# EG60411 Biomaterial Science

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2G103, 10:10-11:25, Tuesday

## Biomaterial Science （2015 Schedule）

| # | Date | Content |
|---|---|---|
| 1 | 10/6 | History of papermaking |
| 2 | 10/13 | Pulps – Beating and fiber properties |
| 3 | 10/20 | Pulps – Additives and functions |
| 4 | 10/27 | Papermaking processes & interfiber bonding |
| 5 | 11/10 | Paper– Structural properties |
| 6 | 11/17 | Paper– Surface properties |
| 7 | 11/24 | Paper–Wetting and absorption properties |
| 8 | 12/1 | Paper– Mechanical and optical properties |
| 9 | 12/8 | Polysaccharide chemistry by Assoc Prof Akiko Nakagawa |
| 10 | 12/15 | Recent research of paper science and technology |
| 11 | 12/22 | Examination |

## Lecture information and contact

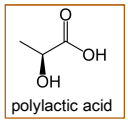
- Homepage of “Biomaterial Science (T. Enomae)”
- http://www.enomae.com/
  → Handouts in lecture(講義資料)
- E-mail address
  → t@enomae.com
  for any questions and visit to laboratory
  (Bio-Agr. Bldg. 生農C209 or 総合A618)

## Biomaterial and Biomaterial Science

- **What biomaterial is**

Materials constituting components and the structure of organisms processed to provide properties required for the use such as:

**Wood, paper, cellophane, rubber, leather, polylactic acid**

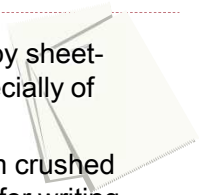


polylactic acid

- **What biomaterial science is**

Science and technology for providing high performance to biomaterials

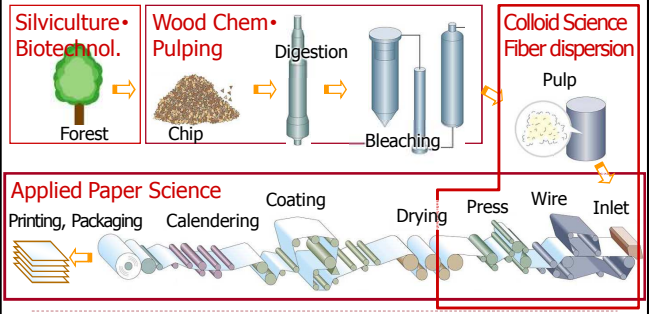
## “Paper” —Definition



- “A thin, flat material obtained by sheet-forming and drying fibers especially of plants”
- “A thin, flat material made from crushed wood or cloth used especially for writing and printing on and in packaging”
  - **Cambridge Dict.**
- Plant fibers, especially wood-sourced, as a raw material of paper are called “a pulp”

## Scope of Paper Science

- Colloid Sci ( Fiber dispersion system ) + Applied Paper Sci



## Who has affected you most?

- "Who has affected you most in your life so far?" was voted in an internet site.
- Jesus Christ received the second largest numbers of votes
- (A) received the largest.
- Without paper, printing technology would not have developed, nor would wealthy life today be guaranteed.

## Origin of paper

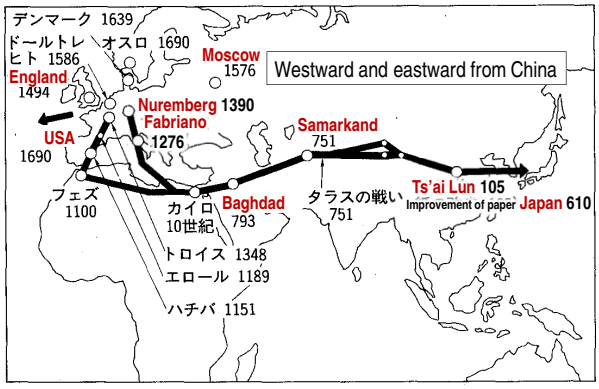
- Ts'ai Lun is traditionally regarded as the inventor of paper. Exactly, however, he invented the composition for paper along with the papermaking in A.D. 105.
- The fibrous materials used in those day were bark, hemp, silk, and fishing net.

蔡倫

## Origin of paper

- The world oldest paper found in that is estimated to be between 179 and 142 BC (early Western Han 漢朝).
- It was used as a map, where mountains, waterways and roads are drawn.

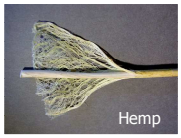
Fangmatan (放馬灘) paper




Spread of papermaking technology

## History of papermaking tech. -Materials

- **Hemp** (Cannabis大麻・ Linen亜麻)
  - → Cannabis has been used for cloth and fishing net in China and Japan. Linen in Europe.
- **Rags**
  - → Recycling of cloth woven originally from hemp. Cotton from the age of Industrial Revolution
- **Bast (skin) fibers**, such as Paper Mulberry etc. for Japanese paper




## History of papermaking tech. -Materials

- **Leaves**, of Treang tree to make "Sastra"
- **Wood**, capable of producing on a large scale
- **Kenaf**
  - → A kind of hemp promoted for forestry preservation, but not accepted any more.
- **Plastics**, synthesized paper from polypropylene called "Yupo"

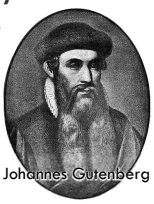
Treang tree

Sastra

## Origin of Printing technology

**Gutenberg** (1395? –1468)
invented a printing press in around 1445.
The invention consisted of
- mass-producing movable type;
- oil-based ink from linseed oil; and
- a wooden printing press similar to the agricultural screw presses

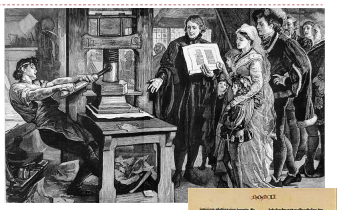
and allowed the mass production of printed books and was economically viable for printers and readers alike.


Johannes Gutenberg


Movable type

## 42-line Bible (42B)

- Gutenberg printed and published 180 copies of 42-line Bible.
  - → The start of the age of the printed book in the West



- Relationship with paper
  - → Increased paper demand
  - → Development of mass production of paper
  - → Use of wood as a papermaking material
  - → Invention of paper machine to produce "continuous paper".

## The Greatest Inventions of the Past 2000 Years

Edited by John Brockman and published on Jan 12, 2000

- John Brockman, a novelist of USA, asked "What is the most important invention in the past two thousand years? and Why?" to famous.
- "Reading glasses" and "eraser" were unexpectedly proposed.
- Many people including Dr. Philip Anderson, a Nobel prize winner, chose "**printing technology**" because it promoted knowledge occupied by privileged people to the public.
- Another physical scientist chose "watch" for quantification of time passage that was dependent on one's sense so far.
- "Heliocentric theory", "mathematics", "differential and integral calculus", "democracy", and "religion" were also supported.



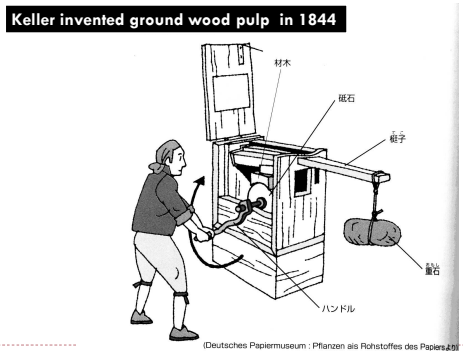

See http://www.edge.org/documents/Invention.html

## History of papermaking tech. – Machine

| | |
|---|---|
| 1670 | Hollander beater invented [Holland] |
| 1719 | Reaumur submitted his invention - paper can be made from wasp hives- to the Academy [France] |
| 1798 | Louis-Nicolas Robert invented manufacture of continuous paper [France] |
| 1844 | Keller invented ground wood pulp [Germany] |
| 1851 | Burgess [USA] and Watts [England]invented soda pulping to make wood pulp. |
| 1856 | Healey received a patent of corrugated [England] |
| 1856 | Tilghman invented the sulfite pulping [USA] |
| 1879 | Dahl invented Kraft pulping [Germany] |
| 1950 | Hardwood pulping initiated[Japan] |
| 1968 | Thermo-Mechanical Pulping (TMP) Developed[Sweden] |
| 1977 | Quinone-added pulping invented [Japan] |

## Mechanical pulping – Groundwood pulp

- GP or SGW ([Stone] Groundwood Pulp)




## Old printed material in Japan

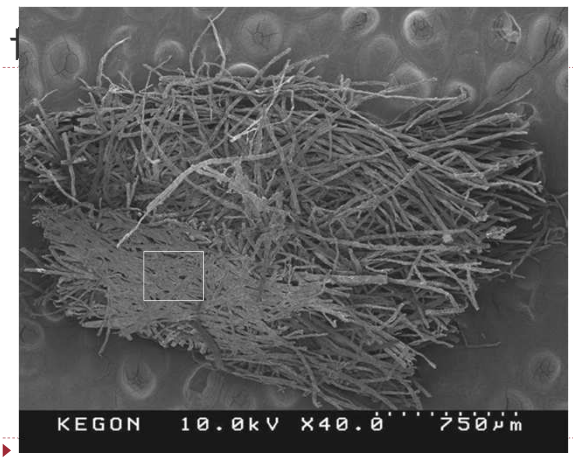
In 764, Emperor Koken had holy texts (無垢浄光陀羅尼経) printed on paper one million copies for peace of Japan, contained in one million wooden miniatures of a three story tower, and laid out in the ten great temples like Horyu-temple and Todai-temple.

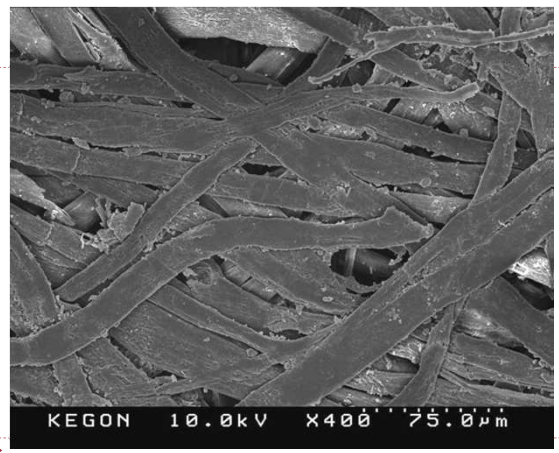
## The world oldest printed material

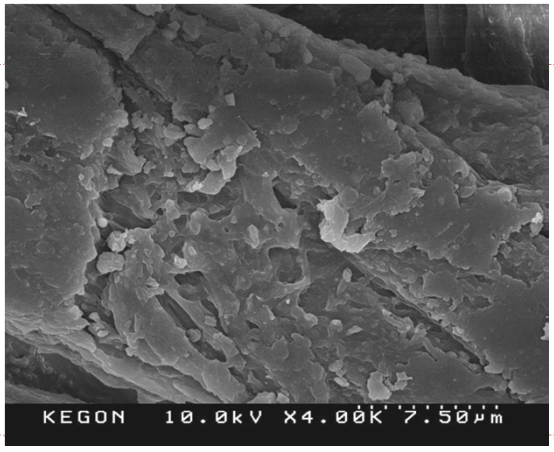
In 1966, printed holy texts was discovered in the Buddha tower of Bukkoku-temple (**仏国寺**) of Keishu, Shinra (**新羅慶州**), currelty Korea(**韓国**). This tower is known to have been built in 751.

## The world oldest printed material

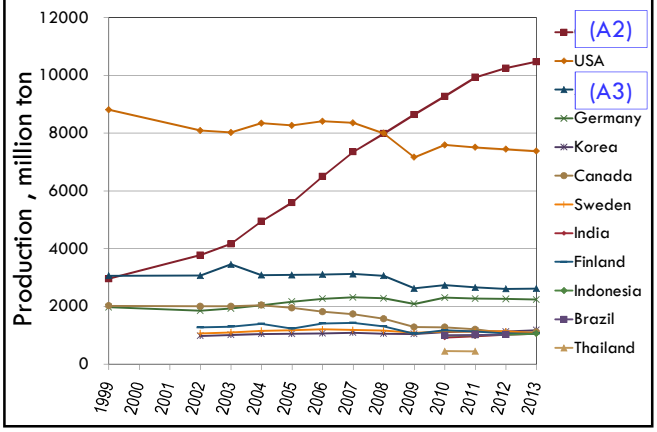
Paper with holy texts (**華厳経**) written in 755, Silla era (**新羅**) was analyzed.



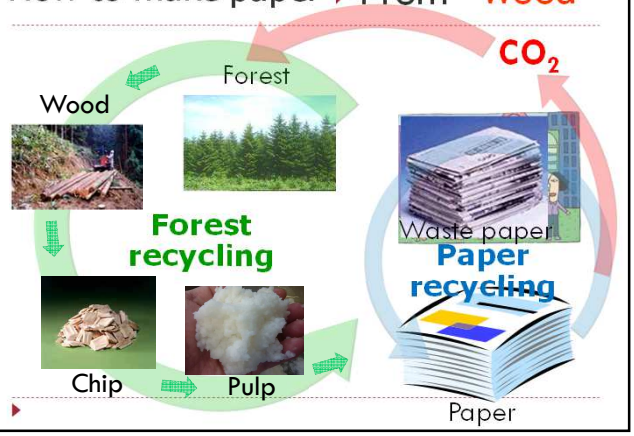




## Production of paper and paperboard



## How to make paper ▸ From "wood"

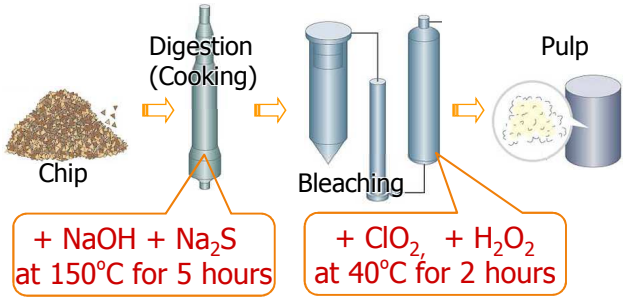



## Ratios of waste paper recovery and utilization
Top 10 countries of paper production (2013)

Sourced from Annual Review of Global Pulp and Paper Statistics (RISI)

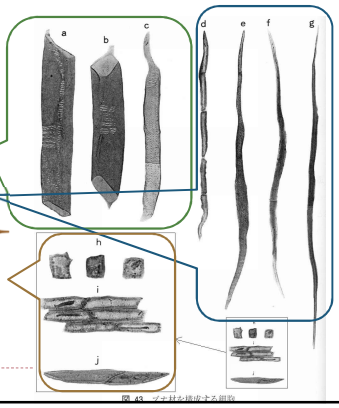
| Prod. order | Country | **Recovery, %** | Utilization, % |
|---|---|---|---|
| 5 | Korea | **96.0** | 87.5 |
| 3 | Japan | **79.8** | 64.5 |
| 4 | Germany | **78.7** | 73.6 |
| 6 | Canada | **71.4** | 24.1 |
| 7 | Sweden | **67.7** | 12.8 |
| 2 | USA | **63.8** | 36.1 |
| 9 | Finland | **61.7** | 5.7 |
| 10 | Indonesia | 56.6 | **59.1** |
| 1 | China | 44.8 | **71.1** |
| 8 | India | 27.8 | **56.3** |

## **Wood chips** to **pulp**

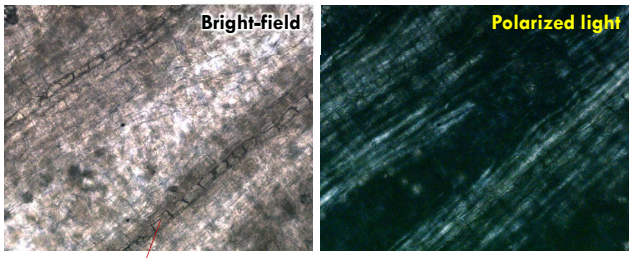



## Wood tissue – cells of beech tree

| Component of hardwood tissue | |
|---|---|
| Vessel | 20% |
| Wood fiber | 60% |
| Axial parenchyma cell | 10% |
| Radial parenchyma cell | 10% |



## Axial parenchyma cell

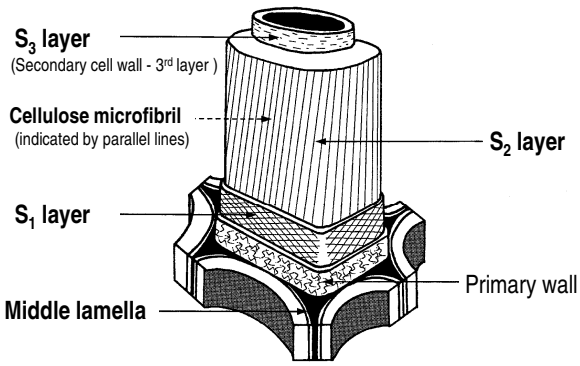



parenchyma cells

**Bast fibers**

0.1 mm

## Wood tissue – structure of cell wall

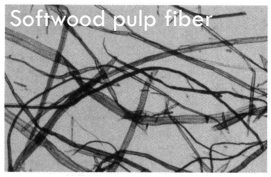


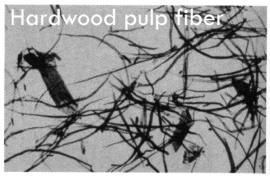

Structure of plant cell wall and axial direction of cellulose microfibrils

# Kind of pulp

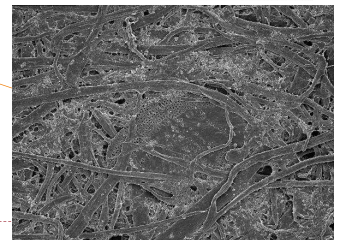
- **Pulp**
  - **Fibers mainly consisting of cellulose extracted from plant such as wood by mechanical or chemical treatment**
- Mechanical pulp [MP]
  - Fibers extracted from wood by crushing
- Chemical pulp [CP]
  - Fibers extracted from wood by dissolving lignin
- Deinked pulp [DIP] (recycled pulp)
  - Fibers extracted from waste paper by removing ink

# Chemical pulp – Fiber geometry

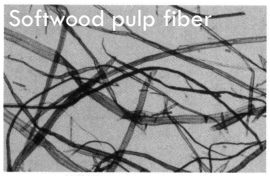


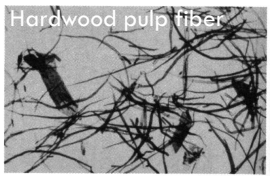




- Copy paper consists of (B) wood pulp fibers
- Observe pulps

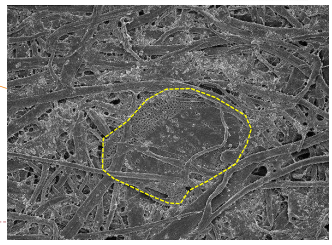


# Chemical pulp – Fiber geometry



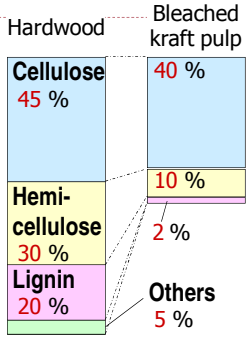




- Copy paper consists of hardwood pulp fibers
- Observe pulps



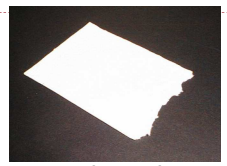
# Wood composition – Major 3 components

| Chemical component | Approx. ratio (%) | |
|---|---|---|
| | Softwood | Hardwood |
| Cellulose | 45 | 45 |
| Hemicellulose | 25 | 30 |
| Lignin | 25 | 20 |
| Others<br>Terpenoid<br>Resin acid<br>Fatty acid<br>etc. | 2 - 8 | |




Change of Composition by kraft pulping

# Form of pulp

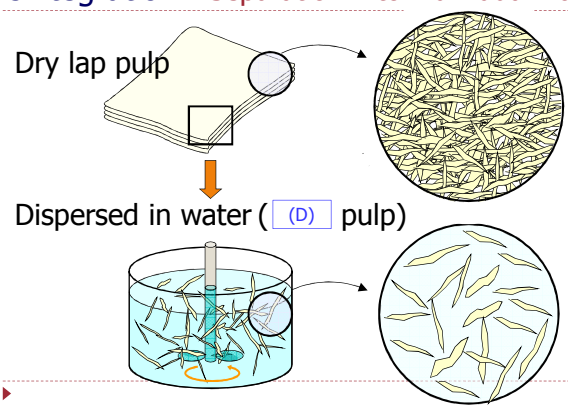


Dry lap pulp

- **Slush pulp**
  Pulp suspension with concentrations of approx. 1-4%
- **Lap pulp**
  Pulp Formed and folded by wet machine. Called "**Dry lap**" when dried
- **Bale pulp**
  A bunch of pulp sheets compressed and bound with a wire

Transported (C) pulp

# Disintegration - Separation into individual fibers



## Standard disintegrator (defibrator)

- Pulp is put in water in steel container with ca. 3.4 L capacity
- Stirred with a propeller mixer at 3000 $min^{-1}$ (rpm)
- Latency of MP should be removed at high temperature (Latent=hidden)

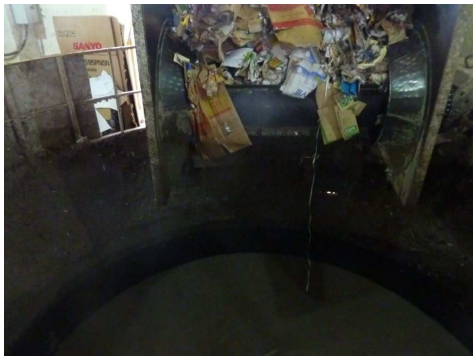
| Pulp | Dry mass | Water volume | Revol-utions |
|---|---|---|---|
| Chemical | 30 g | 2.0 L | 30,000 |
| Mechanical | 60 g | 2.7 L | 60,000 |

## Waste paper in yard

## Waste paper and pulp

## Belt conveyer

## Disintegration in industry (pulper)



## Disintegration in industry (Drum pulper)