ABSTRACT

Fibre-reinforced polymer-matrix composites enjoy the reputation of having high specific stiffness and strength compared to metals. Therefore, these materials are very attractive for lightweight applications such as aeronautics, transport, sports and so on. Structural components with high quality demands are often produced by autoclave-assisted curing. The quality of the final composite component is strongly influenced by the conditions of the autoclave cycle, i.e. cure time, pressure and temperature. To assure optimal quality of the composite part, there is a growing demand for sensors capable of in-situ monitoring of the curing process during the autoclave cycle.

Thin-film thermocouples (TFTC) are a promising candidate to fulfill in-situ temperature sensing. Unlike more conventional fibre-, foil- or micro-sensors, TFTCs can be embedded without major impact on the composite’s structural life, integrity and mechanical properties. In this work, the feasibility of self-sensing composites based on embedded TFTCs deposited by DC magnetron sputtering is explored.

CONCLUDING DEPOSITION CONDITIONS

We are looking for the most favorable sputter conditions of both chromel Ni90Cr10 and constantan Cu55Ni45 for optimal performance of E-type TFTC deposited on thermal sensitive epoxy substrates.

Scanning 30 different conditions for each material by varying the discharge current I, the argon pressure P and the Target-Substrate distance d.

Details
- Residual gas pressure < 1E-04 Pa
- Average layer thickness ~350 nm
- Target Size: 2 inch circular targets

Apparatus
- Thermal Flux (E-probe)
- Resistivity (4-point probe)
- Layer Density (XRR)

EXPERIMENTAL

Embedding a TFTC

Laser-cut sputter mask
Deposition of chromel leg
Deposition of constantan leg
Embedding TFTC in prepreg lay-up
Cured composite

REQUIREMENT I: LOW THERMAL FLUX

The thermal flux towards the substrate must remain low in order not to exceed the glass temperature of the epoxy resin.

CHROMEL

\[ \text{Thermal Power Density (mW/cm²)} \]

CONSTANTAN

\[ \text{Thermal Power Density (mW/cm²)} \]

The thermal power towards the substrate is mainly determined by the TS-distance. The Ar pressure only plays a minor role.

A higher discharge current results in a higher thermal power. Low current and large TS-distance are therefore beneficial for sputter depositions on thermal sensitive polymeric surfaces.

REQUIREMENT II: LOW RESISTIVITY

The resistivity of both legs of the TFTC must remain low in order to achieve good thermal emf output for sensing applications.

CHROMEL

\[ \text{Resistivity (Ohm-cm)} \]

CONSTANTAN

\[ \text{Resistivity (Ohm-cm)} \]

Resistivity depends on both the Ar pressure P and the TS-distance d during deposition. This makes \( P \times d \) a useful process parameter to link the resistivity of the thin film to the sputter process.

Low resistivities are obtained by sputtering at small \( P \times d \) values. The resistivity increases with decreasing current only for larger \( P \times d \) values. For both materials the resistivity is linked to the density of the thin film.

CONCLUSION

The constrains of low thermal power towards the substrate and low resistivity of the TFTC legs require the depositions to occur at low current and pressure and intermediate target-to-substrate distance. Given the thermal capacity of a type of fibre-reinforced polymeric substrate, appropriate sputter conditions for the deposition of each leg of the E-type TFTC can be selected.