

## CNS-UCSB *Traveling Technologies* Research Template

### Example Value Chain Analysis for Nanosilver

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This is the Research Template Steps & Resources, completed for nanosilver. Note that references are used to keep track of where the information comes from. You will use many different data sources, so be sure to keep track of what data is from which source.

#### *Things to identify before you begin:*

- **Keywords and various spelling of your product:** Nanosilver, Nano silver, nano-silver, Silver nanoparticles, Ag
- **Frames of reference:**
  - *Type of chain: tangible supply chain*
  - *Supply chain position: raw material: nanomaterial forward*
  - *Phase: Bulk vs. nanomaterial*
    - Nanoscale metals are often too costly to replace their conventional counterparts except in less price-sensitive applications such as rocket fuel, high-end health care applications, or where load levels are low and cost is less critical (Freedonia 2009).
    - Metal nanoparticles have yet to show that they're a significant improvement over current materials in many applications, or to become available at prices, which make them economically viable alternatives (Lux 2006).
    - Nanosilver over bulk material: by being nano in scale, it is [smaller](#) than the bacteria and thus can block them instead of just disabling them.
- **Innovation to commercialization process phase:** Phase III: mass production (Lux 2004)
- **Classification systems to identify products and firms:**
  - North American Industrial Classification System (NAICS): 212222: Silver Ore Mining
  - International Patent Classification ([IPC](#)) System: version. 2009.01:
    - *Section:* C: Subsections: Chemistry; Metallurgy (Ag (silver) is a noble metal)
    - *Class:* C22: Metallurgy; ferrous or non-ferrous alloys; treatment of alloys or non-ferrous metals
    - *Subclasses:* C22B: Production or refining of metals; pretreatment of raw materials and B22F 9/00: Making metallic powder or suspensions thereof
    - *Group:* C22B 11/00: Obtaining noble metals
      - C22B 11/02: by dry processes
      - C22B 11/06: chloridising
      - C22B 11/08: by cyaniding
      - C22B 11/10: by amalgamating
      - C22B 11/12: apparatus thereof

- 1) **STEP 1: Read industry overviews, surveys, and markets reports for bulk and nanomaterials and identify the following:** (Lux 2006)
  - **Definition** of metal nanoparticles: particles made of metals, most commonly silver, gold, aluminum, or nickel. These particles can also be coated with hydrophilic or hydrophobic substances. Applications vary due to properties of the metal.
  - **Purpose:** Silver is mainly used for antimicrobial properties.
  - **History:** Silver nanoparticles have been around for millennia, but they were not purposefully engineered to optimize properties and exploit new applications. Only in the last two decades have scientists started to purposefully engineer silver nanoparticles to optimize their properties and exploit new applications. Silver was used to prevent and treat diseases in ancient Greece and Rome, and it was used as a disinfectant, and colloidal silver ion solutions were used in the 1920s as a topical antibiotic.
  - **Properties of Nanosilver**
    - Reactivity
    - Conductivity
    - Bioprobes: Raman spectroscopy detects light scattered from a molecule, and can be enhanced by nearby metal nanoparticles in a technique called Surface Enhanced Raman Spectroscopy (SERS), for in vivo or in vitro biological sensing.
  - **How you make it (synthesis):**
    - **Condensation:** a solid metal is evaporated in an inert gas atmosphere, and then rapidly condensed to form a powder of nanosized clusters. Adjusting the temperature, gas environment, and evaporation rate controls the size. This method yields highly pure particles. Variations include:
      - Physical vapor synthesis (PVS): an electric arc is used to vaporize solid metal.
      - Vacuum evaporation on running liquids (VERL): the evaporated metal condenses into a thin film of viscous material
      - Chemical vapor deposition (CVD): a metal is vaporized and deposited on a substrate.
    - **Milling:** bulk material is ground down with an additive that prevents agglomeration. Time and the atmospheric medium affect the size of the particles. This method runs the risk of having nanoparticles with additives still in them.
  - **Key Applications:**
    - **Antimicrobials:** nanosilver has antimicrobial properties, believed to come from silver ions released from the surface and inhibiting the respiratory pathway of microbes.
    - **Biological assays:** Oxonica is developing silver-based Raman-active particles for multiplex assays.
    - **Conductive inks:** depositing nanoparticles by ink-jet printing is used for products such as radio frequency identification (RFID) tags printed on plastic or silver. Nanotechnologies, Inc. is developing low-temperature, conducting ink-jet ink composed of silver nanoparticles dispersed in an organic solution.
  - **Drivers of innovation:**
    - **Drug resistance:** as more microbes become resistant to the drugs used to eradicate them, especially antibiotic resistant bacteria, there is a strong need for new, broad-spectrum antimicrobials.

- *Life Sciences*: technology is needed to detect multiple targets at once in high-throughput arrays.
- **Momentum for commercialization**: there is a great interest in the antimicrobial properties of nanosilver. Other metal nanoparticles are in a holding pattern until companies can demonstrate significant improvement over current technologies.
- **Challenges**:
  - *Displacing current materials*: metal nanoparticles have yet to show that they're a significant improvement over current materials in many applications, or to become available at prices which make them economically viable alternatives.
  - *Reliability*: synthesis methods are still in early stages, and companies need to work on producing nanoparticles with reliable properties. Many report that companies are not able to produce the materials to the specifications they claim.
  - *General*: metal nanoparticles have not raised as many red flags regarding environmental, health, and safety. The metals used (notably silver and gold) are typically very non-toxic to humans. However, unique properties on the nanoscale, such as reactivity, may lead to unforeseen side effects in applications that require large exposures (Lux 2006).

## 2) STEP 2: Identify supporting environment and institutions

Categories of Stakeholders: Examples

- **Government**: Environmental Protection Agency (EPA), National Nanotechnology Initiative (NNI) & Coordinating Office, U.S. Food & Drug Administration (FDA), National Institute for Occupational Safety and Health (NIOSH)
- **Industry Associations**: NanoBusiness Commercialization Association (NanoBCA), International Association of Nanotechnology
- **Universities, Community Colleges, K-12**: NSF-Funded Nanotechnology Centers and Networks, NNIN Nanotechnology Education Site
- **NGOs**: OECD Nanotechnology Groups, International Council on Nanotechnology (ICON), Woodrow Wilson Center (WWC) Project on Emerging Nanotechnologies (PEN), Micro and Nanotechnology Commercialization Education Foundation (MANCEF)
- **Business, Technology, and Service Providers**: Nano Science and Technology Institute (NSTI), Foresight Institute, International Alliance for NanoEHS Harmonization (IANH)

## 3) STEP 3: Identify firm participants

- U.S. Census [Industry Statistics Sampler](#) for NAICS 212222
  - Establishments: 11; Employees: 577
- Nanosilver database: total of 65 companies & 11 countries (Fauss 2008)

## 4) STEP 4: Create a broad supply chain and identify end markets

- **Stage 1: Forms and Classifications of Nanomaterial**: metal nanoparticle
  1. Nanopowder
  2. Colloid (for use in liquid applications)
  3. Masterbatch (for polymer applications)
- **Stage 2: Forms of Nanointermediates**

1. Coating or spray: nanomaterial is used to create a coating/spray
2. Nanomaterial is added directly to an intermediate product
- **Stage 3: Part I: Forms of Nano Enabled (final) Products**
  1. Nano-coated product: manufacturer purchases nano-enabled coating and applies the coating to a final product. This final product is sold with the applied coating.
  2. A final product incorporates an intermediate product with nanomaterial
  3. A final product is an intermediate product
  4. Nanomaterial is added during the manufacturer of a final consumer product without a distinct nanointermediate stage
- **Stage 3: Part II: Markets:** nanosilver is found in material and manufacturing, healthcare & life sciences, and to a lesser extent, electronics and IT markets. Applications in energy-related markets were not identified. The 240 products from the Nanosilver Commercial Product Inventory (Fauss 2008) were classified into these markets and are listed in the following table. In Table 2, the top product categories are listed. These categories were provided in the Nanosilver Inventory (Fauss 2008), however the numbers in the actual report were higher than the numbers provided in the database inventory because some products were classified in multiple categories. The report identifies 249 products however the inventory only has 240 unique products. The commercial products were classified under a scheme similar to the PEN Consumer Product Inventory with two additional categories: medical applications and public.

**Table 1: Nanosilver Products by Market**

Market	Products	Share of Total (%)
Materials & Manufacturing	125	52%
Healthcare & Life Sciences	89	37%
Electronics & IT	26	11%

Source: Author analysis of products listed in Fauss (2008)

**Table 2: Distribution of Product Categories: Report Totals & Inventory Totals**

Categories	Total	Listed in Inventory
Health & Fitness	131	129
Home & Garden	26	24
Food & Beverage	25	23
Cross-Cutting	23	22
Appliances	15	15
Medical Applications	10	10
Electronics & Computers	8	8
Public	6	6
Goods for Children	5	3
Automotive	0	0
<b>Totals</b>	<b>249</b>	<b>240</b>

Source: Fauss (2008), Totals Based on Figure 2. Distribution of Product Categories (p. 8); categories overlap, but the inventory only includes one category and subcategory for each product, so cannot determine overlaps.

- 5) **Repeat step 4 and identify firms in each stage of the supply chain:** of the 240 products, 214 are sold as final commercial products and 26 as precursor products for purchase by manufacturers (Fauss 2008).

**Table 3: Distribution of Commercial Products by Nanomaterial Type/Form**

Form	Precursor (26)	Commercial (214)	Total (240)
Coating	7	59	66
Liquid	6	50	56
Not Available	1	43	44
Solid	5	36	41
Spun	3	13	16
Coating/Spray	0	10	10
Powder	4	3	7

Source: Fauss (2008): Based on Figure 1: Distribution of Commercial Products by Nanomaterial Type/Form p. 5; Note: Frederick verified that report data matches the PDF inventory database for the type/form column (240 total)

**Table 4: Products and Companies by Value Chain Segment & Market**

Value Chain Stage & Markets	Products	Companies
<b>Nanomaterials</b>	<b>10</b>	<b>5</b>
<b>Nanointermediates</b>	<b>17</b>	<b>16</b>
Materials & Manufacturing	12	11
Medical & Hygiene	5	5
<b>Nano-Enabled Products</b>	<b>213</b>	<b>60</b>
Materials & Manufacturing	103	
Electronics & IT	26	
Medical & Hygiene	84	
<b>Total</b>	<b>240</b>	<b>81</b>
<b>Overlaps: Indicates Degree of Integration</b>		<b>16</b>

Source: author analysis based on data from Fauss (2008)

- **Step 1: Nanomaterials (Nanosilver): 10 of 240 products**
  1. *Nanopowder*
    - SilverSure, AgActive, UK
    - Silver Nano Powder, Nano Plasma Center, South Korea
    - Nanocid Powder, Nanocid, Iran
    - NTbase Nanosilver Powder, NT Base Co, Ltd., South Korea
  2. *Colloids*
    - Nanocid Colloid, Nanocid, Iran
    - Nanover, Nanogist Co, South Korea
    - NTbase Nanosilver Colloidal, NT Base Co, South Korea
  3. *Master Batch*
    - Nanocid Masterbatch, Nanocid, Iran
    - NTbase Nanosilver Master batch, NT Base Co, South Korea
    - NTbase Nanosilver Textile Master Batch, NT Base, South Korea

- **Step 2: Nanointermediates: 17 of 240 products**
  - 1. *Coatings*
    - Nano Silver Poly Technology, Daewoo Electronics, Germany
    - E47 Antimicrobial Fiber Technology, E47, US
    - Nano Shield, IOGEAR, US
    - Bio Silver & Bio Shield, LG Electronics, South Korea
    - NTC Nano Silver Coating, Nano Care Technology, China
    - Silcryst, Nucryst Pharmaceuticals\*: Medical Applications: Coatings
  - 2. *Nanomaterial added to Intermediate/Component Product*
    - Cross-cutting: Fabric & Thread
      - Nanotex, Goodweaver Textile Co, Taiwan
      - Biosilver, Hyosung, South Korea
      - Nano Magic Silver, Hyosung, South Korea
      - SmartSilver, Nanohorizons US
      - NanBabies Silver Ion Material, NanBabies, US
    - Cross-cutting: Bedding/Pillows: Contour-Foam, Sharper Image, US
    - Cross-cutting: Appliances: Silver Nano Health System, Samsung, South Korea
    - Medical Dressings: Beiersdorf AG Silver Technology, Beiersdorf AG, Germany
    - Food & Beverage: Supplements
      - NanoSil Dietary Supplement, Conseal International, US
      - Advanced Colloidal Silver, Utopia Silver Supplements, US
    - Personal Care: Colloidal Silver Liquid, Skybright Natural Health, New Zealand
- **Step 3: Part I: Nano-Enabled Final Products: 213 of 240 products**
  - 1. *Coating applied to final product (applied by the final product manufacturer<sup>1</sup>)*
    - Nano-silver infused gold plated curling irons, Andis, US
    - Food container, A-DO Global, South Korea
    - Nano Silver Cutting Board A-DO Global, South Korea
    - Milk bottle, Babydream, South Korea
    - Mug cup, Babydream, South Korea
    - Nano Silver Teeth Developer, Babydream, South Korea
    - Notebook computer, Samsung, South Korea
    - Split Type Air Conditioner, Samsung, South Korea
    - Silver Nano Refrigerator, Samsung, South Korea
    - Socks, AgActive, UK
    - 100% cotton sheet sets, AgActive, UK
    - Bath and sport towels, AgActive, UK
  - 2. *Final product incorporates nano-enabled intermediate product with nanomaterial*
    - Elastoplast with PUR Gel, Beiersdorf AG, Germany
    - Elastoplast SilverHealing, Beiersdorf AG, Germany
    - Hansaplast med Silver Technology, Beiersdorf AG, Germany
    - Hansaplast med Silver Technology with PUR Gel, Beiersdorf AG, Germany
  - 3. *Intermediate product or raw material sold as the final product*

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<sup>1</sup> Due to space, examples only provided for each category

- NTC Antimicrobial/Abrasion-resistant Nano Silver Coating, Nano Care Technology
- Silver Nano Powder, Nano Plasma Center, South Korea
- Nanocid Colloid, Nanocid, Iran
- 4. *Nanomaterial added during final product mfg. without clear intermediate stage*
  - *In solids (i.e. soap)*
    - Silver Aloe Skin Care Bar, Utopia, US
  - *When final product is a liquid/spray (i.e. shampoo). In some cases, it is unclear how or when nanomaterials are added; possible that a mixture (intermediate) containing the nanomaterial is added to a liquid/spray to make the final product.*
    - Germ Slayer, Aluwe, US
    - ASAP Health Max 30, American Biotech Labs, US
    - ASAP Solution Plus, American Biotech Labs, US
    - Advanced Colloidal Silver, Utopia, US
- **Stage 3: Part II: Nanosilver Markets:** the following products are listed in (Fauss 2008)

**Table 5: Markets, Categories, and Sub-Categories from all Value Chain Segments**

Market & Category	Sub-Category	Totals	Share of Total (%)
<b>Materials and Manufacturing</b>		<b>125</b>	<b>52%</b>
Health & Fitness		56	
	Clothing	52	
	Sporting Goods	4	
Home & Garden		12	
	Cleaning Products	5	
	Bedding/Pillows	4	
	Hardware	2	
	Pets	1	
Food & Beverage		11	
	Storage	8	
	Cooking	3	
Appliances	All	15	
Public Goods	Hardware (All)	6	
Goods for Children	All	3	
Cross-Cutting	All	22	
<b>Healthcare &amp; Life Sciences</b>		<b>89</b>	<b>37%</b>
Health & Fitness		55	
	Personal Care	38	
	Cosmetics	17	
Food & Beverage	Supplements	12	
Home & Garden	Cleaning Products	12	
Medical Applications	All	10	
<b>Electronics &amp; IT</b>		<b>26</b>	<b>11%</b>
Health & Fitness	Personal Care	18	
Electronics & Computers	All	8	

**Example research area: Globalization & Governance: Identify leading firms (& common strategies) and countries (or states) by product**

- **Product** (nanosilver): Nanotechnologies Inc. and Nanux (Lux 2006)
- **Market** (nanomaterials through nano-enabled products):
  - *Healthcare & Life Sciences:*
    - Nycryst Pharmaceuticals (Canada): public start-up: sells nanoparticulate silver wound dressings on the market, and is developing pharmaceuticals for skin and respiratory diseases (Lux 2006).
    - Nanux (Korea): private start-up: large producer of silver nanoparticles for consumer antimicrobial applications (Lux 2006).
  - *Electronics & IT:*
    - NanoMas Technologies: in Nov. 2008, Germany-based BASF’s venture capital company invested \$1.5 million in this startup company developing products such as silver nanoparticle inks for printable electronics (Freedonia 2009).
  - *Materials & Manufacturing:*
    - Nanotechnologies Inc. (USA): private start-up: produces a variety of metal nanopowders including silver and aluminum (Lux 2006).
- **Participating countries:**
  - The *Silver Nanotechnology Commercial Inventory* (Fauss 2008) identified 11 countries with firms participating in the nanosilver value chain: China, Germany, Iran, Japan, New Zealand, Singapore, Korea, Taiwan, Thailand, U.K., and USA.
  - **Global Market Size:** Global: estimated 2005 market size of metal nanoparticles: \$89 million (Lux 2006). The projected 5-year compound annual growth rate for metal nanoparticles (2005-2010): 54% (Lux 2006).

**Table 6: Leading Countries Number of Nanosilver Products by Country**

Country	Number of Products	Share of Total Products
United States	117	49%
South Korea	53	22%
China	21	9%
New Zealand	14	6%
Germany	11	5%
Taiwan	11	5%
United Kingdom	6	3%
Iran	3	1%
Japan	2	1%
Singapore	1	<1%
Thailand	1	<1%

Source: Fauss (2008)



## Nanosilver Resources

1. **Industry overviews, surveys and market reports for bulk & nano materials**
  - Sizing Nanotechnology's Value Chain (Lux 2004)
  - Plunkett's Nanotechnology Almanac 2008 (Plunkett 2008)
  - Freedonia Focus: Nanocomposites (Freedonia 2008)
  - Freedonia Focus: Nanomaterials (Freedonia 2007; 2009)
2. **Identify firm participants**
  - The Nanotech Report 4<sup>th</sup> & 5<sup>th</sup> editions: Vol. I (Lux 2006; 2007)
3. **Leading firms, organizations, & industries**
  - **Identify corporate structures and profiles of leading companies:**
    - *Lexis Nexis Academic*: corporate affiliations
    - Edgars: 10K filings
  - **By product:**
    - *Standard & Poor's*: have to look up individual companies; do not have nanotechnology industry surveys
    - *Datamonitor*: do not have nanotechnology market reports
    - *OneSource, Hoovers, Plunkett's, Mergent Online*
  - **By market: databases that have leading companies include:**
    - Mintel Reports, Hoovers, Euromonitor, OneSource, Plunkett's
  - **By global leadership:**
    - Lux Nanotech Report, 4<sup>th</sup> Edition vol. I (Lux 2006). Includes a section on Key Companies for each classification.
    - *OneSource, Plunkett's, Euromonitor (includes Europe and US), Mergent Online*
  - **By country/location:**
    - Historic country leaders: *Investext*
    - Present country leaders: *OneSource, Datamonitor, Plunkett's, US Commercial Service Reports, Trade Data (Trade-Stats, United States International Trade Commission (USITC), OTEXA)*
    - [US NanoMetro Map](#): Project on Emerging Nanotechnologies
    - U.S. States: if NAICS codes are known, use the [2002 Census](#) link
4. **Create a broad supply chain**
  - CRS Engineered Nanoscale Materials (Schierow 2008)
  - Freedonia Focus: Nanomaterials (Freedonia 2007; 2009)
  - The Nanotech Report 4<sup>th</sup> & 5<sup>th</sup> editions: Vol. I (Lux 2006; 2007)
  - Euromonitor (for steps 5 & 6 market & distribution channels)
5. **Repeat steps 1-4; Determine supply chains for your final product's (step 4)**
  - Fauss Nanosilver Database with 240 products (Fauss 2008)
  - CRS Engineered Nanoscale Materials (Schierow 2008)
  - Freedonia Focus: Nanomaterials (Freedonia 2007; 2009)
  - The Nanotech Report 4<sup>th</sup> & 5<sup>th</sup> editions: Vol. I (Lux 2006; 2007)
  - Project on [Emerging Nanotechnologies](#) at the Woodrow Wilson Center
  - Meridian Institute's [Nanotechnology and Commodities](#) Database

## 6. Institutions

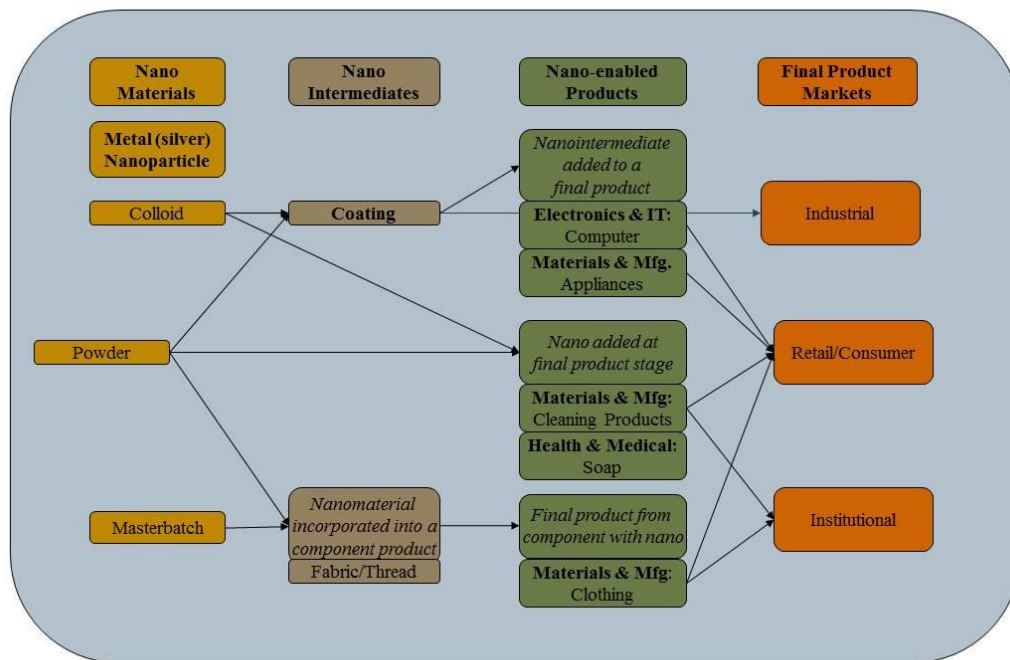
- *Plunkett's* Nanotechnology List: Associations/Organizations (Plunkett 2008)
- CRS Nanotechnology: Policy Primer (Sargent 2009)
- CRS National Nanotechnology Initiative (Sargent 2008c)
- CRS Federal Support for Nanotechnology Research 2007
- CRS Nanotechnology & Environment, Health, Safety (Sargent 2008a)
- CRS Engineered Nanoscale Material/Regulatory Challenges (Schierow 2008)
- Chapter 6: Nanotech Environmental, Health & Safety Risk (Lux 2006)
- [Project on Emerging Technologies](#): Environment, Health & Safety Research

## 7. Identify global and U.S. industry statistics

- *General*
  - *Plunkett's* Nanotechnology Statistics (Plunkett 2008)
  - Nanotech Report, 4<sup>th</sup> edition vol. I (Lux 2006)
  - CRS Nanotechnology & U.S. Competitiveness (Sargent 2008b)
- *Patents*
  - Key Patents: Nanotech Report, 4<sup>th</sup> edition vol. I (Lux 2006)
  - IP Outlook: Nanotech Report, 4<sup>th</sup> edition vol. I (Lux 2006)

Taking the general nanotechnology value chain presented earlier in this guide, we can pick out the components for nanosilver:

### *General Nanosilver Value Chain*



Source: Frederick, Stacey (2009). Duke University, Center on Globalization, Governance, & Competitiveness (CGGC)

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