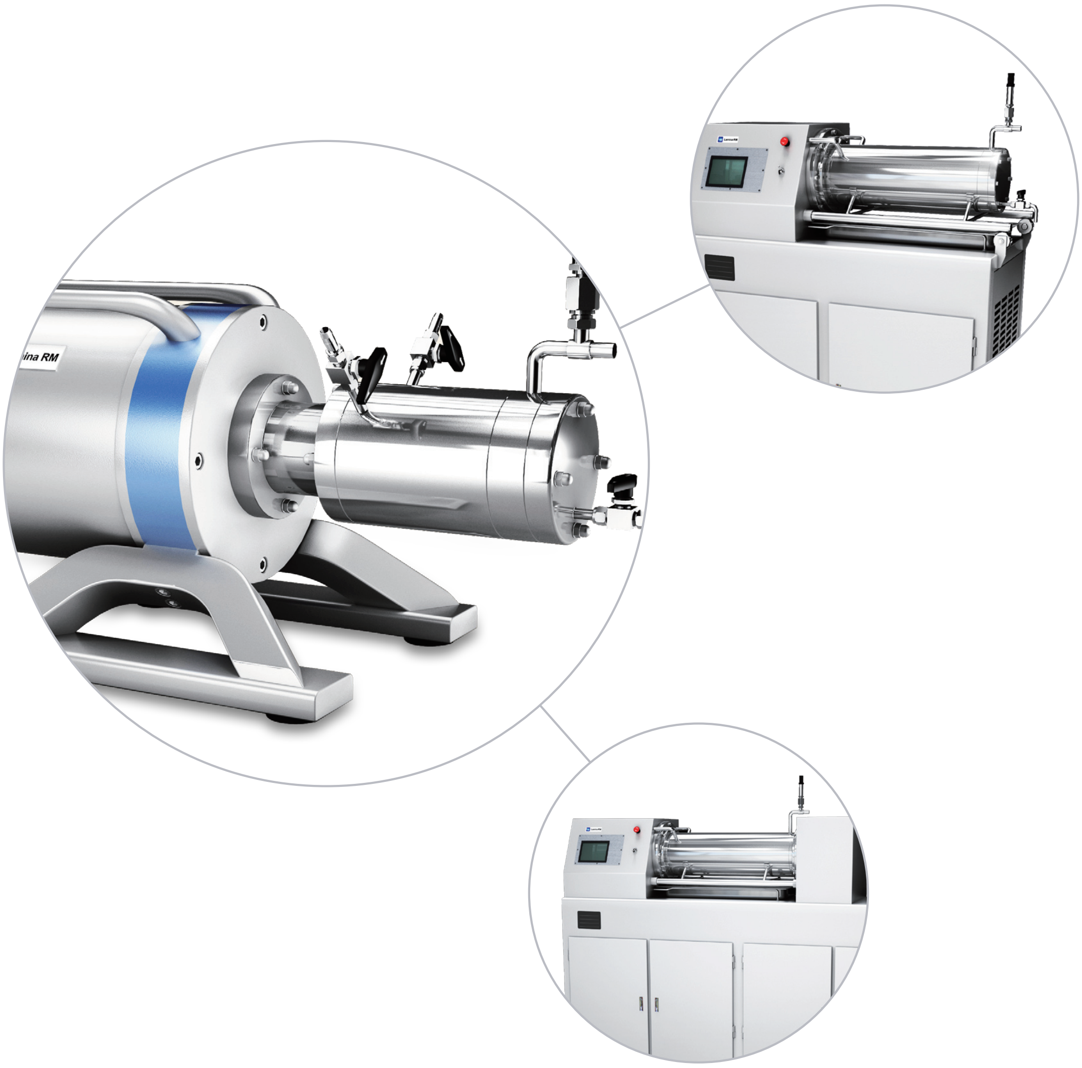
Laminar

Application Note
(LCTR® Reactor)

Laminar Co., Ltd.



CONTENTS

LCTR®-series

LCTR®-series means a reactor using **a Taylor fluid flow** developed by our company, which is **the first chemical reactor in the world** to produce high-purity substances uniformly.

- 7-times more powerful mixing capability
- Production of high-purity powder
- Property enhancement of powder
- Precise temperature control
- Dead-zone Zero
- Facilitation of scale-up
- 3-times higher productivity

Expected effect

Cost
- Minimizing labor cost (full automation)
- Reducing electrical cost
- Reducing material cost
- Reducing space and buying additional equipment

Marketability
- Pioneering a new market
- Increasing market size
- Applicable to all materials

Productivity
- Shorten the developing time on a Commercial scale
- High productivity
- Easy to control the process

Lithium ion battery (Lithium Carbonate)

Material Properties

Lithium Carbonate (Li_2CO_3)	
Molecular weight (g/mol)	73.891
Melting point (℃)	723
Boiling point (℃)	1310
Shape	Odorless white powder

Objective

To develop the production method of Lithium Carbonate from sea water or brine

Experiment method

$2LiCl + Na_2CO_3 \Rightarrow Li_2CO_3 + 2NaCl$ (Liquid-Liquid reaction)

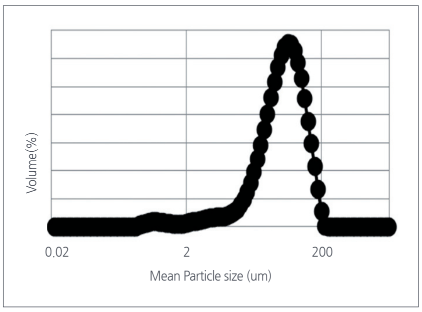
$2LiOH + CO_2\,(g) \Rightarrow Li_2CO_3 + H_2O$ (Gas-Liquid reaction)

Comparison Table

Division	Current	Our reactor
Process	Batch reactor	Taylor reactor
Production Process	incontinuous	continuous
Purity (%)	99.5	99.5
Particle size (㎛)	over 100	over 100
Reaction time (min)	60	30

Result

Analysis result of Li_2CO_3 particle size



Analysis result of Li_2CO_3 by SEM

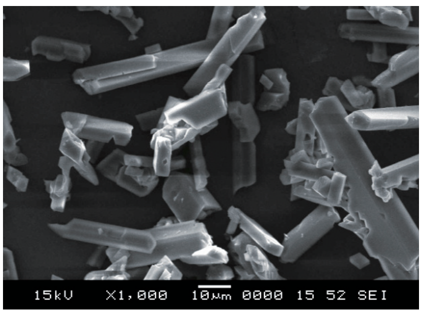
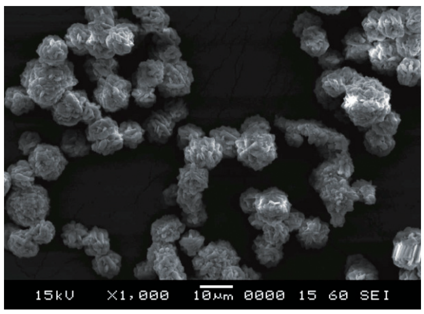


Plate type



Sphere type

Lithium ion battery [$(Ni_xCo_yMn_z)(OH)_2$]

Material Properties (Confidential)

Objective

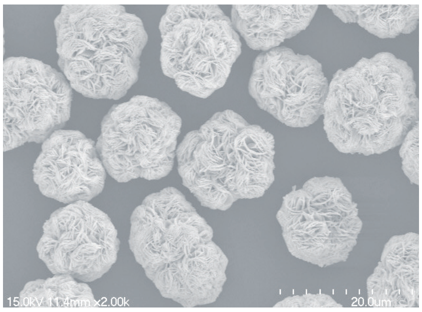
To make particle distribution uniformed and produce high-density precursor

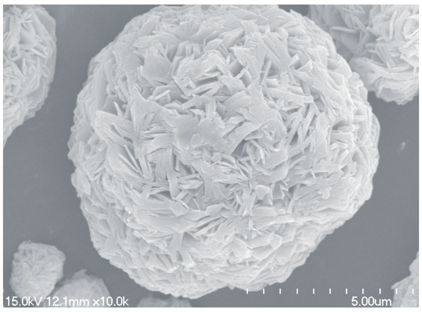
Comparison Table

Division	Current	Objective
Particle size (㎛)	10	10
Reaction Time (h)	8~16	2~4
Production Process	Batch	continuous
Span ($[D_{90}-D_{10}]/D_{50}$)	0.5	0.2
Tap density (g/mL)	2.1	2.2
pH	11	11

Result

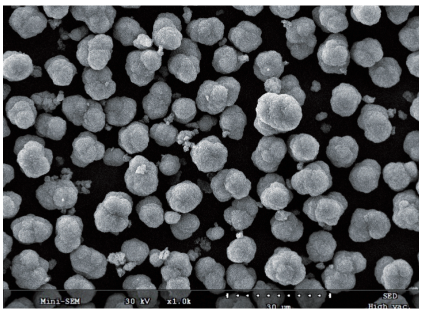
Ni : Co : Mn (1 : 1 : 1)

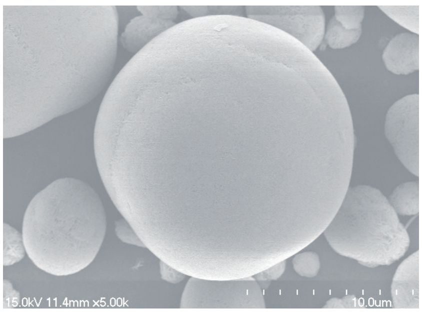


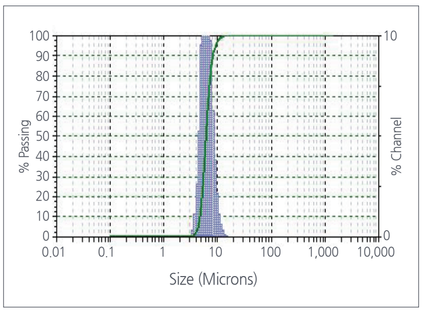


Analysis result by SEM

Ni : Co : Mn (5 : 3 : 2)







Analysis result by SEM

Analysis result by PSA

Fuel Cell (LNF)

Material Properties (Confidential)

Objective

To grow the particle size

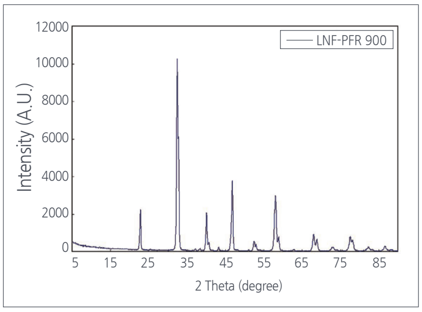
Result

The particle, which precipitates with LNF by our Taylor reactor, gets twice bigger
It is much easier to control pH and flux.
There is crystal growth caused by uniformed mixing.

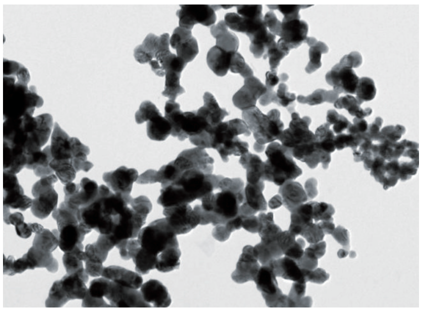
Comparison Table

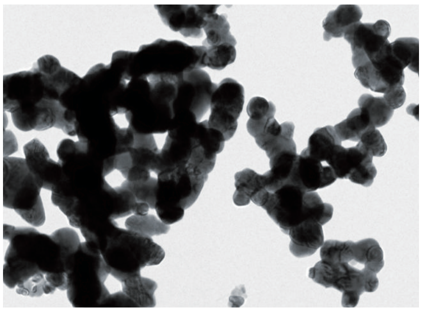
Division	Current	Our reactor
Particle size (nm)	50	200
Production Process	continuous	continuous

Result



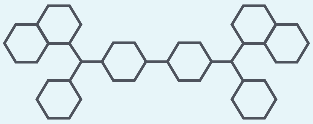
Analysis result by our reactor


Existing


Our reactor

OLED material (NPB)

Material Properties

	N,N'-Bis(naphthalen-1-yl)- N,N'-bis(phenyl)benzidine
Application	OLED-Hole Transport
Abs.Max	339 nm (in CH_2Cl_2) 352 nm (in THF)
Formula	$C_{44}H_{32}N_2$
Molecule weight	588.76
Shape	white powder

Objective

To develop re-crystallization process of high-purity OLED by wet-process

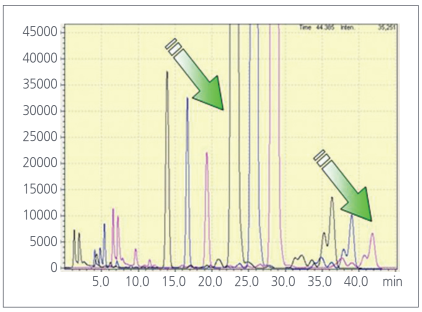
Experiment method

High-purification process by the difference in solubility (Cooling and Drowning-out Crystallization)

Comparison Table

Division	Current	Objective
process	dry-process	wet-process
Purity (%)	99.99	99.99
Process type	Batch	continuous
Temperature (℃)	270~280	0 ~ 80
Pressure (Torr)	$10^2 \sim 10^6$	normal pressure
Recrystallizatoin time (h)	12~24	0.5~1
Cost ($/kg)	10,000	3,000

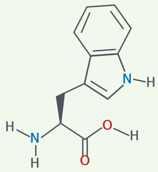
Result



The result of impurities' decrement by our reactor

Tryptophan

Material Properties



Molecular formula : $C_{11}H_{12}N_2O_2$	
Molecular weight : 204.23 g/mol	

Objective

To develop commercial technology through the improvement in purity and increase in recovery.

Experiment method

Cooling and Drowning-out Crystallization and adding polymer

Result

· Current problems

Energy expense is high since the current process uses vacuum evaporation production expense is also high due to long process time.

Low-grade Tryptophan is produced due to the inferior property.

· Solution

Hybrid crystallization should be used for commercialization since it is hard to solve problems by just one process

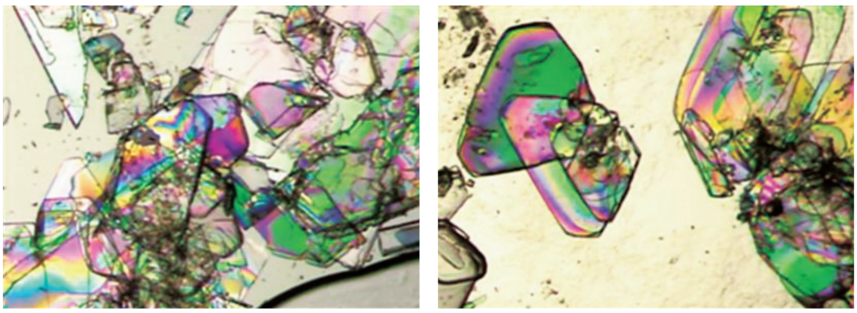
· Result

Increment in 3% purity (98%) and 15% recovery rate (85%) and decrement in 1/6 process time

Comparison Table

Division	Current	Our reactor
Recovery rate (%)	60	75
Purity (%)	95	98
Particle size (㎛)	30	more than 50

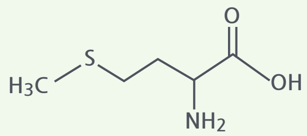
Result



Analysis result of Tryptophan by SEM

Methionine

Material Properties



Molecular formula : $C_5H_{11}NO_2S$

Molecular weight : 149.21 g/mol

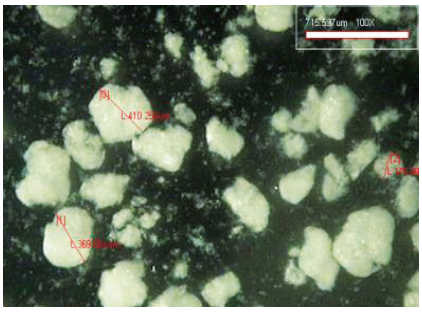
Objective

To develop commercial technology through the improvement in purity and increase in recovery.

Comparison Table

Division	Current	Our reactor
Recovery rate (%)	60	80
Purity (%)	95	98
Particle size (㎛)	50	200

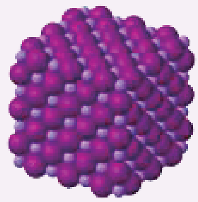
Result



Analysis result of Methionine by SEM

NaI

Material Properties



Sodium iodide (NaI)	
Molecular weight (g/mol)	149.894
Melting point (℃)	661
Boiling point (℃)	1,304
Shape	white solid

Objective

To remove Chlorine

Comparison Table

Division	Current	Our reactor
$[Cl^-]$ (ppm)	2,000	500
Recovery rate (%)	95	99

Catalyst

Material Properties (Confidential)

Objective

To produce continuous catalyst

Experiment method

pH	7
Agitation speed (rpm)	600
Reaction time (min)	10~30
Develop process	Our reactor (Continuous)

Continuously producing catalyst setting at pH 7

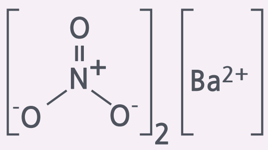
Result

Able to control pH by PID controller and continuously produce catalyst

Able to Control the desired particle shape (only in the case that pH should be consistent)

Barium Nitrate

Material Properties



Barium Nitrate, $Ba(NO_3)_2$	
Molecular weight (g/mol)	261.37
Melting point (℃)	590
Boiling point (℃)	10.5 g/100 mL (25 ℃)
Shape	white crystals

Objective

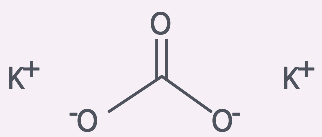
To remove heavy metal

Comparison Table

Type of reactor	PFR reactor	Our reactor
Recovery rate (%)	80	85
Purity (%)	4	1
[Heavy metal] (ppm)	10	2

$K_2CO_3 \cdot 1.5H_2O$

Material Properties



Potassium carbonate, K_2CO_3	
Molecular weight (g/mol)	138.205
Melting point (℃)	891
Boiling point (℃)	112 g/100 mL (20 ℃)
Shape	white, hygroscopic solid

Objective

To produce $K_2CO_3 \cdot 1.5H_2O$

Comparison Table

Division	Current	Our reactor
Recovery rate (%)	-	95
Purity (%)	-	99.9
Hydrate type	5 H_2O, anhydrous	1.5 H_2O, 5 H_2O, anhydrous

Electronic material

Food

Fine chemical

Petrochemistry

Environmental

Flame Retardant

Material Properties (Confidential)

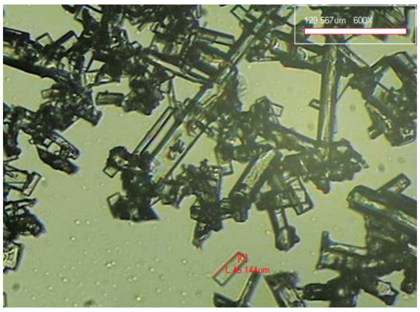
Objective

To remove Chlorine

Comparison Table

Division	Current	Our reactor
Recovery rate (%)	80	over 90
Purity (%)	100	100
[Cl^-] (ppm)	1,000	60

Result



Analysis result of Flame Retardant by SEM

Toner

Material Properties (Confidential)

Objective

To remove heavy metal

Comparison Table

Division	Current	Our reactor
Process	Evaporation	Drowning-out Crystallization
Recovery rate (%)	60	99.5
Purity (%)	98	98.5
[Heavy metal] (ppm)	50	23

SiO_2

Material Properties

Silicon dioxide (SiO_2)	
Molecular weight (g/mol)	60.08
Melting point (℃)	1600-1725
Boiling point (℃)	2,230
Density (g/cm³)	2.648

Objective

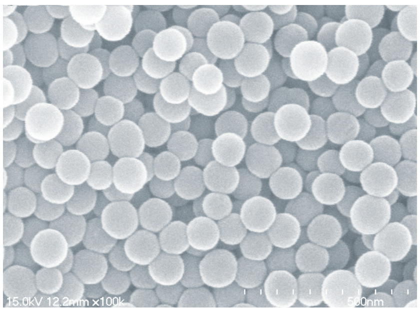
To produce 100 nm uniformed silica particle

Experiment method

Temperature (℃)	40
Agitation Speed (rpm)	600
Reaction Time (min)	30
Development process	Continuous
Reaction process	Sol-Gel process

Result

It was impossible to produce uniformed particle due to the delay time on nucleation.
Nucleation and crystal growth occurs in each reactor

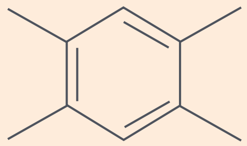


Analysis result of SiO_2 by SEM

Electronic material
Food
Fine chemical
Petrochemistry
Environmental

Durene

Material Properties

	Durene (1,2,4,5-tetramethylbenzene)	
	Molecular weight (g/mol)	134.22
	Melting point (℃)	79.2
	Boiling point (℃)	196

Objective

To separate isomers

Experiment method

Isomers separated by melt crystallization

Comparison Table

Division	Current	Our reactor
Process	Distillation	Melt crystallization
Recovery rate (%)	75	89
Density (%)	97	99
Operative temperature (℃)	Over 200	-30~ordinary temperature

p-DIB

Material Properties (Confidential)

Objective

To use p-DIB by separating isomers and impurities.

Experiment method

Isomers separated by melt crystallization

According to literate researches, the melting point of p-DIB is 129℃ and also the melting points of the other two isomers and impurity are 20℃, 45℃ and 119℃ respectively.

Result

Petro chemical substances are normally separated into isomers by distillation. However, it is hard to separate substances with similar boiling points. Our reactors separate them by melting points.

Our reactors are able to separate more than 98% of p-DIB after filtering out impurities by sweating process many times.

The recovery rate is over 80%

LG Chemical introduced our reactors in production.

Result

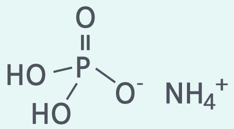
Purity : 98 % ↑

Isomer separation

p-DIB (purity over 98%)

Ammonium dihydrogen phosphate

Material Properties



Ammonium dihydrogen phosphate ($NH_4H_2PO_4$)	
Molecular weight (g/mol)	115.03
Melting point (℃)	190
Shape	white tetragonal crystals

Objective

To produce $NH_4H_2PO_4$ from waste acid

$NH_4OH + H_3PO_4 \rightarrow NH_4H_2PO_4 + H_2O$

Comparison Table

Division	Current	Our reactor
Process	Vacuum evaporation	Reaction crystallization
Particle size (㎛)	200	300
Recovery rate (%)	70	80
Reaction time (h)	2	0.5

$NiSO_4$, $CoSO_4$

Material Properties

Objective

To design the process to extract Ni and Co crystal dissolved in waste fluid.

Experiment method

Extracting the high-purity $NiSO_4$ and $CoSO_4$ by drowning-out crystallization.

Result

Production possibility of $NiSO_4$ and $CoSO_4$ with the right hydrate

Rare earth in waste fluid is reusable for production since it is analyzed that the purity and recovery rate are over 99.5% and 90% respectively.

Result

$CoSO_4$

$NiSO_4$

Mn_3O_4

Material Properties

Manganese(II,III) oxide (Mn_3O_4)	
Molecular weight (g/mol)	228.812
Melting point (℃)	1,567
Boiling point (℃)	2,847
Density (g/cm³)	4.86

Objective

To collect high-purity Mn_3O_4 in waste fluid

To execute two processes by our only one reactor

Experiment method

Temperature (℃)	70
Agitation speed (rpm)	1,000
Reaction time (h)	30
Develop process	Continuous reactor (LCTR Series)

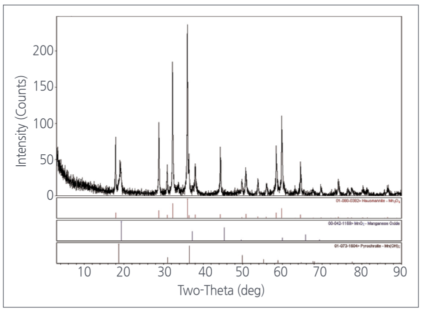
$MnSO_4 + NaOH \rightarrow Mn(OH)_2$ (Liquid-liquid reaction) ┐
$Mn(OH)_2 + O_2 \rightarrow Mn_3O_4$ (Gas-liquid reaction) ┘ ▶ Process of batch reactors

$Mn(OH)_2 + NaOH + O_2 \rightarrow Mn_3O_4$ (Liquid-liquid and Gas-liquid reaction) ▶ Process of our reactor

Result

Shortening the process time due to using only one reactor in two processes.

Over 99.5% in purity



Analysis result of Mn_3O_4 produced by our reactor

Fe_3O_4

Material Properties

Iron(II,III) oxide (Fe_3O_4)	
Molecular weight (g/mol)	231.533
Melting point (℃)	1,597
Density (g/cm^3)	5.17

Objective

To collect Fe_3O_4 in waste fluid

To execute two processes by our only one reactor

Experiment method

Temperature (℃)	80
Agitation speed (rpm)	600
Reaction time (h)	30
Develop process	Continuous reactor (LCTR® Series)

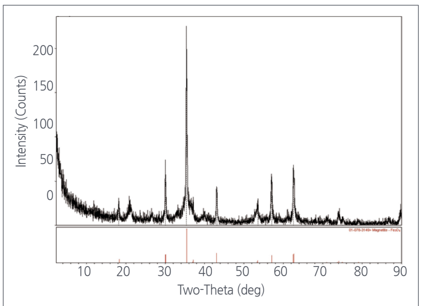
$FeCl_2 + CaO \rightarrow Fe(OH)_2 + O_2 \rightarrow Fe_3O_4$ (Liquid-liquid-Gas reaction)

$FeCl_2 + CaO + O_2 \rightarrow Fe_3O_4$

Result

Shortening the process time due to using only one reactor in Solid-Liquid-Gas reaction process.

Reducing the installation and operation cost



Analysis result of Fe_3O_4 produced by our reactor

HISTORY

2014. 07	Expansion (Headquarter & Lab : #512 / Factory : #209)
2014. 06	Attraction of investment from Samho Green Investment
2014. 06	Selected the Energy technology development Project and obtained U$860,000 by one of the government organizations, MOTIE
2014. 05	Certified Green Technology
2014. 05	Certified CE marking
2014. 04	Selected POSCO Venture Partners 7th membership
2013. 09	Moved to #209, 27, Dunchon-daero 457beon-gil, Jungwon-gu, Seongnam-si, Gyeonggi-do, Korea
2013. 08	Selected the Energy technology development Project and obtained U$800,000 by one of the government organizations, MOTIE
2013. 02	Certified Employee Invention
2013. 01	Made an agency contract with Unitechnology in Japan and started exporting
2011. 12	Semi Grand Prize (Seoul International Invention Fair, KIPA)
2011. 07	Certified ISO 9001/14001
2011. 04	Established R & D Center
2011. 01	Factory Registration Certification
2010. 11	Venture Enterprise Accreditation (KIBO)
2010. 10	Moved to #902, 27, Dunchon-daero 457beon-gil, Jungwon-gu, Seongnam-si, Gyeonggi-do, Korea
2010. 08	Established

Laminar Co., Ltd.

Laminar

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