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Anjugramam - Kanyakumari Main Road, Palkulam,Variyoor P.O. - 629 401, Kanyakumari District.

CAI 335 : SOLAR AND WIND ENERGY SYSTEMS

UNIT 1

SOLAR ENERGY RADIATION AND SOLAR THERMAL COLLECTORS

Prepared by:

Mr.Arunpandian.N.

Assistant Professor

Department of Agricultural Engineering

Selective surfaces in solar thermal systems play a crucial role in improving the efficiency of solar collectors by enhancing the absorption of solar radiation while minimizing the loss of heat. These surfaces are specifically engineered to optimize energy collection, making them a key feature in solar thermal technologies like flat-plate collectors, evacuated tube collectors, and other solar energy systems.

Purpose of Selective Surfaces

The primary purpose of a selective surface is to maximize solar radiation absorption while minimizing heat loss through emission of infrared radiation (radiative losses). Solar radiation consists mainly of visible light and infrared radiation, and a good selective surface should absorb most of the incoming radiation but emit as little heat as possible to the surroundings. This improves the overall efficiency of the solar thermal system.

Characteristics of Selective Surfaces

A selective surface has two key characteristics:

1. High Absorptance (α): The surface must be highly absorptive to solar radiation, particularly in the visible and near-infrared spectrum (wavelengths between 0.3 to 2.5 micrometers). High absorptance ensures that most of the incoming solar energy is absorbed rather than reflected or transmitted.

2. Low Emittance (ε): The surface should have low emittance in the infrared region (long-wavelength radiation, typically 3 to 50 micrometers). Low emittance means that the surface radiates less energy, reducing heat loss to the surrounding environment, especially at high temperatures.

These properties are generally represented as:

- Absorptance (α) > 0.90 for effective absorption.

- Emittance (ε) < 0.10 for minimal heat loss.

Types of Selective Surfaces

There are several ways to create selective surfaces, and different materials and coatings are used to achieve the desired thermal properties.

1. Metallic Coatings:

- Copper and aluminum are commonly used metals for absorber plates. They are good conductors of heat and can be coated with special materials to increase their absorptance and reduce emittance.

- Copper, in particular, is often used in high-performance systems because of its excellent thermal conductivity. However, copper's natural surface may not be sufficiently selective, so it is typically coated with a selective material.

2. Ceramic Coatings:

- These coatings are usually applied to metal substrates and are designed to create a surface with both high absorption and low emissivity. Ceramic coatings are durable and can withstand high temperatures, making them suitable for high-efficiency solar collectors.

- A common example is the use of **titanium nitride (TiN)** or **tungsten (W)** coatings, which are known for their selective properties and resistance to oxidation.

3. Black Chrome Coatings:

- Black chrome is a widely used selective coating in solar thermal applications due to its combination of high absorptance and low emittance. The black chrome layer is deposited onto a metal surface like copper or aluminum using electroplating techniques.

- This coating absorbs sunlight effectively while minimizing thermal radiation losses.

4. Cermet Coatings:

- Cermet coatings consist of a combination of ceramic materials and metals. These coatings offer high solar absorptance and low emittance. The ceramic component helps with low emittance, while the metal component enhances thermal conductivity. Cermet coatings are particularly used in high-temperature applications.

5. Vacuum Deposition Coatings:

- Techniques like sputtering or evaporation are used to apply thin films of materials that have selective properties. These films are often made from metals like gold, silver, or titanium, and can achieve extremely low emissivity values. These coatings are often used in evacuated tube collectors, where high performance at elevated temperatures is required.

6. Organic Coatings:

- Organic polymers or carbon-based coatings can also be used as selective coatings. These materials are sometimes cheaper to produce but may not offer the same high temperature resistance as metal or ceramic coatings. Research continues to improve the longevity and thermal performance of organic-based coatings.

Performance of Selective Surfaces

The efficiency of a solar collector depends largely on the quality of the selective surface. An ideal selective surface should have:

- Durability: It should withstand long-term exposure to sunlight, weather, and environmental conditions without degrading. This is particularly important because the collector needs to maintain high absorptance and low emittance over time.

- Stability at High Temperatures: The surface should remain effective even under high operating temperatures (over 100°C), as solar thermal systems often operate at elevated temperatures.

- Cost-effectiveness: While high-performance selective coatings are critical, they should also be cost-effective to make the solar thermal system commercially viable.

Example Applications of Selective Surfaces

Selective surfaces are used extensively in a variety of solar thermal applications:

- Flat-Plate Collectors: These collectors use selective coatings on absorber plates to maximize heat absorption and minimize heat loss.

- Evacuated Tube Collectors: In evacuated tube systems, the absorber tubes are coated with selective surfaces to ensure high absorption and efficient heat transfer.

- Solar Power Plants: Large-scale solar thermal power plants, such as concentrated solar power (CSP) plants, often use highly selective surfaces to focus and absorb solar radiation and convert it to heat for power generation.

Conclusion

Selective surfaces are an essential component in solar thermal systems. Their ability to absorb solar radiation efficiently while minimizing heat losses through radiation is key to improving the overall performance of solar energy collectors. Different materials, coatings, and manufacturing techniques are used to create selective surfaces, depending on the specific requirements of the solar thermal system and the desired performance characteristics.