Infrared absorption in thick film resistors

B. Uluğ, A. Uluğ, E. Sener*
Department of Physics, and *Department of Chemistry, Faculty of Arts and Sciences, İnönü University, Malatya, Turkey

Infrared absorption in polymer and glass-based thick film resistors has been measured between 400 and 1500 cm⁻¹. Sample structures are discussed on the basis of X-ray, Fourier transform-infrared and resistance-temperature data. It is shown that in polymer-based thick film resistors, the particulate phase is mostly responsible for the infrared absorption between 400 and 900 cm⁻¹, whereas the infrared absorption at higher wave numbers is related to the continuous phase. In glass-based thick film resistors, absorption is mostly determined by the highly doped glass. The results indicate that thick film resistors can be used as an absorbent coating in the 400-1500 cm⁻¹ region by suitable selection of the continuous and particulate phases.

1. Introduction
Thick film resistors (TFRs) consisting of conducting and insulating phases have been known and widely used in the electronic industry for over 20 years [1]. TFRs are normally supplied as a "paste" which consists of submicrometre size conducting and nonconducting particles suspended in a viscous organic fluid. After printing the paste, organic solvents are removed during drying and the organic binders are burned out in the first stage of the heating. Maximum heating temperature is selected well above the glass transition temperature and thus the resultant TFR has a structure in which the particulate phase is randomly distributed in a continuous phase. Depending on the type of continuous phase, which is either some sort of glass or a thermosetting polymer, TFRs are classified as cermet and polymer types.

Electrical properties of TFRs are mainly determined by the volume fraction of the conducting phase [2]. It is known that some impurities are added to the paste in order to achieve low temperature and voltage coefficients of resistance. The energy level of such impurities lies deep in the band gap of the insulating phase and somehow affects the electrical conduction processes [3]. Together with these, low-resistive activation terms ranging from 0.1-10 meV [4, 5] suggest that these systems might have a strong electromagnetic absorption in the infrared and microwave regions.

The aim of this work was to investigate the infrared absorption properties of thick film resistors and to correlate them with their structural and electrical properties in an attempt to see if they could be used as absorbent coating in the infrared (IR) region.

2. Experimental procedure
Commercially available cermet and polymer thick film pastes (ESL 391x and RS1511x series, respectively) having sheet resistivities of 10²-10⁵Ω/□ were used in this work. Film samples with dimensions of 23 mm × 10 mm and 2.5 mm × 2.5 mm were screen printed on 96% alumina substrates for X-ray and resistance measurements, respectively. After printing, the samples were dried and cured under the conditions given in Table I. Cured samples were labelled as C2–C5 for cermet types and P2–P5 for polymer types. The thickness of the cured samples was measured by Talysurf-4 and found to be 25 ± 5 μm.

For IR measurements, bulk samples were prepared on 96% alumina substrates and cured under the same conditions as their film counterparts. Then, the samples were scraped out from the substrates and ground in an agate mortar. The mixture of KBr and the sample (1% by weight) was pelletized under vacuum by a pressure of 10 ton. IR spectra of homogeneous pellets were obtained using a BOMEM MB100 FT-IR spectrophotometer and are given in Figs 1 and 2 for polymer and cermet types, respectively.

A Rigaku-RadB automated X-ray powder diffractometer with copper anode and graphite monochromator were used for compositional investigations. XRDs were obtained with a scan speed of 1° min⁻¹ in the continuous scan mode. The composition of the conducting phases was determined by comparing the spectrum with the standard data stored in the computer. The results are given in Fig. 3.

Resistance data were collected using an automated data work station. A closed-cycle helium refrigerator

<table>
<thead>
<tr>
<th>Type</th>
<th>Drying</th>
<th>Curing</th>
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<tbody>
<tr>
<td></td>
<td>Temp.(°C)</td>
<td>Time(min)</td>
</tr>
<tr>
<td>Polymer</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>Cermet</td>
<td>150</td>
<td>30</td>
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Figure 1 IR absorption spectra of polymer thick film resistors and TiO$_2$. (a) P2, (b) P3, (c) P4, (d) P5, (e) TiO$_2$.

Figure 2 IR absorption spectra of cermet thick film resistors. (a) C2, (b) C3, (c) C4, (d) C5.

Figure 3 X-ray powder diffractograms of the samples. (a) C2, (b) C3, (c) C4, (d) C5, (e) P2, (f) P3, (g) P4, (h) P5. s Substrate, (•) TiO$_2$, (□) RuO$_2$, (○) PtO$_2$, (○) Cd, (■) Al$_2$Ti, (●) TiCl, (●) Ag$_2$S, (●) MoS$_2$, (△) PdTi, (□) PtTi, (○) CuInSe$_2$, (+) Pt$_3$Pd$_2$Sn$_2$, (○) PtIn, (□) CdTi.