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Short communication

A novel graphene oxide-polyimide as optical waveguide material: Synthesis and thermo-optic switch properties

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ABSTRACT

In this work, a novel graphene oxide-polyimide (GOPI) as optical waveguide material was prepared. The structure, mechanical, thermal property and morphology of the GOPI was characterized by using fourier transform infrared, UV–visible spectroscopy, near-infrared spectrum, thermogravimetric analysis, differential scanning calorimetry, scanning electron microscope and transmission electron microscopy. The thermo-optic coefficients (dn/dT) are -9.16×10^{-4} (532 nm), -7.56×10^{-4} (650 nm) and -4.82×10^{-4} (850 nm) $^{\circ}C^{-1}$, respectively. Based on the thermo-optic effect of prepared GOPI as waveguide material, a Y-branch with branching angle of 0.143° and Mach-Zehnder thermo-optic switches were designed. Using finite difference beam propagation method (FD-BPM) method, the simulation results such as power consumptions and response times of two different thermo-optic switches were obtained.

1. Introduction

Azobenzene groups [1] are known to exist in two isomeric states, a thermodynamically stable trans form and a meta-stable cis form. Therefore, when they are irradiated with a linearly polarized light of appropriate wavelength they undergo a reversible trans to cis photoisomerization processes and photoinduced optical anisotropy [2] is generated as a result of the azobenzene molecules. Polyimides [3] (PIs) have an important class of high performance polymers and the excellent physicochemical properties such as high glass transition temperature and low dielectric constant value; and these characteristics have led to broader potential applications.

Recently, some Mach-Zehnder thermo-optic (TO) switches have been investigated [4]. Gao [5] designed a 2 × 2 TO switch with a MMI-MZI structure. This TO switch has a switching power of 7.5 mW and a switching speed of 0.4 ms by optical simulation. Yan [6] reported a polymer/silica hybrid 2 × 2 TO switch on the basis of DC (directional coupler)-MZI structure, the switch has a switching power of 7.2 mW based on optical analysis. Liang [7] investigated a 2 × 2 DC-MZI TO switch; the device has a power consumption of 7.2 mW. In this work, a novel graphene oxide-polyimide (GOPI) which owns lower power consumption and better heat resistance by introducing graphene oxide and polyimide as waveguide material was prepared. The TO coefficients (dn/dT) were obtained using the attenuated total reflection (ATR) method. Based on the TO effect of GOPI, 1 × 2 Y-branch and 2 × 2 Mach-Zehnder TO switches were simulated. Compared to conventional azo material [8,9], the GOPI has excellent thermal stability owing to the high temperature resistance of polyimide. Based on the simulation results, the power consumption of 2 × 2 TO switch is only 2.31 mW.

2. Experimental sections

2.1. Synthesis of amino functionalized graphene oxide

Graphene oxide was synthesized using the modified Hummers' method and was exfoliated by mild ultrasound for 5 h. Then, NMP (50 mL) and graphene oxide (50 mg) were dispersed in flask and was heated to 30 °C for 1 h. Afterwards, ethylenediamine (75 mL)

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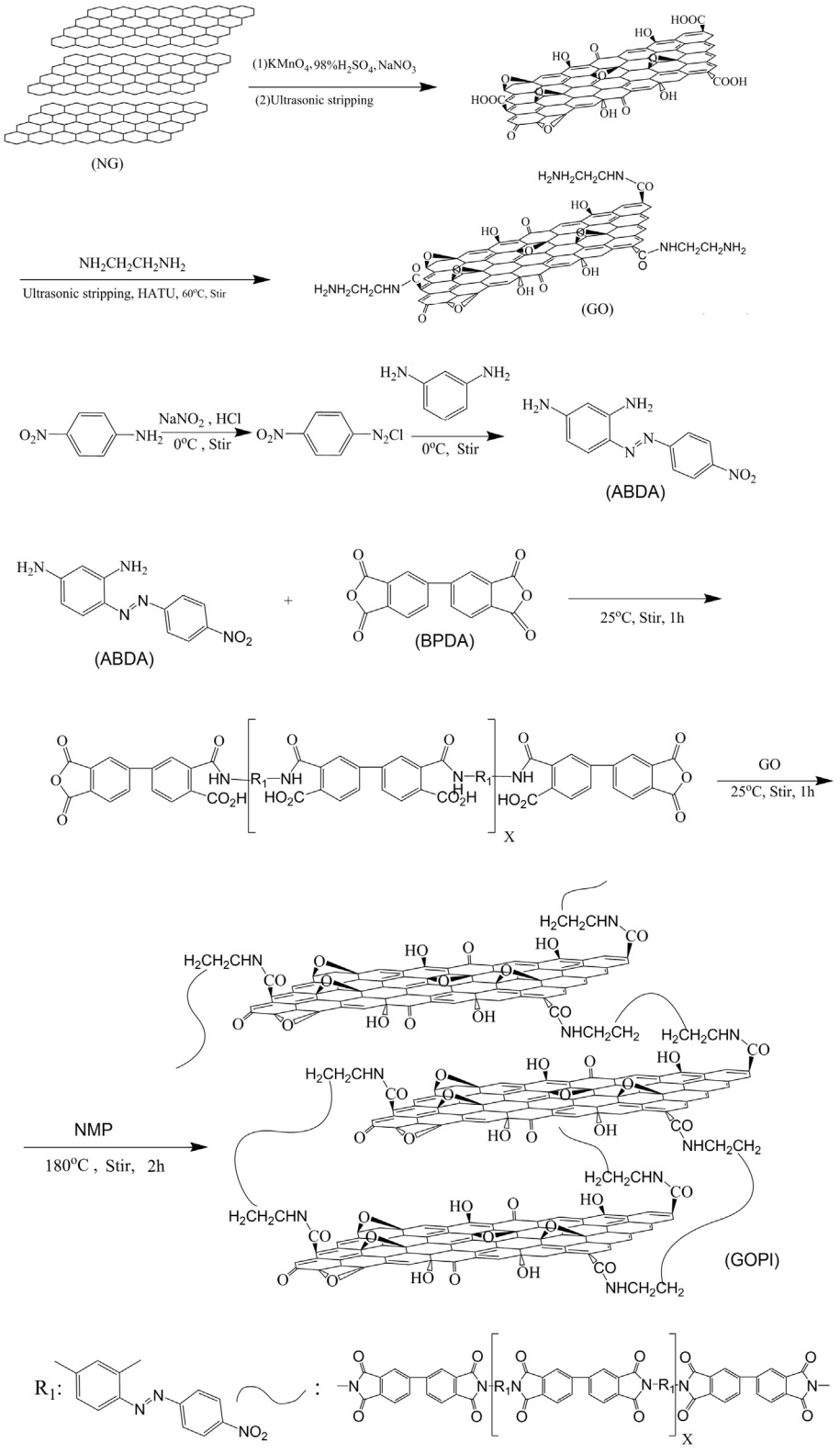

Fig. 1. The synthetic route of graphene oxide-polyimide (GOPI).

and 2-(7-aza-1H-benzotriazole-1-yl)-1,1,3,3-tetramethyluronium hexafluorophosphate (HATU, 3 mL) were added into the mixture and kept for 8 h below 65 °C. Then, the mixture was washed with ethanol; and the amino functionalized graphene oxide (GO) was dried at 55 °C in a vacuum oven.

2.2. Synthesis of azobenzene diamines chromophore

p-nitroaniline (1.38 g), deionized water (25 mL), HCl (2.5 mL) and $NaNO_2$ (0.69 g) were added to a flask at 5 °C for 1 h. Then, the diazonium salt was coupled with m-phenylenediamine (1.08 g) for