THERMAL DEGRADATION OF POLY(VINYL BUTYRAL) IN ALUMINA, MULLITE AND SILICA COMPOSITES

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Abstract

Thermal degradation of poly(vinyl butyral) (PVB) and its mixtures with alumina, mullite and silica was investigated by non-isothermal thermogravimetry in the temperature range of 323 to 1273 K. The analysis of the data was carried out using a three-dimensional diffusion model. Results showed that the kinetic parameters (activation energy and pre-exponential factor) of the PVB degradation are different for polymer alone, and ceramic/polymer composites. The overall weighted mean apparent activation energy showed an increasing reactivity in the order of PVB<alumina + PVB<mullite + PVB<silica + PVB. This shows that the acidic and basic surface characteristics of the ceramics promote the thermal degradation of PVB and, the more acidic silica affects the degradation more than mullite and alumina. The effect of pellet compression pressure in the range of 4000 to 8000 psig is also investigated.

Keywords: ceramics, kinetic analysis, polymer, PVB, thermal degradation

Introduction

A knowledge of kinetic analysis is necessary to investigate quantitatively the thermal decomposition behavior of organic polymers which are used extensively in ceramic processing. Even though the organic polymer binders play a temporary role in the manufacture of various ceramic components such as multichip modules, the thermal degradation of binders determines the quality of the ceramic substrate. It has been reported that incomplete binder burnout would retard densification rates and limit the final density achieved. In addition, the residual carbon left behind after thermal degradation affects optical, electrical and mechanical properties of the substrate. The residual carbon in excess of 50

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to 100 ppm would decrease the density and also affect many substrate properties like flexural strength, breakdown voltage [1] and dielectric constant [2]. In order to optimize the binder removal processes, some attention has been paid to studies such as polymer degradation mechanism [3–5], interactions of ceramics and binders [6–8], and effect of processing variables [9]. However information on kinetics of thermal degradation is limited.

Literature review

There has been a considerable amount of work on the thermal degradation of polymers in ceramic surfaces. Parker et al. [10] studied the mobility of polymer in the presence and absence of alumina and plasticizer. Bakht [4] studied the thermal degradation of PVB copolymers in the temperature range of 473 to 723 K. The PVB used had different degrees of vinyl butyral substitution. Thermal Volatilization Analysis (TVA), Thermogravimetric Analysis (TG) and Infrared Spectroscopy (IR) were used to investigate the composition of the volatile products formed due to the decomposition of PVB. Bakht observed the products of thermal degradation of PVB to be mainly water and butyraldehyde. He proposed both a free radical mechanism and a molecular elimination mechanism to interpret the formation of butyraldehyde.

Sacks et al. [7] carried out a series of studies on the degradation mechanisms and pyrolysis behavior of PVB and acrylic polymers (i.e. poly(methyl methacrylate) and poly(methacrylic acid)). Degradation experiments were carried out for polymers alone and for polymer–ceramic mixtures in nitrogen or oxygen atmospheres. They found that the mechanism of thermal degradation of poly(methyl methacrylate) to be depolymerization, and furthermore they observed that the reaction was accelerated by the presence of oxygen (thermal-oxidative degradation). In the case of poly(methyl methacrylate) and alumina mixture, a surface reaction between the polymer and the ceramic was indicated by Fourier transform infrared spectroscopy (FTIR) and gas chromatography (GC) results, but not in poly(methyl methacrylate) and silica mixture. The thermal degradation mechanism of poly(methacrylic acid) found by Sacks et al. is very different compared to that of poly(methyl methacrylate). However similar surface reactions were observed in polymer/ceramic mixtures. In general, the results agree with the mechanism proposed by Bakht [4]. Similar work carried out in an oxygen atmosphere showed different results due to oxidative degradation.

Masia et al. [8] investigated the effect of various oxides on PVB burnout behavior in air and in argon atmospheres. They found that the oxides used have significant catalytic effects on both thermal and thermal-oxidative degradation of PVB. Masia et al. concluded that besides surface chemistry, the surface structure, number of hydroxyl groups, percentage of free water, amount of oxy-