A Novel Silicone Ladder Polymer with High Thermal Stability for Optical Waveguides

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Polymer waveguides have been investigated for use as flexible and low cost optical interconnects and optoelectronic integrated circuits. Polyphenylsilsesquioxane (PPSQ) is an inorganic polymer with a ladder type structure consisting of siloxane bonds as a main chain and phenyl groups as a side chain (Fig. 1). PPSQ has received considerable interest in the microelectronic industry due to high thermal resistance over 400 ºC, good chemical and mechanical stability, and low dielectric constant. As PPSQ has also high optical transparency in spite of a non-deuterated or non-fluorinated structure and the cost of synthesis is lower than deuterated or fluorinated polymer waveguide materials,[1] PPSQ has been suggested as a promising material for wafer-scale optical waveguide interconnects. Controllability of the refractive index is a requisite for optical waveguide materials. However, no report can be found in which the refractive index of the silicone ladder polymer is controlled. We have developed a novel silicone ladder copolymer (PVSQ) with a controllable refractive index by partially substituted vinyl groups for phenyl groups in the side chain of PPSQ.

PVSQ copolymers were prepared in the two steps, i. e., hydrolysis and condensation of trichlorophenylsilane and trichloro(vinyl)silane.[1] The visible-near-infrared absorption spectrum of the PVSQ film with 10 mol% vinyl groups after cured at 350 ºC for 1 h was showed in Fig. 2. Three peaks attributed to the harmonics of the C-H vibrations were observed in the near-infrared region. We emphasize that there were no peaks at the wavelengths used for data communication and telecommunication.

As the refractive index is a function of the molecular refraction and the molecular volume, the introduction of vinyl groups to the side chain of PPSQ is expected to induce the change of the refractive index. The in-plane refractive indices (nTE) of PVSQ films cured at 200 ºC with vinyl group content of 0 - 100 mol% are shown in Fig. 3. The refractive indices decreased with increasing the vinyl group content, and can be precisely controlled between 1.558 and 1.523.

The thermal decomposition temperatures of PVSQ defined as that at which 10% weight loss occurred in a N_2 atmosphere decreased with increasing the vinyl group content, but all still showed the decomposition temperatures above 500ºC, ensuring enough thermal stability for polymer waveguide applications.

We have developed a novel heat-resist optical waveguide silicone ladder copolymer with high transparency in the visible and near-infrared region, 0.6-1.7 µm, which is the region used for data communication and telecommunication. The refractive index can be controlled by introducing the different substituents to the side chain of PPSQ and changing the content. This indicates the potential of these polymer waveguides for applications to integrated optical devises.

[1] N. Yasuda et al, *J. Soc. Electr. Mater. Eng.*, **1998**, 7, 28; N. Yasuda et al, *Chem. Lett.*, **2001**, 1189; N. Yasuda et al, *Bull. Chem. Soc. Jpn.*, **2001**, 74, 991.

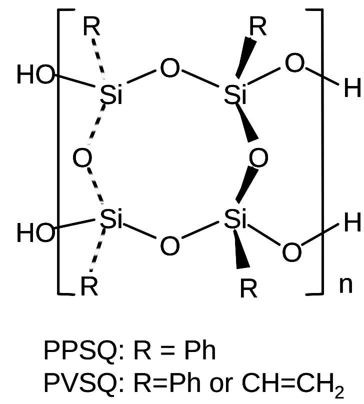

Figure 1. Structures of PPSQ and PVSQ.

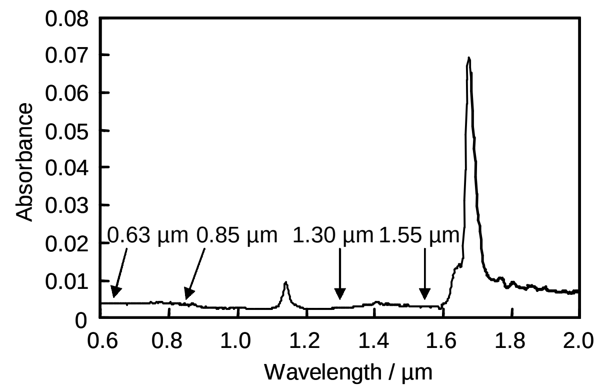

Figure 2. The visible-near-infrared spectra of PVSQ film with the 10 mol% vinyl group content in the side chain.

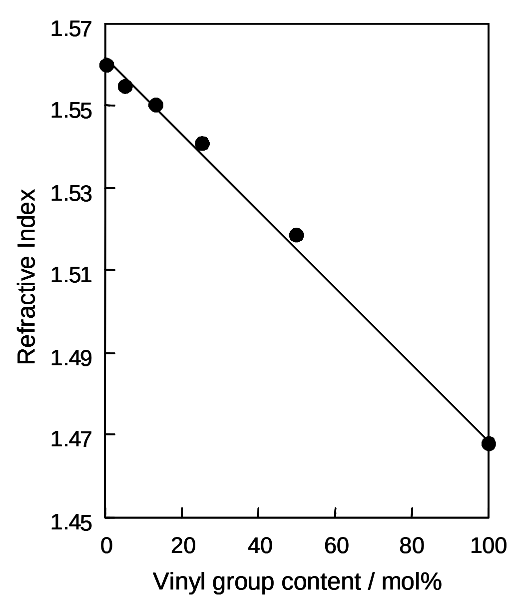

Figure 3. The controllability of the refractive indices (nTE) of PVSQ films with the vinyl group content of 0 - 100 mol% cured at 200ºC for 1h.