Definition and function of Packaging and Packaging materials

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Introduction

✓ **Packaging has been with humans for thousands of years in one form or the other.**

✓**Packaging dates back to when people first started moving from place to place.**

✓ **Originally, skins, leaves, and bark were used for food transport.**

✓**Four thousand years ago, sealed pottery jars were used to protect against rodents, and glass making was an important industry in Egypt.**

✓ **Tin-plating iron became possible in AD1200, and as steel replaced iron this method became useful**

✓ One hundred years ago there was little use for packaging in the food industries.

✓ Now, tremendous progress has been made in the development of diversified packaging materials and in the packaging equipment.

✓ Over the last three decades, packaging has grown in volume and importance into one of the most significant areas of food production.

WHY PACKAGING IS REQUIRED ??

Factors affecting microbial growth in food

(a) Intrinsic factors:

These are inherent in the food. They include:

- pH
- Water activity
- Oxidation reduction potential
- Nutrient content
- Antimicrobial contents

(b) Extrinsic factors:

Are factors external to the food that affect microbial growth.

- Temperature
- Humidity

PACKAGING PERFORMS FIVE MAIN FUNCTIONS

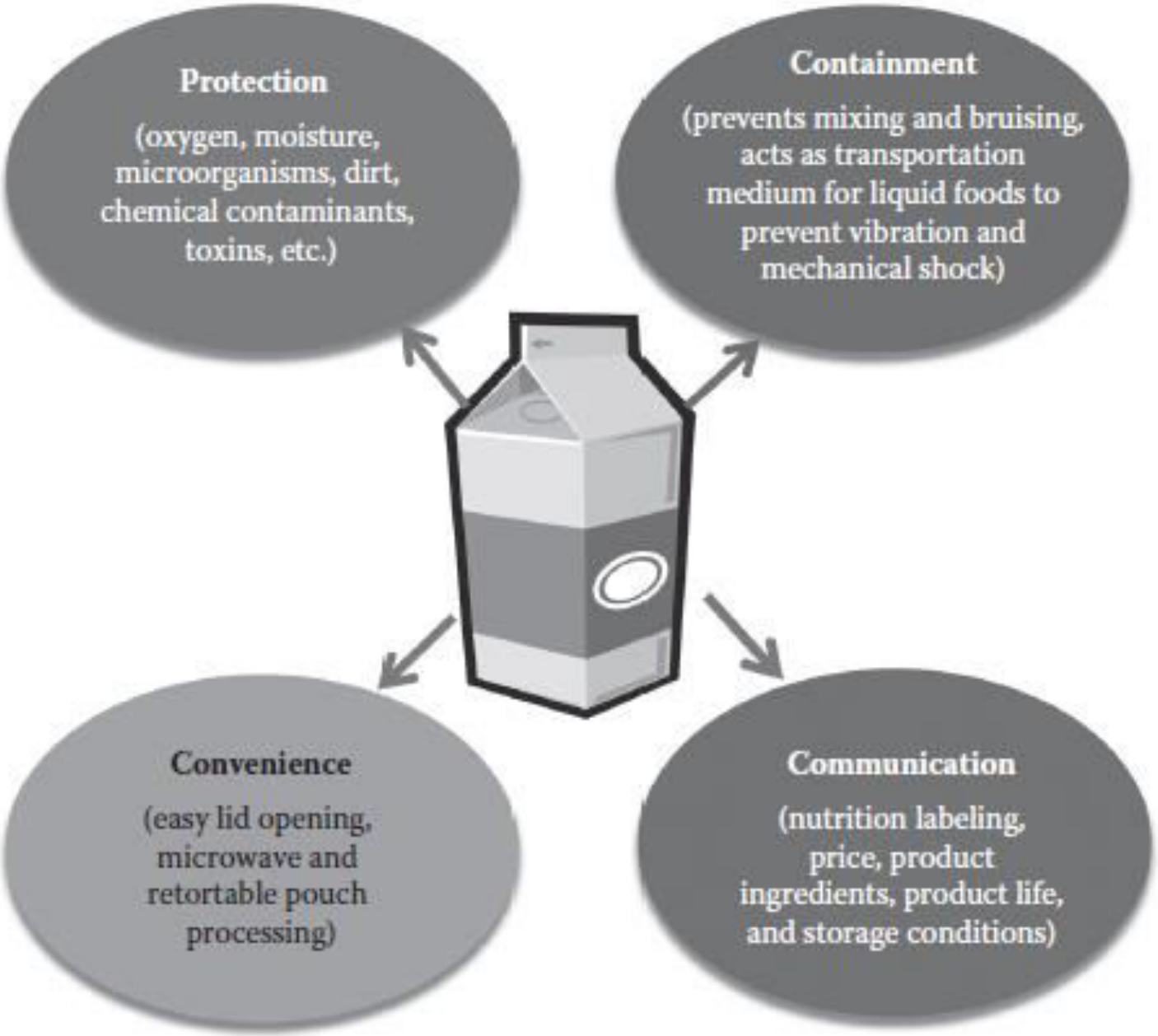
1- Product containment

2- Preservation and quality

3- Presentation and convenience

4- Protection during distribution and processing

5- Provide storage history


Protection
(oxygen, moisture, microorganisms, dirt, chemical contaminants, toxins, etc.)
Containment
(prevents mixing and bruising, acts as transportation medium for liquid foods to prevent vibration and mechanical shock)
Convenience
(easy lid opening, microwave and retortable pouch processing)
Communication
(nutrition labeling, price, product ingredients, product life, and storage conditions)

1-Product Containment

- The first function of packaging is its capability of containment.
The primary purposes of packaging are containment and protection.

- Liquids, semi liquids, and powders, as well as bulk solids, cannot be marketed without suitable containers.

- Containment refers to holding goods in a form suitable for transport, whereas protection refers to safekeeping goods in a way that prevents significant quality deterioration.

2-Preservation by Maintaining Quality

- The second function of packaging is to control the local environmental conditions to enhance storage life and safety.

The main purpose of food packaging is to protect the product from surroundings and maintain the quality of the food throughout the product's shelf life.

- Product shelf life is controlled by three factors:
  - Product characteristics
  - Packaging material properties
  - Environment parameters

- Reactions causing deterioration in foods include enzymatic, chemical, physical, and microbiological changes. Additional problems include insects, pests, and rodents.

Nutritional Quality

- Packaging affects the nutritional quality of foods.

- As antioxidative nutrients such as vitamins C and E are lost. Carotenoid pigments can also be oxidized, leading to loss of color as well as loss of their beneficial effects in the body.

- Lipid hydroperoxides can also result in the formation of aldehydes and other compounds with off-flavors.

Among all other functions of packaging, the protection of foodstuffs against light plays a key role particularly during storage, transport, and sales display.

Barrier Properties

- To achieve the best from packaging, it is important to know product characteristics, properties of individual package, storage, and distribution conditions.

- Barrier properties include permeability of gases such as:

O_2 ,CO_2 ,N_2 , C_2H_4 (Ethylene), water vapor, aromas, and light. These are vital factors for maintaining the quality of foods.

- Packaging materials cannot be chosen solely on the basis of their barrier properties.

- Factors such as proccessability, mechanical properties and chemical resistance and interaction with product and Environmental factors, such as temperature, relative humidity, and light intensity must also be taken into account.

- Now various types of active substances can be incorporated into the packaging material to improve its functionality and give it new or extra functions.

- Such **Active packaging technologies** and **Antimicrobial Packaging** and **Edible Film** are designed to extend the shelf life of foods, while maintaining their nutritional quality and safety.

3. Presentation and Convenience

- **Food labels are intended by law to provide the information that consumers need to be able to make the necessary decisions about those purchases of food.**

- **It is important to display the product in an attractive manner to the potential buyer.**

- **A cleverly designed and beautifully produced packaging can help sell a product, which is an essential ingredient of an effective marketing campaign. The packaging helps in distinguishing products on the shelf, which is a trait especially important when marketing low-fat or nutritional products.**

- **For a package to be effective, it must present the product well and should do its own publicity.**

- Changes in society, such as diminishing population pattern, increasing average age, smaller families, more leisure time, as well as improvements in the quality of life, standard of living, and general level of education, may also demand specific function of packaging.

- Eating styles, such as ready-to-eat meals, snacks, and microwaveable ready meals, have been changed over the years, which need innovation in packaging.

- Packaging should meet the future demand of meeting eating style of the society.

4- Protection during Distribution and Processing

- The fourth function is to protect the product during transit to the consumer. Packaging is part of the distribution process necessary to deliver goods to the consumer and facilitate handling and transportation.

- It also has affected international trade by making shipping of food products possible, allowing seasonal products to be more accessible out of season.

- Packaging can handle better when there are challenges in food distribution chain, such as heat, humidity, or dew.

- It is important to be aware of the distribution challenges and designing of package to suit it.

- In case of prepacked product, it should have the ability to stand the severity or type of process conditions, such as flexible packaging during canning, microwaveable foods, ovenable , and retortable foods.

- Irradiated foods are usually prepacked prior to treatment by ionizing radiation.

- Protective packaging is a term applied to packaging primarily designed to protect the goods, rather than for appearance or presentation.

5-Provide Storage History

- Time-temperature indicator (TTI) is effective for predicting microbial concentrations and other parameters of food quality during shipping and storage.

- It helps in ensuring proper handling and provides a gauge of product quality for sensitive products in which temperature control is imperative to efficacy and safety..

- TTI could be used in chilled foods to identify the temperature abuse during storage and distribution.

- TTIs are tags that can be applied to individual packages or shipping cartons to visually indicate whether a product has been exposed to time and temperature conditions that adversely affect the product quality.

- According to the response mechanisms, TTIs can be divided into three groups: (i) biological, (ii) chemical, and (iii) physical systems

- There are two issues to be considered:

One is the economics .

The other issue is knowledge of the food product.

Ideal Packaging

- Zero toxicity
- High product visibility
- Strong marketing appeal
- Ability of moisture and gas control
- Stable performance over a large temperature range
- Low cost and availability
- Suitable mechanical strength (i.e., strength in compression, wear, and puncture characteristics)
- Easy machine handling and suitable friction coefficient
- Closure characteristics, such as opening, sealing and resealing, pouring

Packaging categories

1- Primary packaging

Primary packaging surrounds the product and features labelling.

2- Secondary packaging

Ease of manual movement of products.

3- Transit packaging

wrapping used to bundle the boxes or crates for transport and distribution.

Selecting the right material

Material selection is based on:

- Technical properties (strength, flexibility, etc.)
- Fitness for purpose (moisture barrier, cushioning, etc.)
- Availability
- Manufacturing capability
- Cost
- Environmental impact
- Regulations

Types of Packaging Materials

From skins, leaves, and bark, tremendous progress has been made in the development of diversified packaging materials and in the packaging equipment.

In general, packaging materials may be grouped into

1- Rigid (wood, glass, metals, and hard plastics).

2- Flexible structures (Plastic film, foil, paper, and textiles).

Plastics

- Wide diversity and extremely **broad spectrum of properties**. Plastics are relatively cheap, light, easily processed and shaped, and easy to seal.

- **Two major drawbacks** are their **permeability to gases and vapors**, and the possibility of their **interacting with the product**.

- Other components in plastics are residual monomer and oligomers, additives such as **heat and light stabilizers, antioxidants, plasticizers, and UV absorbers** as well as processing aids such as **lubricants, slip agents, and antistatic agents**.

- For package sterilization the material of choice is **polypropylene (PP)**, which is used as the outer and inner plies of the laminate with **poly-vinylidene chloride (PVDC)** as the middle layer to provide an **oxygen barrier.**

- Plastics can be classified into **thermosets** and **thermoplastics** which are often made by the process of condensation or additional polymerization.

- **Thermosets** are mainly used in **nonfood applications**, while **thermoplastics** constitute the **major packaging material** used for films, bottles, jugs, and so on for food industries.

- Although several plastics are allowed for food use (such as polyolefins, polyesters, polyvinyl chloride, polyvinylidene chloride, polystyrene, polyamide, ethylene vinyl chloride, laminates, and coextrusions).

- However, plastic use in food packaging has continuously increased because of the low cost and other **functional advantages** such as optical properties, thermostalability, microwavability, and so on.

Table 1.1 Properties of the Commonly Used Plastic Packaging Materials for Food Products

Type	Physical Properties	Mechanical, Chemical, and Miscellaneous Properties	Barrier Properties	Food Use
Polyolefins				
LDPE	Density (910–925 kg m^{-3}), transparency (poor–fair), low crystallinity, temperature range (–50°C to 80°C)	Tough, flexible, resistant to grease and chemicals, good sealing properties	High moisture barrier, very low gas barrier	Bread and frozen food bags, flexible lids, squeezable food bottles, etc.
LLDPE	Density (910–940 kg m^{-3}), transparency (poor–fair), high crystallinity, temperature range (–30°C to 100°C)	Tough, extensible, good resistance to grease, good sealing properties	High moisture barrier, very low gas barrier	Stretch/cling wrap, heat sealant coating, etc.
HDPE	Density (945–967 kg m^{-3}), transparency (poor), high crystallinity, temperature range (–40 to 120°C)	Tough, stiff, strong, resistant to grease and chemicals, good sealing properties, easy to process and form	Extremely high moisture barrier, very low gas barrier	Used for bottles of milk, juice, and water; cereal box liners, margarine tubs; trash and retail bags
PP	Density (900–915 kg m^{-3}), transparency (fair), low crystallinity, temperature range (–40°C to 120°C), high meting point of 160°C	Moderately stiff, strong, good resistance to grease and chemicals	High moisture and low gas barrier	Used for bottles of milk, juice, and water; cereal box liners; margarine tubs; hot filled and microwavable packaging; trash and retail bags
Polyesters	Density (900–915 kg m^{-3}), high transparency (like glass); temperature range (–10°C to 220°C), high meting point of >200°C	High impact-resistance, low scratch-resistance, tough, strong, and resistant to grease and oil	High moisture and gas barrier	Refillable water bottles, sterilizable baby bottles
PETE or PET	Density (1380–1410 kg m^{-3}); high transparency (good), low crystallinity, temperature range (–60°C to 200°C)	Stiff, strong, good resistance to grease and chemicals	Good barrier to gases and moisture, good grease resistance	As containers (bottles, jars, and tubs), semirigid sheets (trays and blisters), and thin oriented films (bags and snack food wrappers)
PEN	Density (1.36 g cm^{-3}), transparency (good), applicable at both high and low temperatures	Stiff, chemical and hydrolytic resistance, thermal and thermo-oxidative resistance	Good gas and moisture barrier, UV light barrier	Suitable for hot refills, rewashing, and recyclable. Suitable for beer and wine bottles to preserve the flavor

(Continued)

Table 1.1 *(Continued)* **Properties of the Commonly Used Plastic Packaging Materials for Food Products**

Type	Physical Properties	Mechanical, Chemical, and Miscellaneous Properties	Barrier Properties	Food Use
Polycarbonate				
PVC	Density (1350–1450 kg m^{-3}), transparency (good), temperature range (–2°C to 80°C)	Strong, stiff ductile, resistant to chemicals, stable electrical properties	High moisture barrier, moderate oxygen barrier, good resistance to grease and oil	Used in bottles and packaging films. Limited use in food applications
PVdC	Density (1600–1700 kg m^{-3}), transparency (good), temperature range (–20°C to 130°C)	Strong, stiff ductile, resistant to chemicals, stable electrical properties	Excellent oxygen and moisture barrier properties, very good grease and oil resistance	Suitable for poultry, cured meats, cheese, tea and coffee, snack foods, and confectionery. May be used in hot filling, low temperature storage, and modified atmosphere storage conditions
Polystyrene	Density (1030–1100 kg m^{-3}); transparency (very good), temperature range (–20°C to 90°C)	Hard and brittle with low melting point	Low moisture and air barrier, fair to good resistance to oil and grease	Used as protective packaging for eggs, disposable plastic ware, cups, plates, bottles, and trays. Expanded form may be used as cushioning material
EVOH	Density (1140–1210 kg m^{-3}), transparency (good), applicable temperatures (–20°C to 150°C)	Stiff, strong, very strong oil and grease resistance	Excellent moisture barrier, high air barrier, very good resistance to grease and oil	Used in coextruded films to avoid its contact with water
Polyamide	Density (1130–1160 kg m^{-3}), transparency (good), applicable temperatures (–2°C to 120°C)	Stiff, strong, good resistance to grease and chemicals	High air and moisture barrier, good resistance to grease and oil	Used for boil-in-bag packaging

Source: Marsh, K., Bugusu, B., *J. Food Sci.*, 72, R39–R55, 2007; Lee, D.S., et al., *Food Packaging Science & Technology*, CRC Press, Boca Raton, FL, 2008.

Note: EVOH, ethyl vinyl alcohol; HDPE, high-density polyethylene; LDPE, low-density polyethylene; LLDPE, linear low-density polyethylene; PEN, polyethylene naphthalate; PETE, polyethylene terephthalate; PP, polypropylene; PVC, polyvinyl chloride; PVdC, polyvinylidene chloride.

Plastic–Food Interaction

- Polymer materials are not absolute barriers. Interactions occur between foods, packages, and polymer materials

In case of plastics, the major source of concern is the component migration.

Migration from plastics is mainly due to:

1- Residual components and reactants from the manufacturing process
2- Compounds formed during conversion into packaging materials and packages
3- Additives incorporated
4- Adhesives used during conversion.

- Other factors includes crystaliity of polymers, glass-rubber transition, environmental conditions, and composition of packaged food.

Metals (Steel, Tin, Aluminum)

- Steel, tin, and aluminum are used mainly for canned foods and beverages. The most common use of metals for packaging is in tin-coated steel and aluminum cans.

- The principal advantages of metal cans are their strength providing mechanical protection, effective barrier properties, and resistance to high temperatures providing stability during processing. it is an advantage for light-sensitive products.

- Disadvantage in that contents are: invisible, heavy mass, high cost, and tendency to interact with contents and environment (internal and external corrosion)

➢ The steel can provide almost perfect barrier protection and, due to its structural strength and ability to handle pressure, can be retorted (cooked under pressure) after sealing .

Metal-Food Interaction

- Corrosion is the destructive attack on a metal through the chemical or electrochemical reaction with the environment. Since **steel corrodes rapidly** in the presence of acidic substances, the **tin acts as a barrier**.

- Some cans are lacquered internally for high-acid products (pH < 3) or for products that change color in the presence of tin.

- Foods that contain **sulfur produce a blackening** of the tin.

GLASS

Advantages

- Glass containers used to be and still are considered a prestigious means of packaging, and serve for the most expensive wines, liqueurs, perfumes, and cosmetics.
- It is highly inert, impermeable to gases and vapors, and amenable to the most diverse shaping. It is an excellent oxygen barrier and completely neutral in contact with foods
- It has the advantage of transparency, but where required it can be given different desired colors.
- It has complete as well as selective light protection properties.

Disadvantages

- Fragility, heavy mass, and high energy requirement during manufacturing.

- The main uses of glass for packaging are in milk bottles, condiments, baby foods, instant coffee, and drinks.

- Glass is not used for frozen products, or for ground or roasted coffee because of breakage costs and the difficulty of vacuum flushing.

Timber, Cardboard and Papers

- Pulp products are widely used in food packaging in the form of different kinds of paper, paperboard, laminates, and corrugated board.

- The main advantages of paper are its low cost, low mass, relatively high stiffness, and excellent printability.

- The main disadvantage is its high sensitivity to moisture, reflected in close dependence on the relative humidity of the environment.

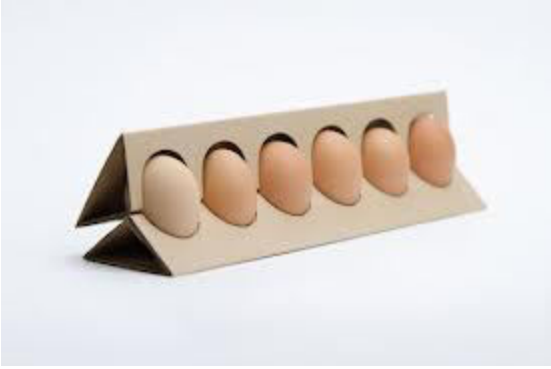
- The basic raw material for papermaking is cellulose.

Timber

Wood is commonly used in box construction but the use of wood for individual packaging (such as cigars) has decreased since the advent of plastics. Examples of timber for packaging are cases, boxes, and casks for long-distance transport.

Cardboard

Choosing a carton for a specific job depends on the capacity of the carton to meet the requirements for that job.



Paper

- Paper is modified with additives (lacquers, waxes, resins, etc.) or coextruded with other polymers to improve its barrier properties.

- Paper and paper boards are used in different forms (corrugated boxes, cartons, bags, sacks, and wrapping paper) for several packaging levels in food and allied products.

Different forms of paper

1. Kraft paper: This paper is used to fabricate bags and wrappings. It is the **strongest paper** and is used for packaging flour, sugar and dried fruits and vegetables.

2. Sulfite paper: This paper is **glazed to improve its appearance**, **wet strength**, and **oil resistance**. It is relatively lighter and weaker than kraft paper but has **high print quality**. It is often used with plastic or foil laminates to prepare packaging materials for biscuits and confectionery.

3. Greaseproof paper: Offering **resistance to oil** but **allowing moisture migration**, greaseproof paper is commonly used to pack cookies, butter, oily foods, candies, and so forth.

4. Glassine: This greaseproof paper has a high degree of smoothness and a glossy finish. It is commonly used for packaging biscuits, fats, fast foods, and so on.

5. Parchment paper: Made from acid-modified cellulose to improve its air and moisture barrier properties, parchment paper is used for butter, lard, and fat packaging.

6. Paperboard: Paperboard is available in several forms (white board, solid board, chip board, fiber board, and paper laminates) and is mainly used in secondary packaging to improve the handling and distribution of food products.

Environmental Issues

Recently, **a new dimension of safety** has arisen, the ecological dimension.

This means that packaging has not only to satisfy physical, chemical, and biological criteria using their life cycle as packaging but once the original function has been fulfilled the packaging should decay without polluting the environment.

Biodegradable material for packaging

Biodegradation is the process by which carbon-containing chemical compounds are decomposed in the presence of enzymes secreted by living organisms.

There are three requirements for the fast degradation process viz. temperature, humidity and type of microbes.

Acceptable bio-plastics

1- Cellulose
2- Starch
3- Poly-beta-hydroxyalkanoates (PHB): a polymer belonging to the polyesters class that are of interest as bio-derived and biodegradable plastics.
4- Polylactide Acid (PLA) plastics: derived from renewable resources, such as corn starch, tapioca roots, chips or starch or sugarcane. In 2010, PLA had the second highest consumption volume of any bio plastic of the world.

Application of nano-composites

- Research on application of nano-composite (scale of 1-100 nm) materials (nano-materials) in packaging is exponentially increasing.

- Nano-composite materials are composed of nanoscale structure that enhances the macroscopic properties of food products.

The common nano-composites used in the food packaging industry

(1) Polymer clay nanoclay increased stiffness, strength, nucleating agent in foams, smaller cell size, higher cell density, and flame retardant

(2) Silica nano-composites of nano silver has excellent antibacterial properties

Thank you