Materials Chemistry and Physics 321 (2024) 129433

Contents lists available at ScienceDirect

Materials Chemistry and Physics

journal homepage: www.elsevier.com/locate/matchemphys

Refractive index tuning and birefringence effect in crosslinked siloxane-acrylate copolymers for optical waveguide applications

Amir Muhammad Noh Amin Abdul Rahman [a], Hazizan Md Akil [a], Mohd Kamil Abd Rahman [b], Noorlisa Harun [c], Zulkifli Ahmad [a,*]

[a] Silicone Polymer Research Group, School of Materials and Mineral Resources Engineering, Engineering Campus, Universiti Sains Malaysia, 14300, Nibong Tebal, Pulau Pinang, Malaysia
[b] Faculty of Applied Sciences, Universiti Teknologi MARA, 40450, Shah Alam, Selangor, Malaysia
[c] Faculty of Chemical and Process Engineering Technology, Universiti Malaysia Pahang, 26300, Gambang, Malaysia

HIGHLIGHTS

- Siloxane-acrylate copolymers with different crosslink network were synthesised.
- Refractive index increases due to densification and aromatic rings polarizability.
- Asymmetrical configuration of the crosslinking agent induce anisotropic network.

ARTICLE INFO

Keywords:
Refractive index
Free volume
Polarizability
Acrylate-siloxane copolymer
Waveguide

ABSTRACT

Tunability of refractive index of polymeric waveguide material could be made by controlling free volume as well as polarizability of constituent materials. Two acrylate-co-polysiloxane series of different crosslinking network were synthesised by utilizing different crosslinker and monomer feeding ratio. Using Claussius-Mossotti/Lorentz-Lorentz (CM/LL) model, fractional free volumes were calculated showing a decrease in the experimental (n_{exp}) compared to theoretical (n_i) refractive indices. Curing agent with asymmetrical configuration induce a crosslink network of higher birefringence. They were respectively fabricated into multimode channel waveguide whose core-clad refractive index differences (Δn) show values in the range 0.0049–0.0408.

1. Introduction

Polymer waveguide is a photonics device offering an optical solution for next generation on-board level interconnect with higher data rate and low loss signal [1]. Polysiloxane is an inorganic polymer widely used in fabrication of optical waveguide [2–4]. In a crosslink polysiloxane system there is an improvement in optical loss by utilizing deuterated-phenyl substituted silane monomer [2]. Despite highly polarisable unsaturated system and low absorbance deuterated content, introducing phenyl moiety is made at the expense of their anisotropic orientation in solid state which induce birefringence.

The working principle of a waveguide is based on the total internal reflection which is related to the ratio of refractive indices of the core and the clad layers. Refractive index tunability of waveguide is essential as related to its mode of application. Beside bend radius ratio, waveguide bend loss has an exponential dependence on the core-cladding index difference. In designing digital optical switches, the large thermo-optic coefficient (TOC) effect is mostly preferred. This enable detectable change of the optical refractive index during slight exposure to thermal stimulus. It is dominantly determined by the packing density of the polymer material henceforth affecting the volume polarizability during expansion of material. Conversely, the fabrication of single or multimode waveguide could be made depending on difference refractive index between the core and the clad. By default, the single mode is thinner compare to the multimode waveguide whose refractive indices difference is $\Delta n \sim 0.5$ %. By preparing the polymers with a minute refractive index difference ($\Delta n < 0.1$ %), a single-mode waveguide can be fabricated with a large core dimension ($d > 50$ μm), which is close to that of multimode fibre [5]. This strategy was opted during fabrication of polymeric variable optical attenuators (VOA)

* Corresponding author.
E-mail address: zulkifli@usm.my (Z. Ahmad).

https://doi.org/10.1016/j.matchemphys.2024.129433
Received 23 April 2021; Received in revised form 14 September 2023; Accepted 6 May 2024
Available online 25 May 2024