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AUTONOMOUS INSTITUTION
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VII Semester

AU3008 Sensors and Actuators

UNIT – 3 - Variable and Other Special Sensors

3.6 Semiconductor Sensor

- A sensor detects an event or a change in a factor and responds with an output. The measured phenomenon may be chemical, electrical, mechanical, radiant, magnetic or thermal.
- Most sensors operate using semiconductors and are therefore called semiconductor sensors. The materials most commonly used for semiconductors include silicon and other members of groups III to V.
- Many types of semiconductor temperature sensors are available, and are classified into five categories:
    - **Voltage output -** linear output, low output impedance.
    - **Current output -** constant current regulator displaying high impedance.
    - **Digital output** - both sensor and analog-to-digital converter integrated on one chip, typically specific to microprocessor chips rather than measuring devices.
    - **Resistance output** - exploits temperature vs. bulk resistance properties of semiconductors to provide more stable sensors, but may heat up which can be hazardous.
    - **Simple diodes** - the least expensive, but require two-point calibration and stable current input for good results

Construction of a Semiconductor Sensor

1. **Sensitive Semiconductor Material**:

- The core component is a semiconductor material like silicon (Si), tin dioxide (SnO_2), or zinc oxide (ZnO).
- The material is chosen based on the application (e.g., SnO_2 for gas sensors, Si for temperature sensors).

2. **Substrate**:
   - The semiconductor material is deposited on a substrate like glass or ceramic for structural support.
3. **Electrodes**:
   - Metal electrodes are attached to the semiconductor for electrical contact, allowing the measurement of changes in electrical properties.
4. **Encapsulation**:
   - The sensor is often encapsulated to protect it from external damage while allowing the target substance (e.g., gas or heat) to reach the sensitive material.
5. **Heater (for some sensors)**:
   - Gas sensors, for instance, may include a heating element to operate at a specific temperature for enhanced sensitivity.

Working of a Semiconductor Sensor

1. **Principle**:
   - Semiconductor sensors operate based on the **change in electrical resistance** or other properties of the semiconductor material when exposed to a stimulus (e.g., heat, light, or gas molecules).
2. **Mechanism**:
   - **Adsorption**: For gas sensors, target gas molecules are adsorbed onto the surface of the semiconductor, altering its surface charge.
   - **Charge Carrier Variation**: This interaction changes the concentration of charge carriers (electrons or holes) in the semiconductor.
   - **Resistance Change**: The change in charge carriers results in a measurable change in electrical resistance.
3. **Signal Processing**:
   - The change in electrical resistance or another parameter is converted into an electrical signal.

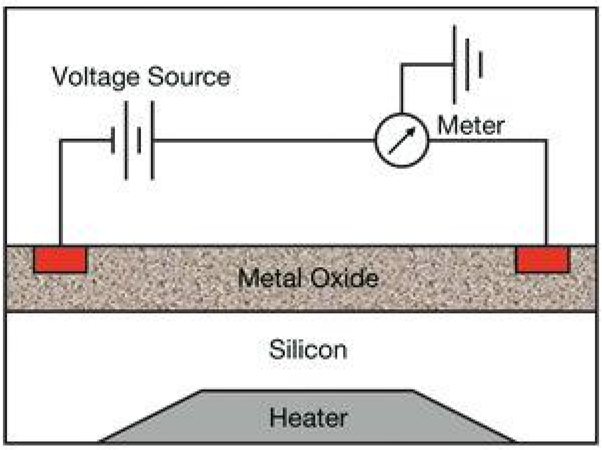
- This signal is processed to quantify the magnitude of the stimulus (e.g., gas concentration, temperature).

Applications

1. **Gas Sensors**:
   - Detect toxic gases (e.g., CO, NO_2), combustible gases (e.g., methane), and air pollutants.
   - Example: Tin dioxide (SnO_2) for detecting carbon monoxide.
2. **Temperature Sensors**:
   - Measure temperature by tracking changes in the semiconductor's resistance or voltage drop.
   - Example: Silicon-based thermistors.
3. **Humidity Sensors**:
   - Measure ambient humidity by detecting changes in conductivity or capacitance.
4. **Light Sensors**:
   - Detect light intensity based on changes in photoconductivity of the semiconductor.

Example:

Semi-conductor Gas Sensor



This image illustrates the **working principle** of a semiconductor gas sensor in a simplified circuit diagram. Here's an explanation of its key elements:

Components:

1. **Voltage Source**:
   - ❖ Provides a constant voltage across the sensor for measuring changes in resistance of the metal oxide layer.
2. **Metal Oxide Layer**:
   - ❖ Acts as the sensing element.
   - ❖ The electrical resistance of this layer changes when gas molecules interact with its surface, altering the flow of current.
3. **Electrodes**:
   - ❖ Connect the metal oxide layer to the external circuit, allowing measurement of resistance.
4. **Meter**:
   - ❖ Measures the current or voltage changes caused by variations in the resistance of the metal oxide layer.
5. **Silicon Heater**:
   - ❖ Maintains the temperature of the sensor at an optimal level for chemical reactions between gas molecules and the metal oxide.

Working Principle of Semi-conductor Gas Sensor:

1. **Initial State**:
   - ❖ Without the presence of the target gas, the metal oxide has a specific baseline resistance.
2. **Gas Interaction**:
   - ❖ When gas molecules come into contact with the metal oxide surface, they are adsorbed.
   - ❖ Depending on the type of gas, this interaction either adds or removes free electrons from the semiconductor.
3. **Change in Resistance**:
   - ❖ The adsorption of gas molecules alters the resistance of the metal oxide layer.

- For reducing gases (e.g., CO), electrons are donated, reducing resistance.
- For oxidizing gases (e.g., NO_2), electrons are trapped, increasing resistance.

4. **Signal Measurement**:
   - The change in resistance is detected as a change in current or voltage by the meter.
   - This change correlates to the concentration of the target gas.
5. **Heater Functionality**:
   - The silicon heater ensures the sensor operates within a specific temperature range, which enhances sensitivity and reaction speed.

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