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Optical Properties of Acrylate-Based Negative-Type Photoresist and Fabrication of Optical Waveguides

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1. Introduction

The search of the new materials, which are suitable for optical devices is getting much attention. Polymeric materials because of their relatively low cost and the ease of processing are suitable for the fabrication of the optical devices. From the possible polymeric materials, acrylic polymers such as poly-(methyl methacrylate) (PMMA) are possible candidates for use in the fabrication of the polymeric optical components[1]. However, PMMA has low stability against the heat and chemical solvents.

Polymeric, acrylate based, negative type photo-resist called PNME [2] is a potentially advantageous material. The material is relatively stable and easy to process [3], so it can be also considered a good candidate for simple optical waveguide fabrication. These were among the reasons for which we decided to measure basic optical properties as the dispersion curve in the normal region, the absorption spectrum of the material up to the infrared region, and also to fabricate light-induced self-written (LISW) waveguides made from PNME.

2. PNME

Composition

The PNME material is a negative-type acrylate-based material. Its composition was described in the work of Espanet et al.[2] The material has three main components. The components are: Petnaerythritol triacrylate, which acts as a polyfunctional acrylate monomer, N-methyldiethanolamin, which acts as a cosynergist, and a dye called Eosin Y (2', 4', 5', 7' – tetrabromofluorescein disodium salt). The concentration of Eosin in the solution was 0.3%. The concentration of N-methyldiethanolamin varied from 5% to 15%, and the concentration of Pentaerythritol triacrylate varied according to the concentration of N-methyldiethanolamin.

Material Properties

It is required of optical devices that they are fabricated from the materials, which are transparent to the light at the operating wavelengths. These can be in the infrared region around 1310 nm, so called telecom region, or in the near infrared region around 850 nm, so called datacom region.

In this article the absorption spectrum of PNME is presented. Figure 1. shows the absorption spectrum of the PNME formulation with 10% concentration of N-Methyldiethanolamin. The absorption peak is located at λ=530nm. Moreover, it can be seen that the material is transparent for the light from the telecom and also from the datacom region even though the graph shows several small absorption peaks due to the vibration of C-H bonds.

Another important property of optical material is the refractive index. Refractive indices were measured by commercial prism coupler for three wavelengths.

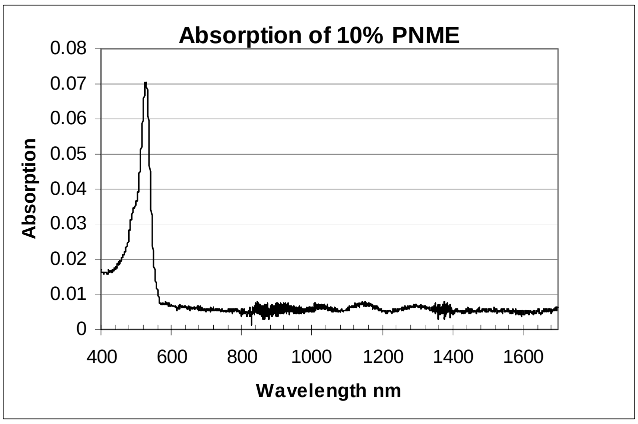

Fig 1. Absorption of PNME formulation with 10% concentration of N-methyldiethanolamin

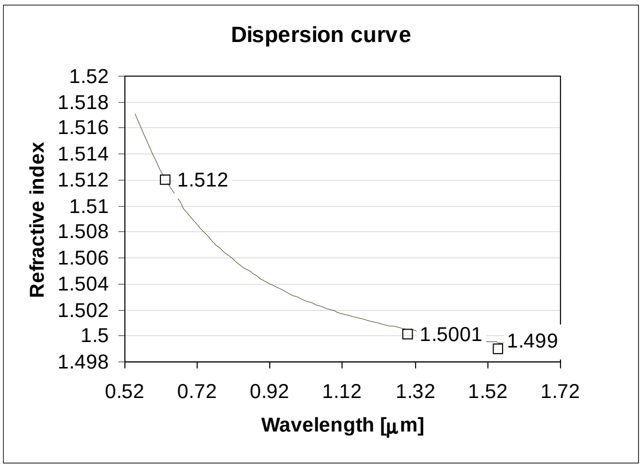

Fig 2. Measured refractive indices and their fit by normal dispersion curve.

Figure 2. shows measured values of index and their fit by normal dispersion curve calculated by Sellmeir's equation.

3. Optical waveguide fabrication

In order to fabricate an optical waveguide using PNME, light-induced self-written optical waveguide[4] was attempted instead of cold UV stamping, the technology we have proposed and demonstrated in [3]. The waveguide fabrication process has a few steps. In first step, a single-mode glass fiber (9.5/125) was inserted into the PNME monomer cell. Then a beam from Ar^+ laser (514nm) was launched to the fiber, and the monomer was photopolymerized by irradiation with the laser through the fiber. We used an irradiation power of order ~1 mW and an irradiation time of 1/128 sec. A solid optical waveguide core with almost the same core size (~10 μm in diameter) and sub-mm in length was formed in the liquid cladding by the "self-trapping-effect" Figure 3. shows the actually fabricated PNME waveguide core. From the figure, the waveguide core was self-aligned to the optical fiber without any precise alignment technique.

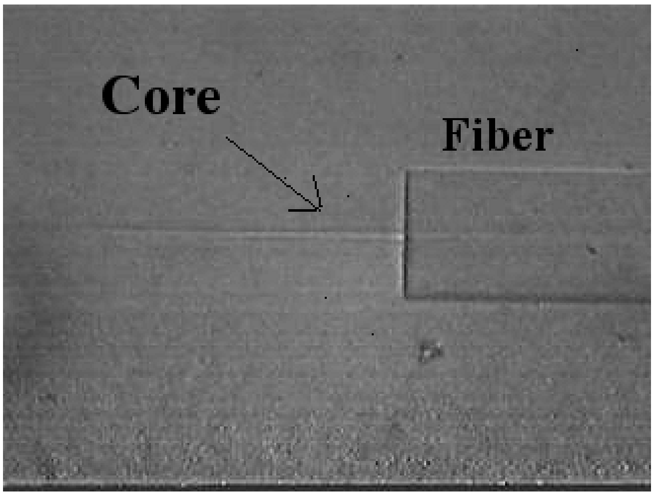

Fig. 3. Photograph of LISW PNME waveguide core self-aligned to the single-mode fiber.

After the core formation residual liquid cladding was removed and a cladding material whose refractive index was precisely controlled in order to satisfy the single-mode condition was covered and solidified. By the simple fabrication process described above all-solid single-mode waveguide can be fabricated. Since the PNME material is transparent in datacom region, multi-mode waveguide can also be fabricated based-on the present simple LISW technique.

4. Conclusions

The optical properties of the PNME were measured. From the properties, the absorption spectra and the refractive index are presented. From the absorption spectra it is possible to see that the PNME is transparent to the light of the telecom and the datacom regions. Moreover, the measurements of the refractive index of PNME were carried out and thus the LISW waveguide could be successfully fabricated. The present technique, which is simple and effective, can be applied to PNME-based optical waveguide modules and for optical interconnections in both datacoms and telecoms applications.

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