18ECO134T – Sensors and Transducers

Unit IV : Session 5 : SLO 2

8.2.1 Thick Film Sensors

Thick film deposition is a mature technique and there has not been substantial improvement whilst thin films are being developed almost at the same pace as microelectronics incorporating latest technology. It is to be noted that thick film process had been in use for producing capacitor, resistor, and conductors—and has subsequently been adopted in sensor development. The processing of a sensor can be expressed schematically as

Step 1: Selection and preparation of a substrate.

Step 2: Preparation of the initial coating material in paste or paint form.

Step 3: Pasting or painting the substrate by the coating material or screen printing it.

Step 4: Firing the sample produced in step 3 in an oxidising atmosphere at a programmed temperature format.

The substrates used for developing thick film over them are alumina (96% or 99.5%) and beryllia (99.5%). These are fired at about 625°C. Others used are enamelled steel which is low carbon steel coated with low alkali content glass frit that are fired at around 850°C. Alumina or beryllia have dielectric constants around 9.5 and 7 respectively with dielectric strength around 5600 V/μm. Thermal expansion coefficients are 6.5×10^{-6} and 7.5×10^{-6} respectively with bulk resistivity being almost the same for both, at about 10^{14} Ωcm, thermal conductivities are 0.36 and 2.5 W/(cmK) respectively. Enamelled steel has better strength and machinability being almost double for those of alumina or beryllia which have values around 175 MPa. Though it has better machinability and improved thermal conductivity, enamelled steel is less costly.

For thin film deposition, alumina and beryllia can also be used. Besides, special glass, quartz, fused silica and sapphire are often used which have similar properties and sometimes even better.

It is to be understood that the compatibility between the substrate and the transducing element in film sensors is very important. For example, there should not be difference of thermal expansion coefficients which would induce stress between them and correspondingly result in zero offset, drift, and instability.

Temperature: Thick film sensors such as (i) thermopiles (usually of gold and gold-platinum alloy), (ii) thermistors (usually with oxides of manganese, ruthenium, and cobalt), and (iii) temperature dependent resistances based on gold, platinum, and nickel are used for temperature sensing.

Pressure: Sensing pressure is possible by making thick film diaphragms or capacitive devices made with alumina (Al_2O_3) and $Bi_2Ru_2O_7$, or piezoresistive devices made of same materials.

Concentration of gases: Gases such as methane (CH_4), CO, and C_2H_5OH can be checked for concentration using films of SnO_2 + Pd, SnO_2/ThO_2 + hydrophobic SiO_2. H_2, CO, C_2H_5OH, and isobutane are sensed by SnO_2 + Pd, Pt, Ba^-, Sr^- and $CaTiO_3$ (Nasicon). Oxygen and hydrogen gases also are separately sensed by these types of films

Humidity: It is sensed by (i) resistive films made from RuO_2 (spinel type)/glass and (ii) capacitive films made from glass ceramic/Al_2O_3. On the other hand, dew point is sensed by films made from ($BaTiO_3/RuO_2$)-glass.

Starting from the same basic material, say $SnSO_4$, one can produce SnO_2-based sensors for H_2, CO, and NH_3, as mentioned in the preceding paragraphs. The host material (1% by weight), $PdCl_2$ mixed with SnO_2 as catalyst and $Mg(NO_3)_2$ (also 1% by weight) is mixed presumably for sensitivity range. The combination is fired at about 800°C for one hour. Selectivity is obtained by a second firing process at almost the same temperature by adding different ingredients for different gases. For H_2 detection, for example, it is mixed with Rh (6% by weight) and fired for 1 hour at 800°C. For CO, ThO_2 is added (5% by weight) and for NH_3, ZrO_2 is added (5% by weight) and processed in the same manner as explained.

For control of the porosity of the films which determine the overall sensor sensitivity, organic materials are added in a selective manner. For example, alcohol is added for H_2 and sometimes, inorganic materials work well with appropriate selection. Silica of different varieties is added for CO and NH_3. The materials so produced are now painted on the substrate and dried, then calcined at controlled temperature for varying times.

The other thick film variety is the ceramic-metal or *cemet* which consists of gold/silver/ruthenium/palladium based complex oxides in an insulating medium, mainly glass (lead borosilicate). There are thick film resistors of the cemet which require precise control of heat treatment. The resistivity is controlled by the size, concentration, and distribution of the metallic (conductive) component, that is, their own resistive properties, and the insulating medium. Pure metal powders and resistor pigments differ in so far as changes in their resistive values are concerned and hence, their embedding in per cent weight changes the resistivity of the sensor developed. Figure 8.1 shows the difference for two typical cases.

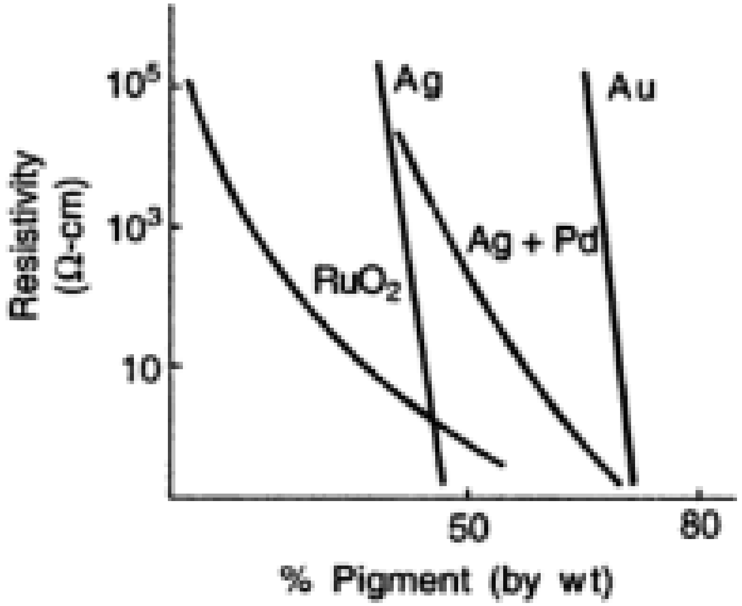

Fig. 8.1 Resistivity variation with change in pigment.

8.2.2 Thin Film Sensors

Thin film sensor processing differs from thick film technology mainly in the film deposition techniques. This technology is similar to that used in silicon micromechanics. A number of techniques are used for thin film deposition, such as:

(a) Thermal evaporation
  (i) resistive heating
  (ii) electron beam heating

(b) Sputter deposition
  (i) DC with magnetron
  (ii) RF with magnetron

(c) Chemical vapour deposition (CVD)

(d) Plasma enhanced chemical vapour deposition (PECVD)

(e) Metallo-organic deposition (MOD)

(f) Langmuir–Blodgett technique of monolayer deposition.

Of these, the thermal evaporation and sputter deposition are decades old. However, in the sputter deposition technique, magnetron sputtering is an improved form where a magnetic field perpendicular to the applied electric field is applied. This increases the ionization probability of the electrons as the Lorentz force $\mathbf{E} \times \mathbf{B}$ restricts the primary electrons near the cathode. As a result, sputtering efficiency is also enhanced.