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Influence of Photolithography on the Cross-Sectional Shape of Polysiloxane as an Optical Waveguide Material on Printed Circuit Boards

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Optical waveguide cross-sectional shapes that deviate from rectangles or squares may cause significant loss of signal. In this study, a photolithography approach was adopted to fabricate waveguides on printed circuit boards, using photo-imageable polysiloxane as a waveguide material. The effects of I-line ultraviolet (UV) lamp exposure, 355-nm Nd:YAG laser direct imaging, and 248-nm excimer laser direct imaging on the cross-sectional shape of waveguides were investigated. For I-line UV lamp exposure, increasing the exposure time could cause changes in the tilt angle of the waveguides from negative (inverted trapezoid) to positive (trapezoid). To obtain rectangular waveguides, the optimum I-line UV lamp exposure time was found to be around 150 s. From the results for 355-nm Nd:YAG laser direct imaging, the width and tilt angle of the waveguides varied with the energy density of the laser beam irradiating the core materials, being controlled by the repetition rate and focus. Lowering the laser energy density could produce waveguides with small widths and tilt angles. Excimer laser direct imaging at 248 nm was found to be unsuitable for waveguide patterning since the core materials could not be cured at this wavelength.

Key words: Optical printed circuit boards, optical waveguides, photolithography, cross-sectional shape, polysiloxane

INTRODUCTION

Development of board-level optical interconnects is being driven by the increased use of high-clock-rate microprocessors and high signal transmission speeds. Optical interconnects are capable of transferring information at a speed of several hundred Gbits/s and have the potential to enhance the speed to Tbits/s,[1] handling a 1000× increase in information compared with metallic interconnects.[2] Other advantages of optical interconnects are reduction of signal noise, attenuation noise, and electromagnetic interference radiation, leading to signal integrity improvement.[2]

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Integration of optical interconnects onto printed circuit boards (PCBs) requires the development of waveguide materials and assembly technologies. There are a number of polymer waveguide manufacturing technologies available on the market for optical PCB (OPCB) fabrication, such as the hot embossing process,[3,4] reactive ion etching (RIE),[5] and photolithography using photo-imageable polymers.[6] The hot embossing process requires a negative tool to mold the waveguides. RIE involves etching using reactive ions, and waveguides developed by RIE may have sidewall roughness problems, resulting in an increase in optical loss.[7] Photolithographic technology with photo-imageable polymers is widely used by PCB manufacturers, where waveguide patterning can be achieved by ultraviolet (UV) curing with subsequent chemical