Nippon Denko Compendium 2017

August 2017

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Company Overview
Company Overview (As of June 30, 2017)

 Established
October 1925

 Head Office
1-4-16, Yaesu, Chuo-ku, Tokyo

 Employees
955 in Nippon Denko and its consolidated subsidiaries (483 in Nippon Denko)

 Business Operations
Manufacture and sale of ferroalloys, manufacture and sale of functional materials, manufacture and sale of environmental recycling systems, and other (electric power generation and supply, fertilizers, etc.)

 Group Affiliates
Ten domestic, three overseas affiliates

 Scale
(Fiscal year ended December 31, 2016; consolidated) (mil)

<table>
<thead>
<tr>
<th>Category</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net sales</td>
<td>58,486</td>
</tr>
<tr>
<td>Total assets</td>
<td>84,563</td>
</tr>
<tr>
<td>Owner's equity</td>
<td>61,233</td>
</tr>
<tr>
<td>Capital</td>
<td>11,026</td>
</tr>
<tr>
<td>Interest-bearing Liabilities</td>
<td>7,891</td>
</tr>
</tbody>
</table>

 Stock
(As of June 30, 2017)

<table>
<thead>
<tr>
<th>Category</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outstanding shares</td>
<td>146,741,292 shares</td>
</tr>
</tbody>
</table>
## Business Sectors and Products

<table>
<thead>
<tr>
<th>Sector</th>
<th>Typical Products</th>
<th>Markets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ferroalloys</strong></td>
<td>Ferroalloys</td>
<td>Steel, stainless steel, and specialty steel</td>
</tr>
<tr>
<td><strong>Functional Materials</strong></td>
<td>Lithium-manganese oxide, Hydrogen storage alloys, Ferroboron, Zirconium oxide, Boron oxide, boric acid, Manganese inorganic chemical products</td>
<td>Lithium-ion batteries, Nickel-metal hydride cells, Neodymium magnets, amorphous metals, Electronic parts, optical lenses glass, surface treatment, Supplements, additives for laminated ceramic capacitors, etc.</td>
</tr>
<tr>
<td><strong>Environment</strong></td>
<td>Chromic recovery, boron recovery, nickel recovery, water and wastewater treatment facilities, Melting and solidification of incineration ash in electric furnaces</td>
<td>Surface treatment, electronic parts, automobile parts, industrial waste disposal plants, Local governments and companies discharging industrial waste</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>Electric power, calcium silicate fertilizer</td>
<td>Power companies, agricultural cooperatives</td>
</tr>
</tbody>
</table>

Company Overview
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## History

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1925</td>
<td>Ogaki Denki Yakin Kogyosho Co., Ltd. (later Nippon Denki Yakin Co., Ltd.) established, begins production and sale of various ferroalloys</td>
</tr>
<tr>
<td>1937</td>
<td>Begins production and sale of chromium chemicals in Kuriyama, Hokkaido</td>
</tr>
<tr>
<td>1963</td>
<td>Nippon Denko Co., Ltd. formed with merger of Nippon Denki Yakin Co., Ltd. and Toho Denka Co., Ltd.</td>
</tr>
<tr>
<td>1969</td>
<td>Tokushima Plant built, begins operation (equipped with pier facilities and large electric furnace)</td>
</tr>
<tr>
<td>1971</td>
<td>Merges Kyokuto Kogyo K.K.</td>
</tr>
<tr>
<td>1973</td>
<td>Starts up chromic acid recovery operations</td>
</tr>
<tr>
<td>1984</td>
<td>Begins production and sale of ferroboron using an electric furnace</td>
</tr>
<tr>
<td>1989</td>
<td>Begins production and sale of zirconium oxide</td>
</tr>
<tr>
<td>1992</td>
<td>Completes new chromic acid recovery plant in Koriyama</td>
</tr>
<tr>
<td>1993</td>
<td>Establishes NST Ferrochrome (Pty) Limited jointly with South African firm Samancor</td>
</tr>
<tr>
<td>1996</td>
<td>Begins sale of AQUA PACK cartridge-type demineralizer</td>
</tr>
<tr>
<td>1999</td>
<td>Begins sale of MR-PACK pure water production unit</td>
</tr>
<tr>
<td>2000</td>
<td>Completes expansion of ferroboron production facility</td>
</tr>
<tr>
<td>2001</td>
<td>Completes construction of boron recovery facility</td>
</tr>
<tr>
<td>2009</td>
<td>Completes new zirconium oxide plant</td>
</tr>
<tr>
<td>2002</td>
<td>Form strategic alliance with Nippon Rensui</td>
</tr>
<tr>
<td>2003</td>
<td>Establishes ND Recycle in South Korea for ion exchange resin recycling</td>
</tr>
<tr>
<td>2004</td>
<td>Acquires lithium manganese battery materials business</td>
</tr>
<tr>
<td>2005</td>
<td>Completes the ND Recycle plant in South Korea</td>
</tr>
<tr>
<td>2008</td>
<td>Installs an in-house power generator making use of gas from the electric furnace at the Tokushima Plant</td>
</tr>
<tr>
<td>2009</td>
<td>Boosts SLP ferromanganese production capacity to 30,000 t/year</td>
</tr>
<tr>
<td>2010</td>
<td>Increases ferroboron production capacity</td>
</tr>
<tr>
<td>2011</td>
<td>Establishes high-carbon ferromanganese production system of 220,000 t/year</td>
</tr>
<tr>
<td>2012</td>
<td>Completes first stage of large-scale plant for automotive battery materials</td>
</tr>
<tr>
<td>2013</td>
<td>Further boosts SLP ferromanganese production capacity to 40,000 t/year</td>
</tr>
<tr>
<td>2014</td>
<td>Completes second stage of large-scale plant for automotive battery materials</td>
</tr>
<tr>
<td>2015</td>
<td>Transfers chromium chemicals business to Nippon Chemical Industrial Co., Ltd.</td>
</tr>
<tr>
<td>2017</td>
<td>Acquires manganese mining interests in South Africa</td>
</tr>
<tr>
<td>2018</td>
<td>Changes Japanese name upon merger with Chuo Denki Kogyo Co., Ltd. (English name unchanged)</td>
</tr>
</tbody>
</table>
## History of Chuo Denki Kogyo

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1934</td>
<td>Chuo Denki Kogyo Co., Ltd. was established as a partnership of Chuo Denki (electric power and equipment provider) and Chichibu Denki Kogyo (provider of ferroalloy manufacturing technology), and began electric furnace production of ferroalloys at the Taguchi Plant (current Myoko Plant in Niigata Prefecture).</td>
<td></td>
</tr>
<tr>
<td>1941</td>
<td>Began producing electrolytic manganese metals.</td>
<td></td>
</tr>
<tr>
<td>1969</td>
<td>Completed construction of Kashima Plant (Ibaraki Prefecture).</td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td>Completed first electric furnace (40,000 KVA) at Kashima Plant.</td>
<td></td>
</tr>
<tr>
<td>1974</td>
<td>Completed second electric furnace (50,000 KVA) at Kashima Plant.</td>
<td></td>
</tr>
<tr>
<td>1976</td>
<td>Began producing manganese sulfates at Taguchi Plant (current Myoko Plant).</td>
<td></td>
</tr>
<tr>
<td>1979</td>
<td>Began producing manganese carbonates at Taguchi Plant (current Myoko Plant), and started research on hydrogen storage alloys.</td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>Test-produced hydrogen fuel cell vehicle at Taguchi Plant (current Myoko Plant) and began testing waste heat recovery system.</td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>Began producing complex manganese dioxide at Taguchi Plant (current Myoko Plant).</td>
<td></td>
</tr>
<tr>
<td>1992</td>
<td>Began producing hydrogen storage alloys at Taguchi Plant (current Myoko Plant).</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>Acquired ISO 9001 certification at Myoko Plant.</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>Began ordinary waste treatment at Kashima Plant.</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>Completed construction of waste melting furnace (EM1) at Kashima Plant and began treatment of industrial waste and special industrial waste.</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>Completed construction of waste melting furnace (EM2) at Kashima Plant. Acquired ISO 14001 certification at Kashima Plant.</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>Kashima Plant recognized as “Ibaraki Prefecture Superior Recycling Facility.”</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>Began producing manganese sulfates for lithium-ion batteries at Myoko Plant.</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>Acquired ISO 9001 and OSHMS (Occupational Safety and Health Management System) certification at Kashima Plant.</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>Acquired Sumikin Molycorp, Inc. (magnet alloys business) from Sumitomo Metal Industries, Ltd. (current Nippon Steel &amp; Sumitomo Metal Corp.) and took over its lithium-ion battery anode materials business; Began producing graphite for lithium-ion batteries at Myoko Plant.</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>Merged with Nippon Denko Co., Ltd.</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>Transferred magnet alloys business to Santoku Corporation and Sojitz Corporation.</td>
<td></td>
</tr>
</tbody>
</table>
Ferroalloys
Ferroalloys, materials essential to steel

Ferroalloys are of vital importance in making steel, as they are a necessary “seasoning” found in every piece of steel.

## Steelmaking process

<table>
<thead>
<tr>
<th>Steelmaker</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>Coke</td>
</tr>
<tr>
<td>Iron ore</td>
<td>Sinter</td>
</tr>
</tbody>
</table>

Blast furnace  →  Converter furnace  →  Completion as steel

They make steel stronger and tougher, as well as more resistant to heat and corrosion.

## Typical ferroalloy products and applications

<table>
<thead>
<tr>
<th>Ferroalloy</th>
<th>Products and applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferromanganese</td>
<td>Make steel stronger</td>
</tr>
<tr>
<td>Siliconmanganese</td>
<td>Nippon Denko main product: Ferromanganese</td>
</tr>
<tr>
<td>Ferrovanadium</td>
<td>Oil well casings, line pipes, springs</td>
</tr>
<tr>
<td>Ferrochrome</td>
<td>Stainless steel products</td>
</tr>
<tr>
<td>Ferrosilicon</td>
<td>Deoxidizing</td>
</tr>
</tbody>
</table>

Ferroalloys market scale (outlook for 2017)

In Japan, approx. 312 billion yen

(Source: Nippon Denko estimate)

The trading price depends mainly on global market conditions.

Trading takes place at a price calculated by converting the global price in US dollars to yen at foreign exchange rates. (Similar to the export industry, the profit structure is such that a weaker yen increases profits.)
Our main product, high-carbon ferromanganese

Main raw materials

Manganese ore
Manganese ore imported from various countries is refined using optimal blending techniques. Saves electricity and other energy.

Coke
Made by steaming and baking coal. Acting as a reducing agent, removes oxygen in the ore.

Electric furnace
Melts at very high temperatures.

Every measure is taken to protect the environment.
Exhaust gas is used as fuel for in-house power generation.

High-carbon ferromanganese
High-carbon ferromanganese is a ferromanganese product having a relatively high amount of carbon.

Nippon Denko has the No. 1 share in Japan

Note: Slag is a by-product occurring in the process of manufacturing metal. (see p. 31)
Global crude steel production in each country and ferroalloy production by product

**Global crude steel production**

![Chart showing global crude steel production from 2012 to 2016.](chart)

- **China**: 1,560, 1,650, 1,647, 1,592, 1,604 (mil.tons)
- **Jpn**: 258, 261, 258, 253, 265
- **EU**: 46, 119, 121, 111, 111
- **CIS**: 122, 109, 106, 101, 102
- **N.America**: 112, 166, 169, 166, 162
- **S.America**: 169, 111, 111, 105, 105
- **Africa**: 731, 822, 823, 799, 808
- **Others**: 258, 261, 258, 253, 265

(Source: WSA data)

**Global ferroalloy production**

![Chart showing global ferroalloy production from 2010 to 2014.](chart)

- **HcFeMn**: 37,333, 37,331, 41,951, 42,175, 45,991 (1,000 tons)
- **M•Lc-FeMn**: 5,003, 2,702, 6,614, 8,248, 8,827
- **SiMn**: 8,043, 10,901, 11,206, 12,097, 12,848
- **FeCr**: 9,539, 9,971, 9,767, 10,789, 11,590
- **FeSi**: 9,119, 10,901, 11,206, 12,097, 12,848
- **Others**: 4,441, 4,426, 4,371, 4,495, 3,985

(Source: IMnI data [FeMn and SiMn]; ICDA data [FeCr]; USGS data [others])
Ferroalloy production in Japan: Ferromanganese is produced domestically

Trends in ferroalloy production and imports, and crude steel production (Japan)

Ferroalloy production and imports (1,000 tons)

Crude steel production (mil. tons)

Note: Figures for ferroalloy production do not include those used as raw materials.
(Source: Steel statistics, Nippon Denko estimates)

Percentage of ferroalloys produced domestically

(Source: Steel statistics)
Ferroalloy raw material: Global production and trade in manganese ore

Global production of manganese ore

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>32.4%</td>
</tr>
<tr>
<td>South Africa</td>
<td>23.8%</td>
</tr>
<tr>
<td>Gabon</td>
<td>7.1%</td>
</tr>
<tr>
<td>Australia</td>
<td>10.8%</td>
</tr>
<tr>
<td>Ghana</td>
<td>4.3%</td>
</tr>
<tr>
<td>India</td>
<td>4.4%</td>
</tr>
<tr>
<td>Brazil</td>
<td>5.1%</td>
</tr>
<tr>
<td>Other</td>
<td>9.5%</td>
</tr>
</tbody>
</table>

Ore from China is mostly low-grade ore
Processing low-grade ore results in a large amount of slag, for a low metal recovery rate.

Mostly high- or medium-grade ore
Less slag is produced than with low-grade ore, so the metal recovery rate is higher.

(Source: IMin data)

Japan’s manganese ore imports

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gabon</td>
<td>15.0%</td>
</tr>
<tr>
<td>South Africa</td>
<td>67.4%</td>
</tr>
<tr>
<td>Australia</td>
<td>17.6%</td>
</tr>
<tr>
<td>Other</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

(Source: Ministry of Finance customs data)

China’s manganese ore imports

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghana</td>
<td>3.2%</td>
</tr>
<tr>
<td>Malaysia</td>
<td>4.9%</td>
</tr>
<tr>
<td>Brazil</td>
<td>7.6%</td>
</tr>
<tr>
<td>Gabon</td>
<td>7.4%</td>
</tr>
<tr>
<td>Others</td>
<td>11.5%</td>
</tr>
<tr>
<td>South Africa</td>
<td>41.6%</td>
</tr>
<tr>
<td>Australia</td>
<td>23.8%</td>
</tr>
</tbody>
</table>

(Source: China Customs data)

Chinese manganese ore import volume

(Source: China Customs data)

Ferroalloys
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Ferroalloy market prices and manganese ore prices

<table>
<thead>
<tr>
<th>Product price (quarterly average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>($/t)</td>
</tr>
<tr>
<td>'11</td>
</tr>
<tr>
<td>0.0</td>
</tr>
</tbody>
</table>

Product prices and ore prices

| ($/t) | ($/Mn%) |
| '11  | '12  | '13  | '14  | '15  | '16  | '17  |
| 0  | 10  | 20  | 30  | 40  | 50  | 60  |

High-carbon ferromanganese
European market (left)

High-carbon ferromanganese
US market (left)

Ferrovanadium (right)

Manganese ore for China

Source: Metals Week [US market]; Metal Bulletin [European market and FV]; TEX Report [others]
Ferroalloys business of Nippon Denko

- Ferrovanadium
  - Feb, 2017: Withdraw from SAJ Vanadium

- Ferrochrome
  - Dec, 2012: Withdraw from NST Ferrochrome (Pty) Limited

- High-carbon ferromanganese
  - Our company’s main product. It is produced domestically, taking advantage of the competitiveness of the Tokushima Plant.
  - From the second half of 2014, Chuo Denki Kogyo high-carbon ferromanganese were added.

- SLP Ferromanganese (our product name)
  - The product has a very high manganese content with few impurities. It is used as an additive in the final stage of steelmaking, in place of manganese metal. (see p. 15)

- Silicomanganese
  - Manganese metal: A metal with a manganese purity of nearly 100%. It is used as an additive in making steel, stainless steel, and aluminum.

### Trends in percentage of each alloy in Nippon Denko ferroalloys sales

<table>
<thead>
<tr>
<th>Year</th>
<th>Ferrovanadium</th>
<th>Ferrochrome</th>
<th>High-carbon ferromanganese</th>
<th>SLP Ferromanganese</th>
<th>Silicomanganese</th>
</tr>
</thead>
<tbody>
<tr>
<td>'12</td>
<td>7</td>
<td>3</td>
<td>47</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>'13</td>
<td>10</td>
<td>1</td>
<td>52</td>
<td>22</td>
<td>7</td>
</tr>
<tr>
<td>'14</td>
<td>1</td>
<td>1</td>
<td>56</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>'15</td>
<td>1</td>
<td>2</td>
<td>62</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>'16</td>
<td>3</td>
<td></td>
<td>66</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

- Ferrovanadium: Yellow
- Ferrochrome: Pink
- High-carbon ferromanganese: Blue
- SLP Ferromanganese: Green
- Silicomanganese: Red

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**What is SLP ferromanganese?**
(SLP: Super-low phosphorus)

- Very low-carbon ferromanganese with manganese purity of 90% and low phosphorus content.
- As a raw material essential to high-grade steel production, it is used in place of manganese metal.

---

**Manganese metal**

- Annual demand for manganese metal in Japan is about 50,000 tons, all of which is imported, some 90% of it from China.
- Because of the very high dependence on China, producing it in areas other than China or possibly switching to an alternative are options being considered.

---

**Strategy**

- An electric furnace was added in 2008. Production capacity was raised from 18,000 tons to 30,000 tons annually.
- In 2010, further expansions raised annual production capacity from 30,000 tons to 40,000 tons.
- We are helping to ensure stable procurement by users and increase our earning power.

---

**Superiority**

- High-purity ferromanganese is being manufactured by means of original technology using as raw material a by-product of high-carbon ferromanganese.
- Demand will rise further with increased production of high-grade steel.

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**Chinese production and exports of manganese metal**

(Source: China Ferroalloys Industry Association [Production]; China Customs data [Exports])

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Resource strategy and optimal location are the way to win out over rivals

- **Domestic production in our top field: High-carbon ferromanganese**

  The Tokushima Plant, one of the world’s most competitive

  Enable *just-in-time supply* by producing in domestic plants located near the sea

  Obtaining stable supply of the ores needed for ferroalloy production
  - Acquired manganese mining interests
    Kudumane Manganese Resources (South Africa)
  - Diversification of ore procurement sources

- **Grow stronger through best-location production**

<table>
<thead>
<tr>
<th>Silicomanganese, ferrosilicon, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Use of low-cost electricity</strong></td>
</tr>
<tr>
<td><strong>Measures</strong></td>
</tr>
<tr>
<td><strong>Participate in Malaysian production</strong></td>
</tr>
<tr>
<td><strong>Pertama Ferroalloys Sdn. Bhd. (Malaysia)</strong></td>
</tr>
</tbody>
</table>
Kudumane manganese mining area
Functional Materials
### Functional materials products

<table>
<thead>
<tr>
<th>Functional materials products</th>
<th>Type and use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium-manganese oxide</td>
<td>Cathode materials for lithium-ion batteries</td>
</tr>
<tr>
<td>Hydrogen storage alloys</td>
<td>Anode material for nickel-hydrogen batteries</td>
</tr>
<tr>
<td>Ferroboron</td>
<td>For amorphous alloys: Raw material of amorphous alloy (FeSiB)</td>
</tr>
<tr>
<td></td>
<td>For magnets: Raw material of neodymium iron boron (NdFeB) magnet alloy</td>
</tr>
<tr>
<td></td>
<td>For steel: Used as additive in steel as one kind of ferroalloy</td>
</tr>
<tr>
<td>Manganese inorganic chemical products</td>
<td>See p. 23 for details.</td>
</tr>
<tr>
<td>Zirconium oxide</td>
<td>For electronic ceramics: Raw material of ceramic capacitors, PZT piezoelectric actuators etc.</td>
</tr>
<tr>
<td></td>
<td>For glass: Used as additive in high-refractive optical glass lenses, etc.</td>
</tr>
<tr>
<td></td>
<td>For functional film: Raw material of optical adjustment coating and hard coating materials, etc.</td>
</tr>
<tr>
<td></td>
<td>Composite oxide for catalysts: Catalytic promoter for purifying automobile exhaust gas</td>
</tr>
<tr>
<td>Boron oxide, boric acid</td>
<td>For glass: Used as additive in liquid crystal glass, optical glass, glass fiber, etc.</td>
</tr>
<tr>
<td></td>
<td>Other applications: Raw material of boron compounds, disinfectants, surface treatment agents, etc.</td>
</tr>
</tbody>
</table>

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Lithium-manganese oxide

- **Nippon Denko and lithium-manganese oxide**
  - World first, Start commercial production in 1997
  - World’s top manufacturer and seller
  - ISO 9001 and ISO 14001 certified plants
  - Winning the sixth January, 2012 Kiyoshi Okazaki prize (EV practical use contribution)

- **Features of lithium-manganese oxide**
  - Highly safe performance
  - Outstanding power characteristics
  - Lower Cost advantages

- **Main applications**
  - Large lithium-ion batteries for EV and HEV.
  - Large lithium-ion batteries for Energy storage system.

Battery materials manufacturing plant (Takaoka, Toyama Prefecture)

Spinel crystal structure have safe and thermal stability features
Hydrogen storage alloys

- **Hydrogen storage alloys (Metal hydride alloys)**
  - 1992 started commercial production.
  - Global No.1 supplier of these alloys for use in hybrid car batteries employed in Toyota hybrid vehicles.
  - ISO 9001 and ISO 14001 certified plant

- **Main applications**
  Anode material for nickel-hydrogen batteries used as drive batteries in hybrid vehicles.

- **Features of hydrogen storage alloys**
  - Long life span equivalent to vehicle life
  - Ample output to ensure startability at low temperatures and power acceleration

- **Principle of nickel-hydrogen batteries**
  ![Diagram of nickel-hydrogen batteries]

  **Hydrogen storage alloy anode**
  NiOOH+MH

  **Nickel cathode**
  Ni(OH)2+M

  Charge → Discharge

  • Charge
  • Discharge
Amorphous (noncrystalline) alloy ribbons with thickness of just a few tens of microns are produced by extremely rapid cooling of Fe, Si, B, or other alloys from molten state, at a rate of around a million degrees C per second.

Used mainly as the steel core material of amorphous transformers

When amorphous alloys are used as steel core material in transformers, electrical (no-load) loss at the steel core is very small for improved energy efficiency.

In China and India, where the electric power infrastructure is being put in place, adoption of energy-saving amorphous transformers is growing.

In Japan the Top Runner energy efficiency program was applied to industrial transformers in April 2006.

In the US, energy efficiency standards even stricter than Japan’s Top Runner program came into force in January 2010 applicable to distribution transformers.

Demand is expected to grow even further with the growing global trend toward energy efficiency.

A neodymium iron boron (NdFeB) magnet is the strongest kind of permanent magnet. These magnets are essential to making smaller, lighter, and more efficient products from electronic devices to home appliances and automobiles, resulting in energy savings.

Typical applications of NdFeB magnets

- Motors of hybrid vehicles and electric vehicles
- Head actuator mechanism for hard disk drive reading and writing
- Motors in energy-efficient appliances (air conditioners, etc.)
- Electrical generator in wind power system

For steel

Adding a very small amount (10 to 100 ppm) of boron to steel improves its hardenability and high-temperature strength.

Typical applications

- Wires used in suspension bridges, nuts and bolts, claws of power shovels

- Nippon Denko is the only ferroboron manufacturer outside of China.
Manganese inorganic chemical products

■ Overview of manganese inorganic chemical products business
- 1976 Started commercial production
- The only Japanese domestic manufacturer of diverse manganese inorganic chemical products
- ISO 9001 and ISO 14001 certified plants
- Kosher and FDA certified plant (manganese sulfate)

■ Features of manganese inorganic chemical products
- Holder of technology for high-purity refining of manganese ore
- Thorough removal of alkaline metals and alkaline earth metals by crystallization and recrystallization processes
- Thorough removal of iron by use of oxidizing agent and optimization of reaction pH

■ Types and uses of manganese inorganic chemical products

<table>
<thead>
<tr>
<th>Products</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manganese sulfate</td>
<td>Animal feed additives, catalyst raw materials, supplements, fertilizers</td>
</tr>
<tr>
<td>High-purity manganese sulfate</td>
<td>Cathode materials for lithium-ion batteries</td>
</tr>
<tr>
<td>Manganese carbonate</td>
<td>Animal feed additives, surface treatment agent raw materials, soft ferrite</td>
</tr>
<tr>
<td>High-purity manganese carbonate</td>
<td>Additive in laminated ceramic capacitors, thermistors</td>
</tr>
<tr>
<td>Chemical manganese dioxide</td>
<td>Ozone decomposition catalysts, deodorizing catalysts, oxidizing agents for organic synthesis</td>
</tr>
<tr>
<td>Reduced ore</td>
<td>Flux</td>
</tr>
</tbody>
</table>

Manganese inorganic chemical products manufacturing plant (Myoko, Niigata Prefecture)
Zirconium oxide: Material essential in digital devices

What is zirconium oxide?
- Electronic ceramics, with zirconium oxide as raw material, have the electrical properties for storing electricity and converting between electricity and pressure.
- A high refractive index is achieved by using zirconium oxide as an additive in optical glass and functional film.

Nippon Denko and zirconium oxide
- Began production at the Tokushima Plant in 1989
- Won acclaim for ultrafine particles and high purity
- Sold mainly for use in electronic parts and optical lenses

Main applications and products

<table>
<thead>
<tr>
<th>Electronic ceramics</th>
<th>Glass and film</th>
</tr>
</thead>
<tbody>
<tr>
<td>This material is used in ceramic capacitors and ceramic filters in the electrical circuits of digital consumer electronics, PCs, mobile phones and other digital devices. It is also used in inkjet printers, for example in devices controlling ink spraying. Another application is for use in gyro sensors for preventing camera shake and for detecting smartphone tilt.</td>
<td>Another use is in the optical lenses of digital cameras, and in films for liquid crystal displays.</td>
</tr>
</tbody>
</table>
Catalytic promoter for purifying automobile exhaust gas (ceria-zirconia)

- Used in three way catalysts for automobile exhaust gas.
- Its role is to store and release oxygen as oxidation and reduction reactions take place.

\[
\begin{align*}
\text{CeO}_2 & \quad \text{CeO}_{2-x} + \frac{X}{2}\text{O}_2 \\
\text{Oxygen storage} & \quad \text{Oxygen release}
\end{align*}
\]

Development goals
- High oxygen storage capacity
- High reaction (oxygen storage and release) speed
- Thermal resistance

(Three way catalyst for automobile exhaust gas)

- Oxidation and reduction reactions remove pollutants from exhaust

Zirconium oxide for functional film

- Mainly used as an optical adjustment coating material in functional films for touch panels.

**Zirconia properties**
- High refractive index (highly transparent)
- High hardness
- Resistant to photocatalysts

**Development goals**
- High dispersibility in solvent
- Primary particle diameter microscopically small and uniform
Environment
What are environmental recycling systems?

Having a large ion exchange resin recycling plant in Koriyama, Fukushima Prefecture, we rent and sell ion exchange towers which are water treatment equipment and perform resin regeneration on consignment.

Clean Recycle System

Ion exchange towers of wastewater treatment enabling the recovery of water and resources
ND MINICHROPACK: Heavy metal such as the chromium, iron, copper, nickel, cobalt
Various acids, alkali waste water.
H CLEPACK: Boron removal
NI-PACK: Nickel removal
F-PACK: Fluorine removal

Customer

Auto Parts

Water Flushing

(Water Flushing)

(Used)

(Replenishment in the factory)

(Replenishment in the factory)

(Replenishment in the factory)

(Picture: Our Koriyama Plant)

Recovering valuable materials in the regeneration plant

Resources Recycling

Nickel ultrapure material

Paraboron

Recovering boric acid

Features

1. Reuse and resources recycling of Water, the medicine
   - Reuse waste water as deionized water
   - Recycling of the adsorbed ion
2. Commissioned regeneration
   - Don’t need regeneration working or medicine on customer premises from treatment
   - No generation of sludge
3. A variety of sale’s methods
   - Selectable from a rental, purchase, a lease system
   - Suggest the smallest cost in consideration for a period of service, a work load, and funds for equipment

Flow sheet used

GO/GA Type

Water quality monitor

1. Chrome plating solution tank
2. Recovery tank
3. Washing tank

● We also offer boron recovery systems.
   - Our company purchases the recovered boric acid and recycles it.

Pure Water System

Pure water production that meet the needs of a recycling-based society

AQUA PACK

Cartridge demineralizer

- Simple and easy-to-use demineralizer filled with ion-exchange resin
- By simply connecting the unit directly to a faucet
- Creates high-purity water by removing Ca, Na, SO4, Cl, SiO2, etc., in tap water.

MR PACK

Pure Water System that combines the reverse osmosis membrane (RO membrane) with the ion-exchange resin tower.

- Space-saving by a compact design
- Customer’s work of the ion-exchange resin tower reproduction is unnecessary. (reproduce in our factory)
- We offer in accordance with a required specification.

- For washing of surface treatment and electronic parts
- For the water for boilers, air-conditioning, and humidifiers
- For experiments, analysis, and medicine
- For hydrogen production

● Contribution to the hydrogen society

Environment

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History of business
• In 1995, Chuo Denki Kogyo became the first private company in Japan to begin treatment of incineration ash generated from municipalities by melting in a ferroalloy furnace.
• In 2002, a dedicated furnace was put into operation, and treatment of industrial waste was started.
• The processing capacity of the dedicated furnace was increased in 2013.

Features
• Due to high-temperature melting and solidification, the treatment is able to break down dioxin and detoxify and stabilize heavy metals.
• The generated slag being of stable quality, it is sold for a wide range of uses as ECOLAROCK (registered trademark).
• Valuable metals (gold, silver, copper, etc.) contained in the molten metal are recycled and used.

Applications
• Roadbed material
• Leveling material for solar panel installation
• Embankment material for disaster recovery
• Base material for river embankment work

Environment
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Other: Electric Power and Fertilizer
Electric power business

- Hydroelectricity is an extremely clean form of power generation that produces no CO₂ emissions.
- Our Hidaka Plant was a pioneer of power plant development in the Hidaka region, constructing power generation plants in the Horoman river system in the first half of the 20th century.
- Today, Horomangawa Hydroelectric Power Plants No. 2 and 3 produce around 10,000 kW of electricity. Part of this production is used in our plant, and the rest is supplied to an electric power company.

Plans for extensive upgrades to both power plants were drawn up in December 2014. Then, the facilities were certified under the Feed-in Tariff Scheme for Renewable Energy. The No. 2 and No. 3 plants are both being upgraded currently.

<table>
<thead>
<tr>
<th>Power generation facility</th>
<th>Established</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horomangawa Hydroelectric Power Plant No. 2</td>
<td>1940 (currently being upgraded)</td>
<td>3,915kW</td>
</tr>
<tr>
<td>Horomangawa Hydroelectric Power Plant No. 3</td>
<td>1952 (currently being upgraded)</td>
<td>5,900kW</td>
</tr>
</tbody>
</table>

- September 2015 to September 2017: Upgrading of No. 2 plant
- January 2017 to November 2018: Upgrading of No. 3 plant

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Fertilizers with a variety of benefits are created by adding other ingredients to slag.

The fertilizers, for which the (non-metal) slag resulting from ferroalloy production is reused, are produced at our Tokushima and Hidaka Plants.

<table>
<thead>
<tr>
<th>Products</th>
<th>Material</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yume-silica, Maitaro, Umaizo</td>
<td>Phosphate</td>
<td>Improved flowering and fruiting.</td>
</tr>
<tr>
<td>Maidotsukuri</td>
<td>Potash</td>
<td>Stronger roots. More resistant to pests and cold.</td>
</tr>
</tbody>
</table>

In a word, “soil improvement”
Research and development
R&D

Recent research and development example

- Development status of new concepts for catalytic promoters for cleaning automotive exhaust gas (Ceria-Zirconia)
  ① Product that can store/release oxygen more rapidly. 【The speed of OSC is improved up to 20% in comparison with our mass production product】
  ② Product that can enhance catalyzer activity. 【An adsorption phase is hybridized with ceria-zirconia】

- Vanadium dioxide heat storage material
  ① Four types with different heat storage temperatures (transition temperatures) have been test-produced and provided as samples.
  ② Uses other than as a heat storage material are being developed. (thermochromic elements by temperature, temperature switch elements, responsive elements by temperature, etc.)

R&D reorganization

Director of Laboratories
- R&D Laboratory (Anan, Tokushima): Develops ferroalloy technologies, alloy powders and zirconia-based oxides
- Myoko Research Unit (Myoko, Niigata): Develops Rare earth magnet alloys and Mn chemicals

R&D reorganization

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