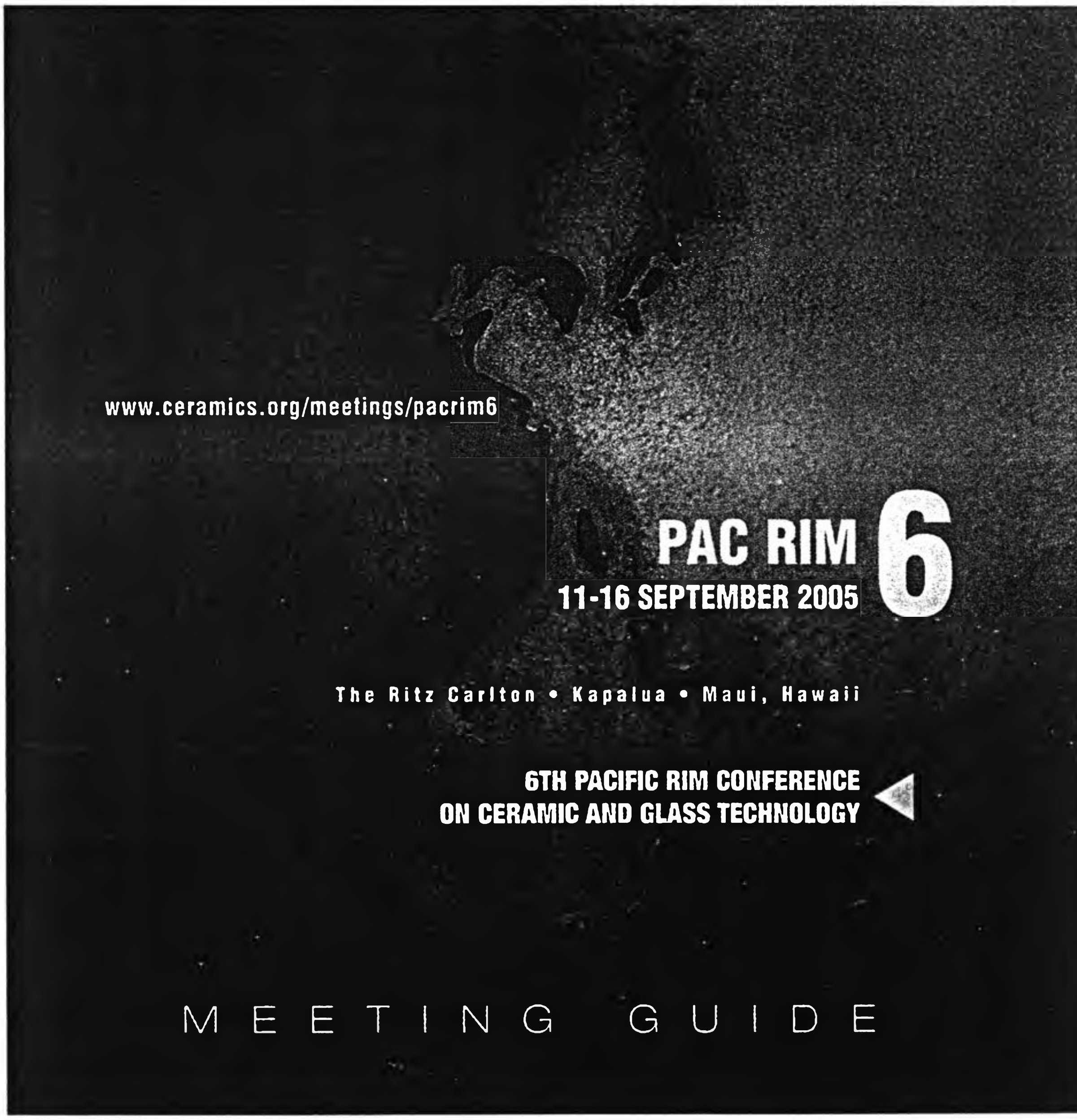
PUBLICATIONS

International Proceeding

1. A. Sakkapas, S. Wada, C. Tawatchai, "Behavior of Deflocculant and Binder on Microscopic Behavior of Green-Body Alumina Used for Preparation of Transparent Alumina Ceramic" *Proceedings of International Conference on 6th Pacific Rim Conference on Ceramic and Glass Technology(PAC RIM 6)*, September 11-16, 2005, Hawaii, USA, p. 45

Domestic Proceeding

1. S. Areeraksakul, S. Wada, T. Charinpanitkul, "Development of High Dense Green-body Alumina by Slip Casting for Preparing the Transparent Alumina Ceramic", *Proceedings of Local Conference on NSTDA Annual Conference 2005 (NAC 2005)*, March 28-30, 2005, Bangkok, Thailand, p. 227.



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Thursday, September 15, 2005

02 — Characterization and Processing of Nanosize Powders and Particles

Ceramic Processing and Fabrication Using Nanopowders

Room: Salon 2

Session Chairs: Makio Naito, Osaka University, Japan; Hiroya Abe, Osaka University, Japan

8:00 AM
(PACRIM-S2-43-2005) Fibrous Nanoparticle Composites for Highly Efficient Thermal Insulation (Invited)
H. Abe*, K. Sato, M. Naito, Y. Itoh, I. Abe, Osaka University, Japan

8:40 AM
(PACRIM-S2-44-2005) Bulk Assembly of Nanoscale Titania
K. Venugopal, R. A. Haber*, Rutgers State University of New Jersey, NJ

9:00 AM
(PACRIM-S2-45-2005) Analysis of Consolidation Behavior of 68 nm-Yttria-Stabilized Zirconia Particles during Pressure Filtration
T. Hiraz*, Y. Tanaka, Kagoshima University, Japan

9:20 AM
(PACRIM-S2-46-2005) Preparation of 3D Colloidal Sphere Arrays Using Barium Titanate Fine Particles and Their Dielectric Properties
T. Hoshina, H. Yasuno, H. Kakemoto, T. Tsurumi, S. Wada*, A. Yazawa, Tokyo Institute of Technology, Japan

10:00 AM
(PACRIM-S2-47-2005) Aerosol Deposition -Compaction of Nano-Sized Ceramics at Room Temperature (Invited)
J. Akedo*, National Institute of Advanced Industrial Science and Technology (AIST), Japan

10:40 AM
(PACRIM-S2-48-2005) Fabrication Method Using a Hybrid Aerosol Beam for Titania and Hydroxyapatite Composite Film
T. Ishiaki*, T. Masahiro, A. Nobuyuki, Osaka University, Japan; A. Jun, National Institute of Advanced Industrial Science and Technology (AIST), Japan; O. Takayoshi, Osaka University, Japan

11:00 AM
(PACRIM-S2-56-2005) Effect of Deflocculant and Binder on Microscopic Behavior of Green-body Alumina Used for Preparation of Transparent Alumina Ceramic
A. Sallapas, S. Wada, C. Tawatchai*, Chulalongkorn University, Thailand

03 — Ceramics and Glasses for Immobilization of Radioactive Waste

International Cleanup Programs

Room: Maui

Session Chair: Lou Vance, Australian Nuclear Science and Technology Organization, Australia

9:00 AM
(PACRIM-S3-5-2005) Progress of R&D on Geological Disposal of High Level Radioactive Waste (HLW) in Japan (Invited)
H. Makino, H. Igarashi*, H. Umeki, K. Shimizu, K. Miyahara, T. Ishiguro, S. Masuda, Japan Nuclear Cycle Development Institute, Japan

9:40 AM
(PACRIM-S3-6-2005) Australian Overview - Radioactive Waste Management Challenges and Opportunities (Invited)
B. D. Begg*, Australian Nuclear Science and Technology Organization, Australia

Glass and Ceramics

Room: Maui

Session Chair: Bruce D. Begg, Australian Nuclear Science and Technology Organization, Australia

10:50 AM
(PACRIM-S3-9-2005) Enthalpy of Formation of $Ce_{(1-x)}ZrxO_2$ Fluorite and $CaPuTi_2O_7$ Pyrochlore
T. Lee*, J. Mitchell, Los Alamos National Laboratory, NM; A. Navrotsky, University of California-Davis, CA; B. Ebbinghaus, Lawrence Livermore National Laboratory, CA

11:10 AM
(PACRIM-S3-10-2005) Ceramics for Immobilization of U-Rich Wastes
M. L. Carter*, E. R. Vance, Australian Nuclear Science and Technology Organization, Australia

06 — Advanced Ceramics for Clean Energy Applications

Tribological Performance and Component Reliability

Room: Plantation 3

Session Chairs: Yasuhiro Goto, Toshiba Corporation, Japan; Hua-Tay Lin, Oak Ridge National Laboratory, TN

8:00 AM
(PACRIM-S6-35-2005) Ceramic Shoes for Safety Gear of Ultra-High Speed Elevator (Invited)
Y. Goto*, Toshiba Corporation, Japan; H. Kobayashi, T. Nakagawa, Toshiba Elevator and Building Systems Corporation, Japan

8:40 AM
(PACRIM-S6-36-2005) Wear Behavior of Micro- and Nano-Sized Non-Oxide Ceramics
S. Guicciardi*, C. Melandri, D. Sciti, A. Bellosi, ISTEC-CNR, Italy

9:00 AM
(PACRIM-S6-37-2005) New Tools for Assessment of Reliability of Structural Ceramic Components (Invited)
M. Ferber*, Oak Ridge National Laboratory, TN

Fracture, Deformation and Mechanical Reliability

Room: Plantation 3

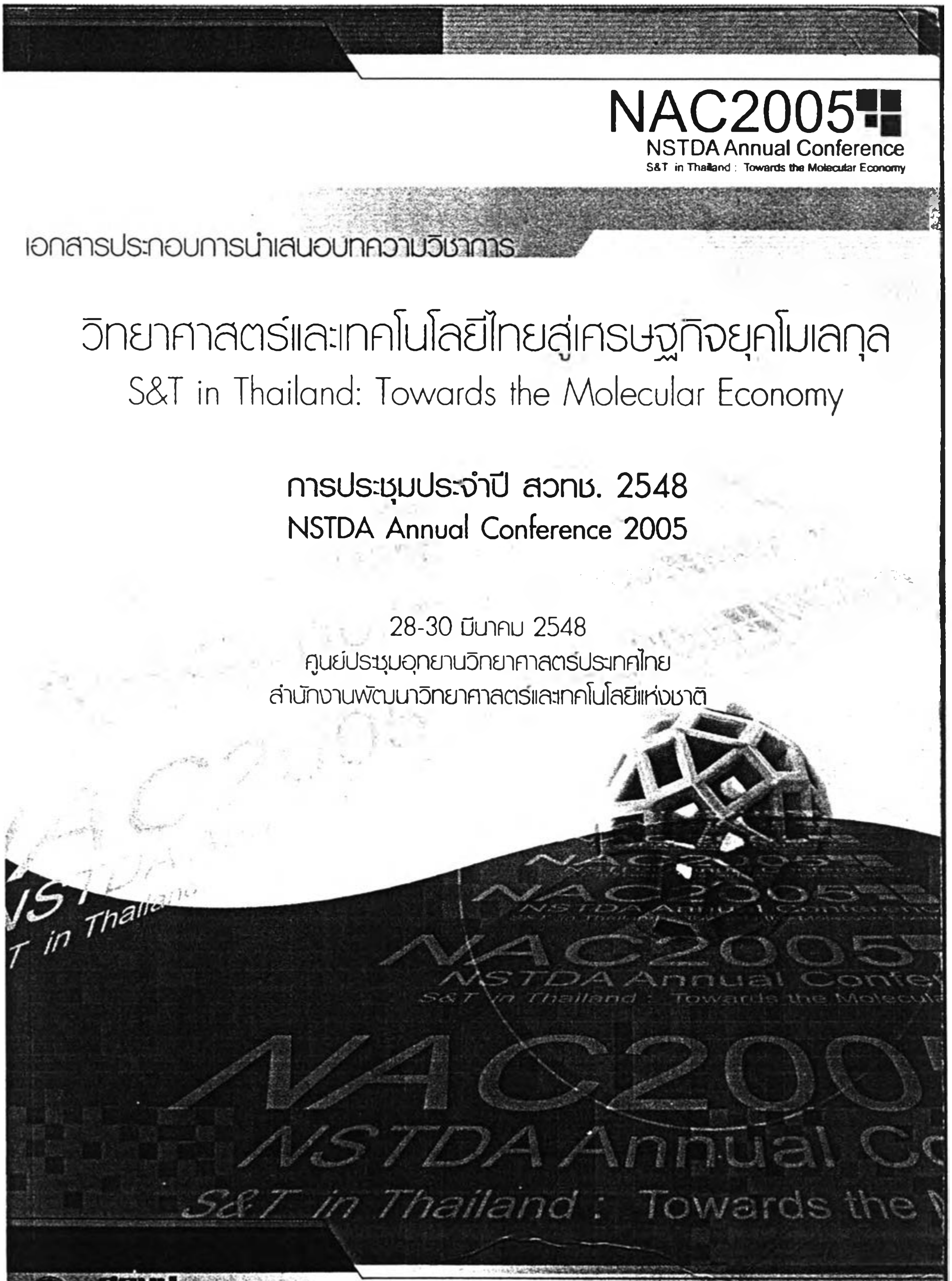
Session Chairs: John R. Hellmann, Pennsylvania State University, PA; Michael G Jenkins, University of Washington, WA

10:00 AM
(PACRIM-S6-38-2005) Comparison of Static Fatigue SCG Models for Dense Ceramics
L. A. Salem, NASA Glenn Research Center, OH; M. G. Jenkins*, University of Detroit Mercy, MI

10:20 AM
(PACRIM-S6-39-2005) Microstructural Characterization and Impression Creep Testing of SiAlON Ceramics
K. M. Fox, E. C. Dickey, D. J. Green, J. R. Hellmann*, Pennsylvania State University, PA; R. L. Yeckley, Kennametal Inc., PA

11:00 AM
(PACRIM-S6-41-2005) Mechanical and Thermal Properties of $LaGaO_3$ Single Crystals
S. Pathak, S. R. Kalidindi, N. Orlovskaya*, Drexel University, PA; M. Radovic, E. Lara-Curzio, Oak Ridge National Laboratory, TN; C. Klemenz, University of Central Florida, FL

11:20 AM
(PACRIM-S6-42-2005) Development of Elevated Fracture Toughness Testing Method Standard for Advanced Ceramics
M. G. Jenkins*, University of Detroit Mercy, MI; L. A. Salem, NASA Glenn Research Center, OH



NAC2005
NSTDA Annual Conference
S&T in Thailand : Towards the Molecular Economy

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วิทยาศาสตร์และเทคโนโลยีไทยสู่เศรษฐกิจยุคโมเลกุล

S&T in Thailand: Towards the Molecular Economy

การประชุมประจำปี สวทช. 2548
NSTDA Annual Conference 2005

28-30 มีนาคม 2548
ศูนย์ประชุมอุทยานวิทยาศาสตร์ประเทศไทย
สำนักงานพัฒนาวิทยาศาสตร์และเทคโนโลยีแห่งชาติ

วิทยาศาสตร์และเทคโนโลยีไทยสู่เศรษฐกิจยุคโมเลกุล 227
S&T In Thailand: Towards the Molecular Economy

Nanomaterials

การพัฒนาเซรามิกอะลูมินาดิบที่มีความหนาแน่นสูงด้วยวิธีการหล่อแบบสำหรับการเตรียมเซรามิกอะลูมินาใส

สักกภาส อารีย์รักษากุล Shigetaka Wada และ ธวัชชัย ชรินพาณิชกุล

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บทคัดย่อ

กระบวนการขึ้นรูปเซรามิกอะลูมินาดิบให้มีความหนาแน่นสูงนั้นเป็นกระบวนการหนึ่งในการผลิตเซรามิกอะลูมินาใส ที่มีความสำคัญเช่นเดียวกันกับ กระบวนการเตรียมวัตถุดิบ และกระบวนการเผาผนึก เนื่องจากเซรามิกอะลูมินาดิบที่มีความหนาแน่นสูงและมีสิ่งเจือปนในปริมาณน้อยจะมีความเป็นรูพรุนต่ำ และมีการเติบโตของเกรนที่สม่ำเสมอในระหว่างการเผาผนึก ซึ่งจะส่งผลให้ได้เซรามิกของอะลูมินาที่มีผลต่อคุณสมบัติเชิงแสงที่ดี ด้วยข้อดีของกระบวนการขึ้นรูปด้วยวิธีการหล่อแบบ ซึ่งนอกจากจะได้เซรามิกดิบที่มีคุณสมบัติดังกล่าวแล้ว ยังทำให้ได้ได้ชิ้นงานที่มีความเป็นเนื้อเดียวกัน อีกทั้งมีค่าใช้จ่ายในการดำเนินการต่ำมากเมื่อเทียบกับวิธีอื่นๆ โดยการเติมสารช่วยกระจายตัวในปริมาณที่เหมาะสมจะเป็นปัจจัยสำคัญที่ช่วยทำให้สามารถเตรียมสารแขวนลอยอะลูมินาเข้มข้นที่มีความเสถียร และไหลเทได้ดีในแม่แบบ ส่งผลให้สามารถเตรียมชิ้นงานเซรามิกดิบที่มีความหนาแน่นสูงได้ จากการทดลองพบว่า การใช้สารช่วยกระจายตัวชนิด เกลือแอมโมเนียมของกรดโพลีเมทธาคริลิกในปริมาณ 1.18-1.94%, 1.25% และ 1.50% ลงในสารแขวนลอยอะลูมินาที่มีความเข้มข้น 70% 75% และ 80% ตามลำดับ จะทำให้สารแขวนลอยที่ได้มีความเสถียร ที่ค่าความหนืดต่ำสุด ดังนั้นจึงเหมาะสำหรับการเตรียมเซรามิกอะลูมินาดิบความหนาแน่นสูงสำหรับเตรียมเซรามิกอะลูมินาโปร่งใส

คำสำคัญ : เซรามิกอะลูมินาดิบ, เซรามิกอะลูมินาใส, วิธีการหล่อแบบ, สารช่วยกระจายตัว

Abstract

Fabrication of alumina green-body with high density is one of the important processes to produce the transparent alumina ceramic besides raw materials preparation process and sintering processes. Since alumina ceramic with high density and minimized contamination could result in less porosity and abnormal grain growth during sintering the outstanding optical properties of alumina ceramic could be expected. Forming of alumina green body using slip casting is not only getting green body could not provide only homogeneous green body but also require very low operating cost compared with other techniques. Addition of deflocculant with appropriated proportion to the ceramic slurry will help provide well-dispersed slurry with high stability and low viscosity. From the experimental results, it could be clearly seen that slurry of alumina with concentration of 70%, 75% and 80% could exhibit the optimal stability and viscosity when defloculant which is NH^{4+} salt of polymethacrylic acid with concentration of 1.18-1.94%, 1.25% and 1.50%, respectively, is added into the slurry.

Keywords : alumina green body, transparent alumina, slip casting, deflocculant

APPENDIX B

Raw Materials Specification

APPENDIX B1 Specification of commercial α-Al_2O_3 powder (TM-DAR) from Taimei Chemicals, Co.,Ltd (Japan)

Purity and content:

Alumina content of "TAIMICRON" is over 99.99%. / Measured by ICP-AES

Al_2O_3	Impurities (ppm)										
(%)	Si	Fe	Na	K	Ca	Mg	Cu	Cr	Mn	U	Th
>99.99	10	8	8	3	3	2	1	<1	<1	<0.004	<0.005

Properties of TM-DAR alumina powder:

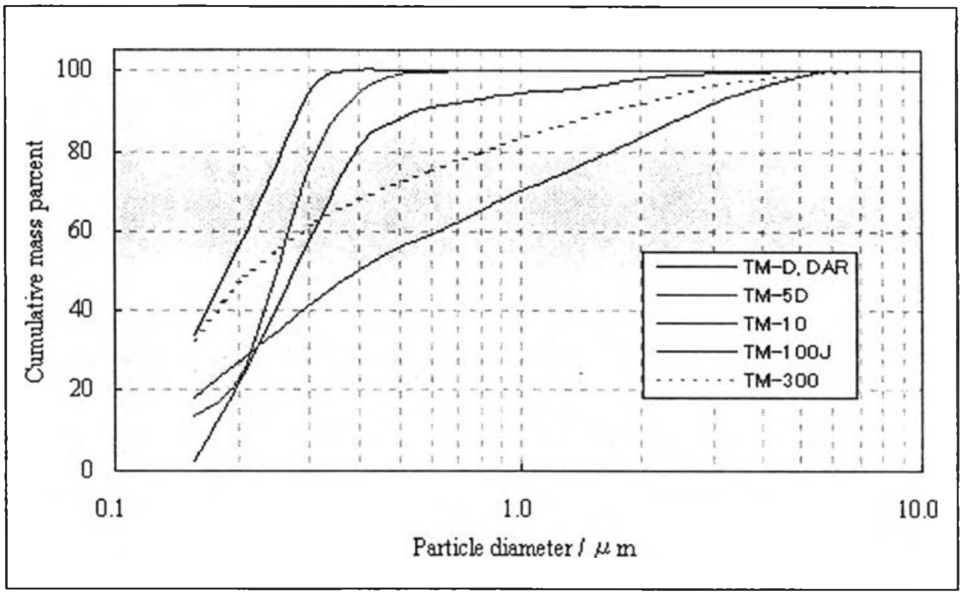
Grade		TM-DAR
Crystalline form		Alpha
B.E.T. Specific surface area / m^2-g^{-1}		14.5
Primary particle size / μm	*1	0.1
Bulk density / g-cm^{-3}		0.9
Tapped density / g-cm^{-3}		1
Pressed density / g-cm^{-3}	*2	2.3
Sintered density / g-cm^{-3}	*2	3.96*3

*1 ; measured by SEM

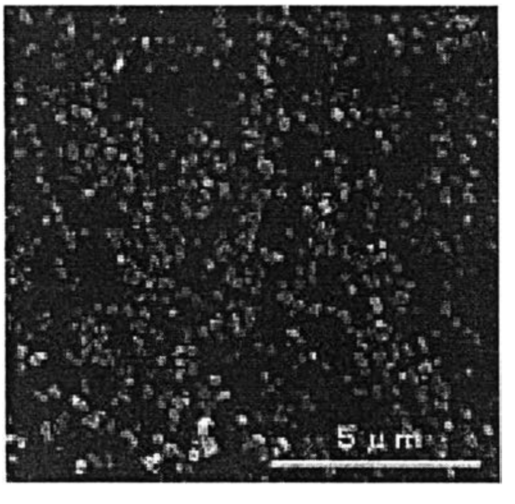
*2 ; uniaxial press at 98MPa

*3 ; 1350°C for 1Hr. in air

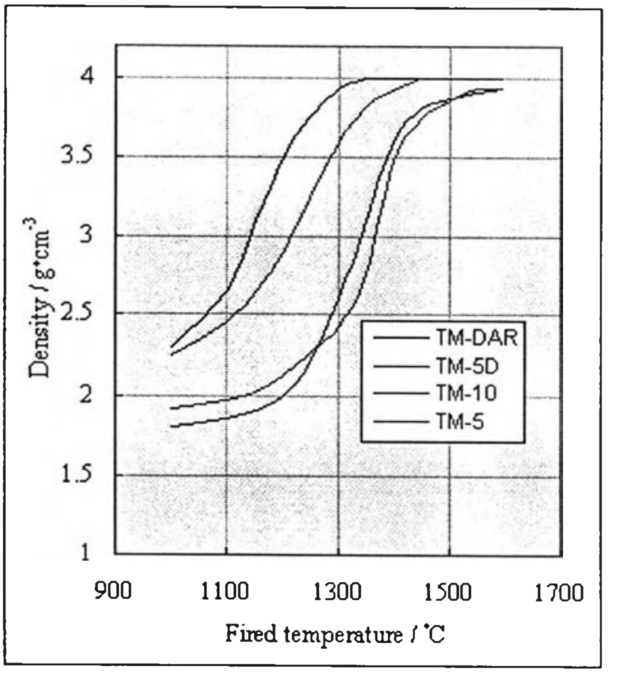
Particle size distributions of each grade / Measured by centrifugal particle sizer:



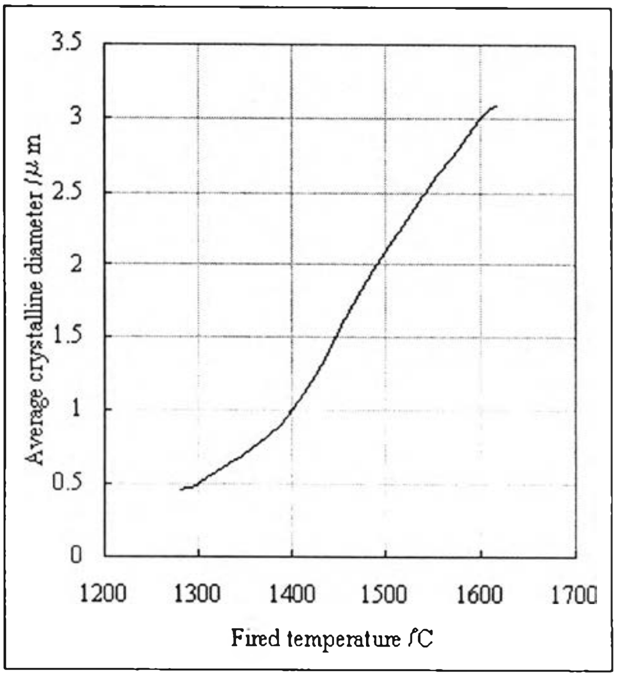
SEM photograph:



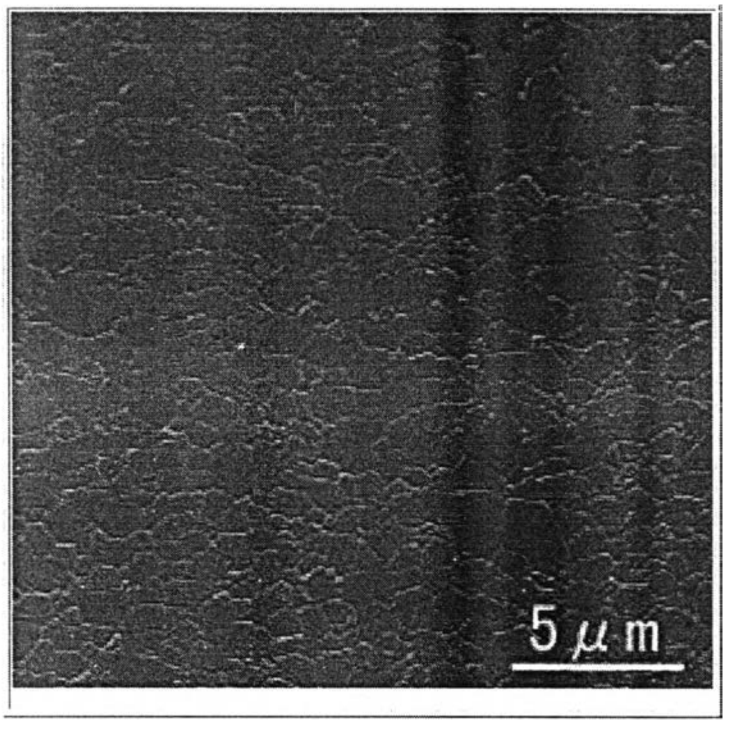
Densification behaviors of each grade uniaxially pressed (98MPa) and fired (1Hr.in air) :



Relationship between firing temperature and crystalline diameter:



Microstructure of sintered TM-DAR body at 1350˚C for 1h in air:



APPENDIX B2 Specification of commercial Blasnose 7M refined CMC

Blanose 7M is derived from Aqualon, a Division of Hercules Incorporated, Aqualon production facilities at Alizay, France

BLANOSE Refined CMC is the sodium salt of carboxymethylcellulose, which has been purified to a CMC content of 98 % minimum. A water soluble polymer, BLANOSE Refined CMC acts as a thickener, rheology control agent, binder, stabilizer, protective colloid, film former and water retention aid for use in a variety of industrial applications.

Type and specifications:

Type	% sodium content	Concentration, %	Range at 25oC, mPa.s	Brookfield LVF setting	
				Spindle No.	RPM
7M	7.0-8.9	2	300-600	2	30

Other specification property:

Property	**Limit**
Purity : 100%	98 min.
Bulk density, g/cm3	0.55-1.00
Moisture, % as packed	8 max.
pH of solutions, all M-type, at 1%	6.5-8.5

Properties and use:

The properties of BLANOSE Refined CMC are used in many industries to improve products.

- Paper and cardboard: Additive for improving dry strength and wet strength, refining additive, solvent and
grease blocker and additive for reducing porosity. As a rheology control agent and water binder for paints,
preparations for film presses, size presses and coatings and as an additive for carbonless copy paper.
- Textile industry: As an additive for warp sizing and finishing.
- Adhesives: Wallpaper adhesive, carpet backing compounds.

In different applications such as welding rods, plate desensitizers and fountain solutions in offset printing, in waterbased paints, for seed coating, emulsion polymerisation, detergents, dry batteries, in drilling applications and in foundation work (diaphragm method).

Packageing and storage:

BLANOSE Refined CMC is packed in 25 kg 3-ply paper bags (with the exception of BLANOSE SB, in 20 kg paper bags), with removable polyethylene inner bag, supplied on pallets of 40 bags each. These are supplied from theAqualon production facilities at Alizay, France, and from warehouse stocks conveniently located near industrial centers. Full packaging details are available from Packaging Data Sheet no. 27.001.
BLANOSE is a non-perishable powder. It is recommended to use the product in rotation on a first-in first-out basis.The product should be stored under dry and clean conditions in its original packing and away from heat. The product is hygroscopic. The packaging is selected in a way to avoid ingress of moisture, but the water content of the packed product may increase if not stored dry.

Product safety:

Read and understand the Safety Data Sheet (SDS) before using this product

APPENDIX C

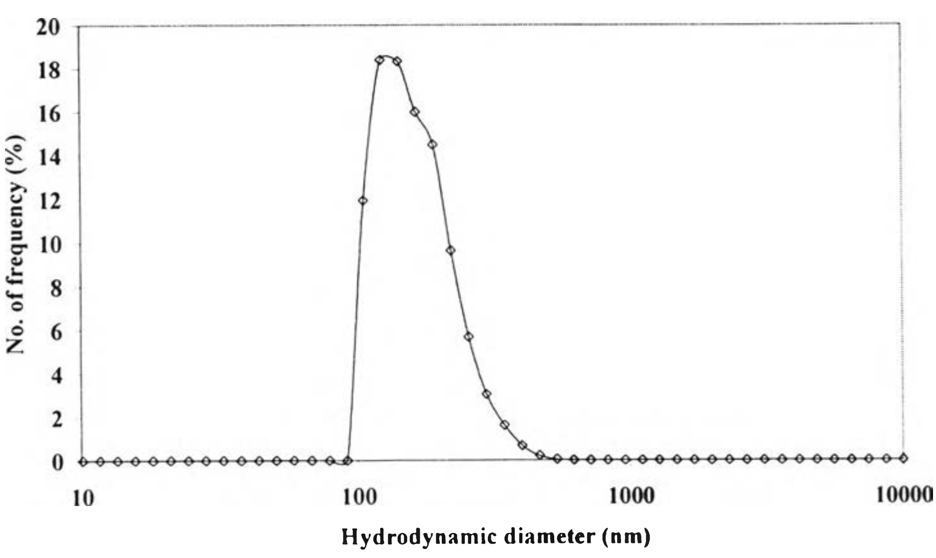
EXPERIMENTAL RESULTS

Appendix C1 Particle size distribution of TM-DAR alumina powder dynamic light-scattering technique (DLS; Malvern Zetasizer 300HSA, UK).

Data 1: size average 162.31 nm (Dp_{50})

Size (nm)	% No.	Size (nm)	% No.	Size (nm)	% No.	Size (nm)	% No.
0.4	0	1.736	0	7.531	0	32.67	0
0.4632	0	2.01	0	8.721	0	37.84	0
0.5365	0	2.328	0	10.1	0	43.82	0
0.6213	0	2.696	0	11.7	0	50.75	0
0.7195	0	3.122	0	13.54	0	58.77	0
0.8332	0	3.615	0	15.69	0	68.06	0
0.9649	0	4.187	0	18.17	0	78.82	0
1.117	0	4.849	0	21.04	0	91.28	0
1.294	0	5.615	0	24.36	0	105.7	11.93
1.499	0	6.503	0	28.21	0	122.4	18.39

Size (nm)	% No.	Size (nm)	% No.	Size (nm)	% No.
141.8	18.33	615.1	0.00131	2669	0
164.2	15.98	712.4	0	3091	0
190.1	14.48	825	0	3580	0
220.2	9.625	955.4	0	4145	0
255	5.672	1106	0	4801	0
295.3	3.045	1281	0	5560	0
342	1.611	1484	0	6439	0
396.1	0.673	1718	0	7456	0
458.7	0.2226	1990	0	8635	0
531.2	0.04752	2305	0	10000	0

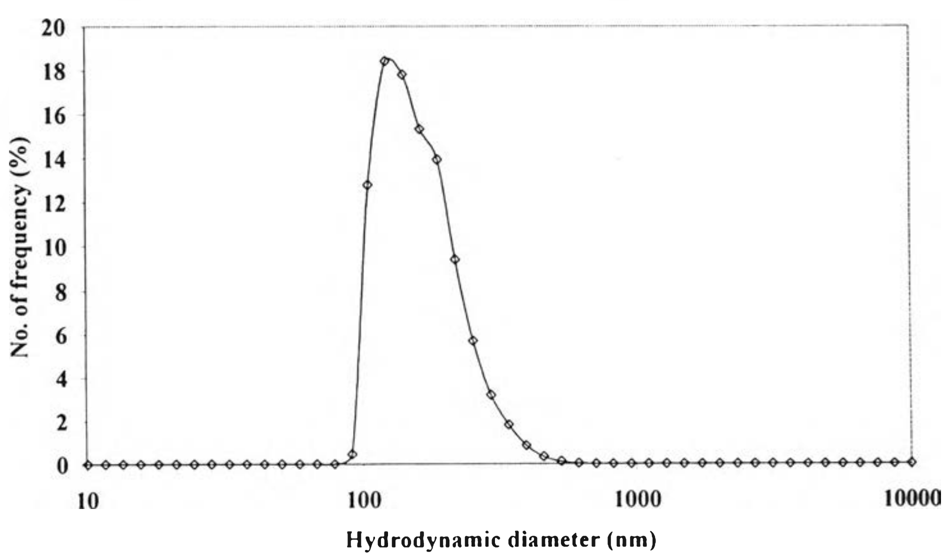


Appendix C1 Particle size distribution of TM-DAR alumina powder dynamic light-scattering technique (DLS; Malvern Zetasizer 300HSA, UK). (Continue)

Data 2: size average 163.36 nm (Dp_{50})

Size (nm)	% No.	Size (nm)	% No.	Size (nm)	% No.	Size (nm)	% No.
0.4	0	1.736	0	7.531	0	32.67	0
0.4632	0	2.01	0	8.721	0	37.84	0
0.5365	0	2.328	0	10.1	0	43.82	0
0.6213	0	2.696	0	11.7	0	50.75	0
0.7195	0	3.122	0	13.54	0	58.77	0
0.8332	0	3.615	0	15.69	0	68.06	0
0.9649	0	4.187	0	18.17	0	78.82	0
1.117	0	4.849	0	21.04	0	91.28	0.455
1.294	0	5.615	0	24.36	0	105.7	12.78
1.499	0	6.503	0	28.21	0	122.4	18.4

Size (nm)	% No.	Size (nm)	% No.	Size (nm)	% No.
141.8	17.79	615.1	0.02274	2669	0
164.2	15.32	712.4	0	3091	0
190.1	13.91	825	0	3580	0
220.2	9.371	955.4	0	4145	0
255	5.675	1106	0	4801	0
295.3	3.185	1281	0	5560	0
342	1.807	1484	0	6439	0
396.1	0.8438	1718	0	7456	0
458.7	0.3383	1990	0	8635	0
531.2	0.1083	2305	0	10000	0

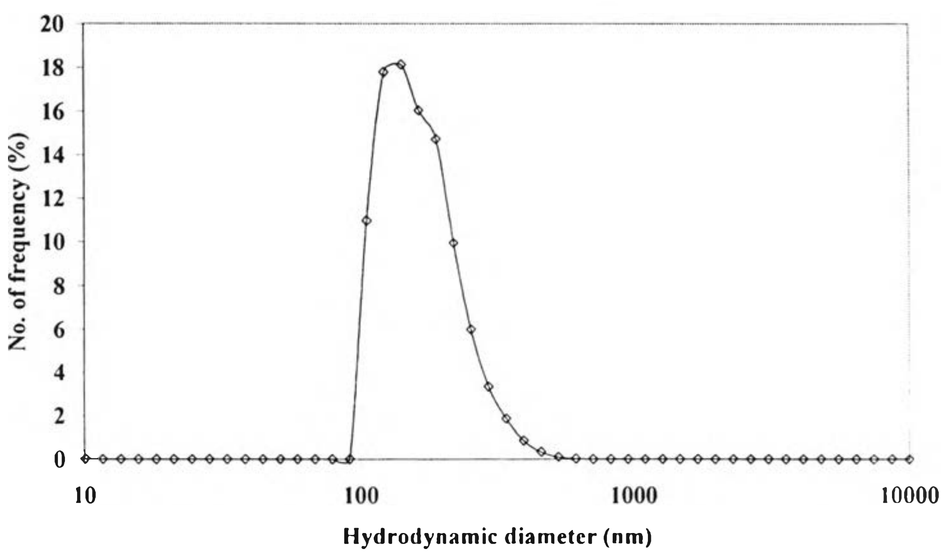


Appendix C1 Particle size distribution of TM-DAR alumina powder dynamic light-scattering technique (DLS; Malvern Zetasizer 300HSA, UK). (Continue)

Data 3: size average 159.83 nm (Dp_{50})

Size (nm)	% No.	Size (nm)	% No.	Size (nm)	% No.	Size (nm)	% No.
0.4	0	1.736	0	7.531	0	32.67	0
0.4632	0	2.01	0	8.721	0	37.84	0
0.5365	0	2.328	0	10.1	0	43.82	0
0.6213	0	2.696	0	11.7	0	50.75	0
0.7195	0	3.122	0	13.54	0	58.77	0
0.8332	0	3.615	0	15.69	0	68.06	0
0.9649	0	4.187	0	18.17	0	78.82	0
1.117	0	4.849	0	21.04	0	91.28	0
1.294	0	5.615	0	24.36	0	105.7	10.96
1.499	0	6.503	0	28.21	0	122.4	17.78

Size (nm)	% No.	Size (nm)	% No.	Size (nm)	% No.
141.8	18.13	615.1	0.01996	2669	0
164.2	16.03	712.4	0	3091	0
190.1	14.72	825	0	3580	0
220.2	9.93	955.4	0	4145	0
255	5.981	1106	0	4801	0
295.3	3.32	1281	0	5560	0
342	1.853	1484	0	6439	0
396.1	0.8458	1718	0	7456	0
458.7	0.3292	1990	0	8635	0
531.2	0.1012	2305	0	10000	0



Appendix C2 Viscosity of 70% solid loading of TMDAR alumina slurry at various concentration of Aron A6114 deflocculant.

Spindle speed (rpm)	% deflocculant (basis on solid weight)	Average Viscosity (mPa.S)
5	0.75	12848
	0.98	402
	1.18	160
	1.53	154
	1.94	263
	2.09	491
	2.29	1022
	2.49	1852
	2.76	2174
10	0.75	7098
	0.98	273
	1.18	130
	1.53	97
	1.94	176
	2.09	319
	2.29	625
	2.49	1099
	2.76	1291
20	0.75	3824
	0.98	225
	1.18	111
	1.53	83
	1.94	131
	2.09	230
	2.29	407
	2.49	681
	2.76	789
30	0.75	2725
	0.98	211
	1.18	129
	1.53	89
	1.94	123
	2.09	200
	2.29	328
	2.49	528
	2.76	609

Spindle speed (rpm)	% deflocculant (basis on solid weight)	AverageViscosity (mPa.S)
50	0.75	1790
	0.98	177
	1.18	116
	1.53	94
	1.94	114
	2.09	161
	2.29	243
	2.49	379
	2.76	436
60	0.75	1535
	0.98	167
	1.18	113
	1.53	99
	1.94	114
	2.09	153
	2.29	221
	2.49	339
	2.76	390
100	0.75	1021
	0.98	150
	1.18	115
	1.53	112
	1.94	121
	2.09	145
	2.29	180
	2.49	289
	2.76	291

Appendix C3 Viscosity of 75% solid loading of TMDAR alumina slurry at various concentration of Aron A6114 deflocculant.

Spindle speed (rpm)	% deflocculant (basis on solid weight)	Average Viscosity (mPa.S)	Spindle speed (rpm)	% deflocculant (basis on solid weight)	AverageViscosity (mPa.S)
	1.00	22048		1.00	3224
	1.15	1035		1.15	375
	1.25	676		1.25	273
5	1.40	782	50	1.40	319
	1.49	750		1.49	304
	1.62	843		1.62	329
	1.99	2109		1.99	462
	1.00	12270		1.00	2763
	1.15	761		1.15	348
	1.25	500		1.25	257
10	1.40	594	60	1.40	302
	1.49	572		1.49	289
	1.62	624		1.62	308
	1.99	1300		1.99	416
	1.00	6714		1.00	1840
	1.15	549		1.15	290
	1.25	380		1.25	228
20	1.40	458	100	1.40	260
	1.49	436		1.49	252
	1.62	473		1.62	266
	1.99	815		1.99	314
	1.00	4853			
	1.15	467			
	1.25	333			
30	1.40	397			
	1.49	375			
	1.62	408			
	1.99	641			

Appendix C4 Viscosity of 80% solid loading of TMDAR alumina slurry at various concentration of Aron A6114 deflocculant.

Spindle speed (rpm)	% Deflocculant (basis on solid weight)	AverageViscosity (mPa.S)	Spindle speed (rpm)	% Deflocculant (basis on solid weight)	AverageViscosity (mPa.S)
5	1.00	29696	50	1.00	4709
	1.50	3296		1.50	890
	2.00	5240		2.00	1288
	3.00	8472		3.00	1672
	3.50	15056		3.50	2778
10	1.00	15504	60	1.00	3915
	1.50	1972		1.50	817
	2.00	3280		2.00	1167
	3.00	4976		3.00	1497
	3.50	8736		3.50	2457
20	1.00	9126	100	1.00	2721
	1.50	1394		1.50	628
	2.00	2136		2.00	880
	3.00	3040		3.00	1156
	3.50	5174		3.50	1755
30	1.00	6955			
	1.50	1193			
	2.00	1728			
	3.00	2350			
	3.50	3956			

Appendix C5 Viscosity of 70% solid loading of TMDAR alumina slurry with 1.18% def. at various concentration of CMC binder

% CMC binder (basis on solid weight)	Spindle speed (rpm)	Viscosity (mPa.s)
0	5	160
	10	130
	20	110.5
	30	128.8
	50	115.8
	60	113.4
	100	115.4
0.05	5	1890
	10	1207
	20	778
	30	630.9
	50	470.8
	60	421.4
	100	320.8
0.1	5	5180
	10	2277
	20	1641
	30	1224.2
	50	836.6
	60	730
	100	503.2
0.3	5	17968
	10	10254
	20	5895
	30	4354.6
	50	2970.8
	60	2587.9
	100	1785.8

Appendix C6 Viscosity of 75% solid loading of TMDAR alumina slurry with 1.25% def. at various concentration of CMC binder

% CMC binder (basis on solid weight)	Spindle speed (rpm)	Viscosity (mPa.s)
0	5	676
	10	500.4
	20	379.6
	30	332.8
	50	273.2
	60	256.98
	100	227.6
0.05	5	6622
	10	3883
	20	2322.5
	30	1838.5
	50	1290.2
	60	1142.1
	100	800.6
0.1	5	13088
	10	6714
	20	4132
	30	3040
	50	2056
	60	1793
	100	1234.6

Appendix C7 Green body density of specimens prepared from A to G type of slurries

Sample	Sample	Mass (g)	Volume (cm3)	Density (g/cm3)	% Relative Density (% R.D.)	AVG.. % R.D
	RA1	4.14	1.66	2.49	62.66	
	RA2	4.20	1.83	2.30	57.67	
	RA3	4.87	2.21	2.20	55.37	
	PA1	2.32	1.02	2.27	57.15	
A	PA2	2.07	0.96	2.16	54.18	56.46
	PA3	4.32	1.99	2.17	54.54	
	PA4	4.08	1.96	2.08	52.30	
	PA5	2.50	1.10	2.27	57.10	
	PA6	4.14	1.82	2.27	57.15	
	RB1	3.61	1.44	2.51	62.99	
	RB2	5.22	2.13	2.45	61.58	
	RB3	5.00	2.00	2.50	62.81	
	PB1	2.86	1.20	2.38	59.88	
B	PB2	5.80	2.45	2.37	59.48	60.39
	PB3	11.56	4.87	2.37	59.64	
	PB4	2.58	1.09	2.37	59.47	
	PB5	5.16	2.18	2.37	59.47	
	PB6	6.09	2.63	2.32	58.18	
	RC1	1.84	0.75	2.45	61.64	
	RC2	4.62	1.88	2.46	61.74	
	RC3	5.15	2.09	2.46	61.91	
	RC4	2.93	1.20	2.44	61.35	
	RC6	2.44	1.00	2.44	61.31	61.67
C	RC7	2.31	0.94	2.46	61.74	
	RC8	5.48	2.24	2.45	61.47	
	RC9	3.66	1.48	2.47	62.13	
	RC10	2.95	1.20	2.46	61.77	

Appendix C7 Green body density of specimens prepared from A to G type of slurries (Continues)

Sample	Sample ID	Mass (g)	Volume (cm3)	Density (g/cm3)	% Relative Density (% R.D.)	AVG. % R.D
D	RD1	3.53	1.51	2.34	58.74	58.76
	RD2	4.59	1.97	2.33	58.54	
	RD3	2.31	0.99	2.33	58.63	
	PD1	7.47	3.17	2.36	59.21	
	PD2	3.61	1.53	2.36	59.28	
	PD4	4.84	2.07	2.34	58.75	
	PD5	2.88	1.23	2.34	58.83	
	PD6	4.90	2.10	2.33	58.63	
	PD7	4.52	1.95	2.32	58.24	
E	RE1	4.12	1.75	2.35	59.15	58.37
	RE2	3.62	1.55	2.34	58.68	
	RE3	3.74	1.60	2.34	58.73	
	PE1	6.33	2.68	2.36	59.35	
	PE2	7.43	3.18	2.34	58.71	
	PE3	3.36	1.48	2.27	57.04	
	PE4	6.44	2.85	2.26	56.78	
	PE5	2.51	1.08	2.32	58.39	
	PE6	4.66	2.00	2.33	58.54	
G	RG1	2.05	0.88	2.33	58.53	59.50
	RG2	1.57	0.68	2.31	58.01	
	PG1	5.62	2.37	2.37	59.58	
	PG2	3.27	1.37	2.39	59.97	
	PG3	6.24	2.62	2.38	59.84	
	PG4	3.20	1.34	2.39	60.00	
	PG5	3.00	1.26	2.38	59.82	
	PG6	2.58	1.08	2.39	60.02	
	PG7	3.40	1.43	2.38	59.74	
H	RH2	2.78	1.21	2.30	57.73	58.36
	RH3	5.52	2.37	2.33	58.52	
	RH11	2.93	1.27	2.31	57.97	
	PH1	4.59	1.97	2.33	58.54	
	PH2	4.76	2.06	2.31	58.06	
	PH3	3.61	1.54	2.34	58.90	
	PH4	4.86	2.07	2.35	58.99	
	PH5	4.66	2.02	2.31	57.96	
	PH7	5.06	2.17	2.33	58.59	

Appendix C8 Green body strength of specimens prepared from A to G type of slurries

Code	Flexure stress at Maximum Flexure load (MPa)	Average Flexure stress (MPa)	Standard deviation (MPa)
RA1	1.74		
RA2	1.64	1.67	0.06
RA3	1.64		
RB1	1.76		
RB2	1.82	1.81	0.05
RB3	1.85		
RC1	2.05		
RC2	2.22	2.15	0.09
RC3	2.19		
RD1	1.85		
RD2	1.74	1.89	0.18
RD3	2.09		
RE1	2.03		
RE2	2.31	2.13	0.15
RE3	2.04		
RG1	2.09		
RG2	2.27	2.18	0.09
RG3	2.18		
RH1	1.19		
RH2	1.59	1.46	0.23
RH3	1.60		

Appendix C9 Summarize results of green biody density and strength

Solid content (%)	Average flexural strength (MPa)	Deviation (MPa)
70	1.67	0.06
75	1.81	0.05
80	2.15	0.09

Solid content (%)	Binder content (%)	Average flexural strength (MPa)
70	0.00	1.67
	0.05	1.89
	0.10	2.13
75	0.00	1.70
	0.05	2.18
	0.10	1.46

Appendix C10 Sintered density of specimen at various sintering temperature in air atmosphere for 2h

Temperature °C	B specimen		G specimen	
	Non-treated with acid	Treated with acid	Non-treated with acid	Treated with acid
1250	94.92	97.47	94.34	97.61
1300	97.72	98.72	98.17	98.88
1350	98.58	99.18	98.62	99.09

Appendix C11 Shrinkage of specimen at various sintering temperature in air atmosphere for 2h

Sintering Temperature °C		shrinkage(%)		
		Diameter	Thickness	vol
1250	BU	13.51	12.93	34.87
	GU	12.70	12.34	33.19
	BT	14.52	13.03	36.45
	GT	13.82	13.14	35.49
1300	BU	13.51	14.53	36.06
	GU	13.88	14.77	36.79
	BT	15.45	17.38	40.93
	GT	15.39	18.98	42.00
1350	BU	15.12	16.21	39.64
	GU	15.71	16.59	40.74
	BT	15.90	18.60	42.20
	GT	16.58	19.28	43.83

Appendix C12 Transmittance of specimen after HIPed at 1300 °C , 130 MPa in argon atmosphere

Wavelength (nm)	% Transmittance			
	BU	GU	BT	GT
200	1	1.2	0.4	0.5
250	3.4	3.8	1.85	1.6
300	6.35	6.6	4.15	3.05
350	9	8.75	6.45	4.35
400	11.6	10.75	9.05	6.05
450	14.35	12.85	12.1	8.05
500	16.95	14.85	15.35	10.2
550	19.4	16.7	18.7	12.45
600	21.7	18.4	22.15	14.8
650	23.75	20	25.45	17.15
700	25.8	21.15	28.8	19.55
750	27.6	22.95	31.9	21.9
800	29.3	24.3	34.95	24.25
850	30.85	25.55	37.85	26.5
900	32.35	26.8	40.55	28.7
950	33.65	27.55	43.15	30.9
1000	34.9	29	45.55	32.95
1050	36.05	30.05	47.8	35
1100	37.3	31.15	49.9	37

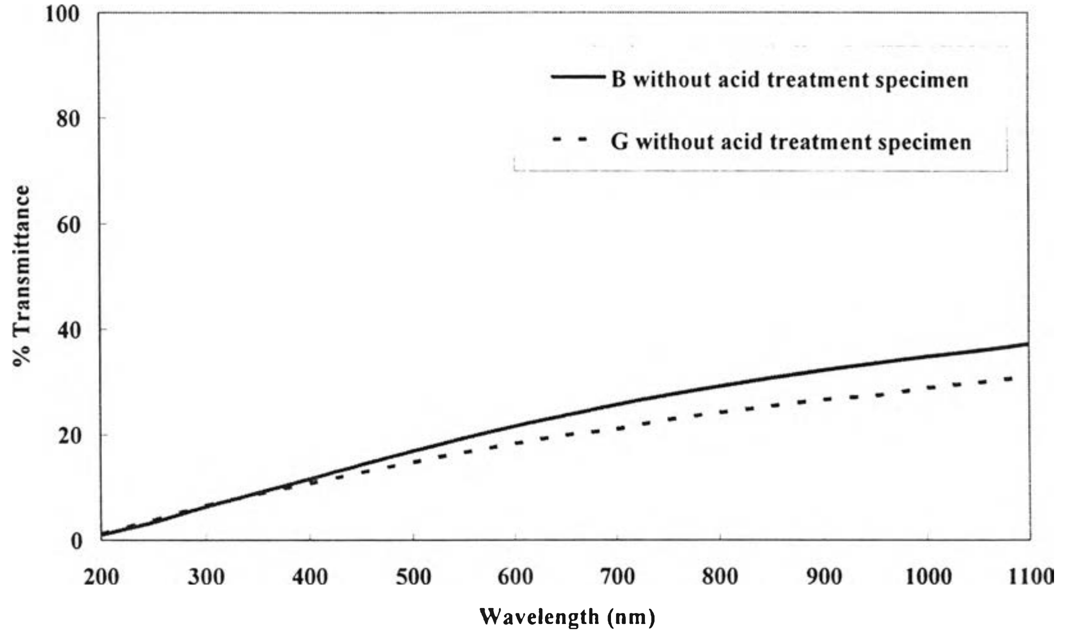


Figure C12.1 Transmittance of B and G specimen without acid treatment

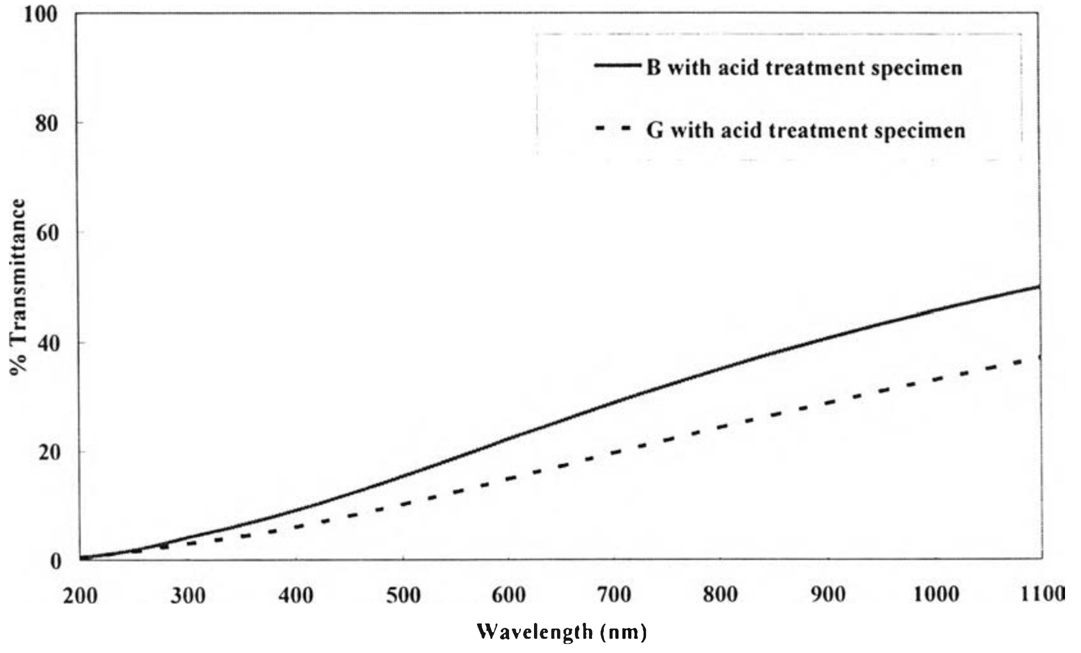


Figure C12.2 Transmittance of B and G specimen withacid treatment

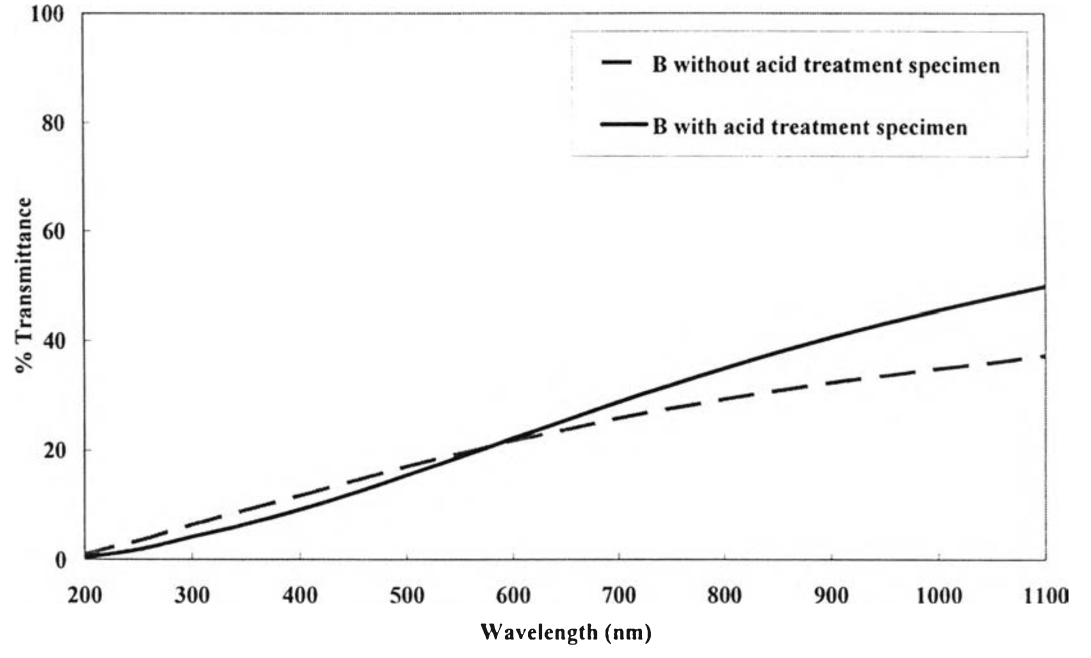


Figure C12.3 Transmittance of B specimens with and without acid treatment

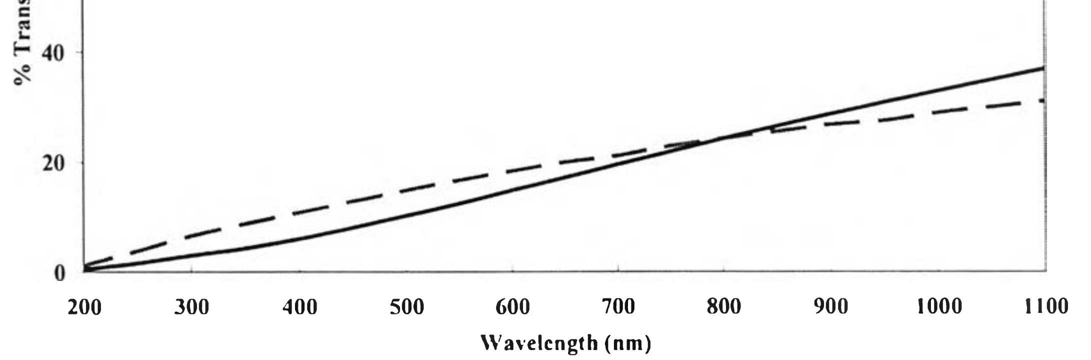


Figure C12.4 Transmittance of G specimens with and without acid treatment

VITA

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