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Studies on the Preparation of Polymer Spherical Symmetry GRIN Sphere and Controlling its Gradient Index Distribution

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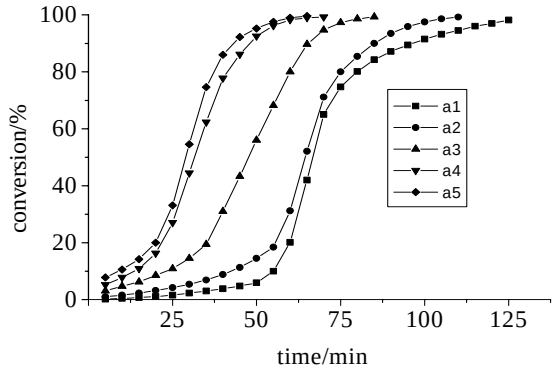
Abstract: In this paper, a polymer spherical symmetry GRIN sphere lens were prepared by the suspension-diffusion-copolymerization(SDC) technique, selecting methyl methacrylate(MMA) as monomer M_1 and acrylic 2,2,2-trifluoroethyl ester(3FEA) as M_2. The radial distribution of refractive index of the lens was measured by the shearing interference method, which demonstrated that the quadratic refractive-index distribution was formed in the sphere lens, and its $\Delta n=0.019$.

Keywords: Suspension-diffusion-copolymerization(SDC), gradient refractive index (GRIN), spherical symmetry GRIN distribution, shearing interferometric technique.

In recent years, polymer spherical symmetry GRIN sphere lens and its arrays are generally noticed. Traditional GRIN small sphere lens is prepared by ion-exchange technique with special glass1,2, but its process has some shortcomings. In this paper, we prepared the polymer GRIN small sphere lens by the SDC technique.

Figure 1 The relationship between MMA monomer conversion and the time at different initiator concentration



Polymerization temperature 70℃, initiator concentration a1～a5(0.5～2.5%)

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SDC is divided into two stages. First, the M_1 monomer (MMA) gradually polymerized to obtain prepolymer spheres(partial suspension polymerization), then the M_2 monomer (3FEA) with the lower refractive index was added to the solution when the reaction reached a certain conversion. We controlled the diffusion[3] based upon the suspension polymerization kinetic curve of the M_1 monomer(MMA) (**Figure 1**). Under appropriate conditions, the concentration of M_2 monomer formed gradient distribution in the prepolymer sphere, then M_1 and M_2 monomer are copolymerized *in-situ*. The resulting 0.6-1.2 mm diameter GRIN spheres were quite symmetrical due to the surface tension. And the internal design of this small GRIN sphere is low crosslinking construction, its hardness and thermal stability are good.

Six different copolymer sphere samples were analyzed by elemental analyzer. The radial distribution of refractive-index of the lens was measured by the shearing interference method. **Table 1** shows the results.

Through the theoretical analysis[4], we got the refractive-index distribution function of the ideal GRIN copolymer sphere and the curve which approximates a symmetry parabola (**Figure 2**).

Figure 3 is the interference pattern[5,6] of sample S3,S5,S6. The radius ratio of samples S3,S5,S6 and their refractive-index are calculated[7]. The refractive-index profile is showed as **Figure 4**.

Table 1 The elemental analysis and refractive index distribution of MMA-3FEA copolymer sphere

Sample number	S1	S2	S3	S4	S5	S6
Time for M_2 pouring [a](min)	20	40	45	50	55	60
M_1 conversion (%)	3.2	8.8	11.3	14.5	18.4	31.2
Carbon content （%）	56.01	57.16	56.20	56.47	56.88	57.08
Hydrogen content（%）	7.57	7.06	8.00	7.99	8.39	8.30
Fluorine content (%)	7.07	6.17	6.26	5.87	4.92	4.55
M_2 permeability [b](%)	80.30	68.08	67.86	63.89	51.20	47.83
Refractive index distribution	0→r refractive index is basically equal	0→r refractive index is different, but Δn is not big	0→r parabola profile，Δn= 0.019	0→r parabola profile basically	0.444r→r gradient refractive index profile	0.741 r→r gradient refractive index profile

[a]Computing from arriving the reaction temperature; Polymerization condition：crosslinking agent concentration 1%, initiator concentration 1%, temperature 70℃

[b]M_2 permeability (%)=（the 3FEA's mass of diffusing into the sphere/the total mass of 3FEA）×100%

Figure 2 Ideal refractive-index profile of the GRIN sphere lenses

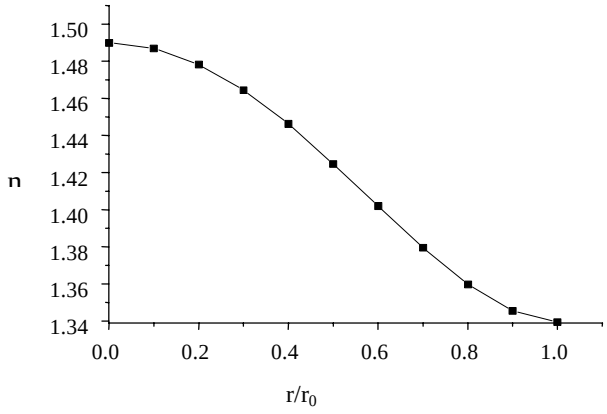
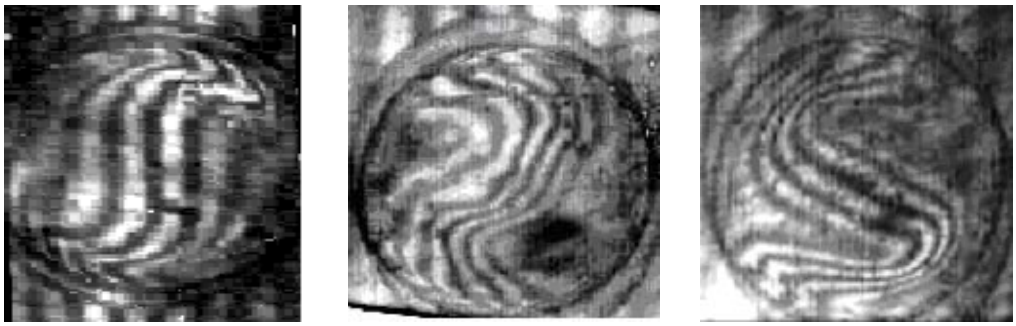
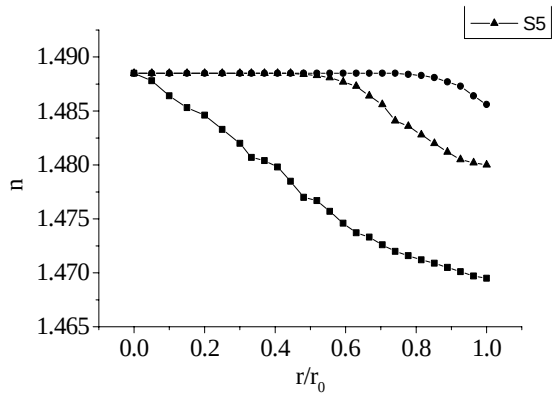


Figure 3 The interference pattern of sample S3，S5，S6

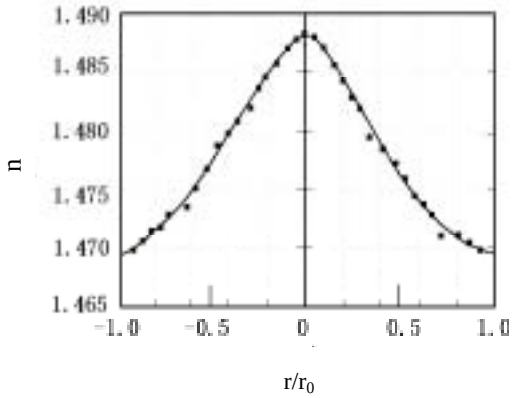


Sample S6 Sample S5 Sample S3



Measuring both sides of the sample S3's interference pattern, we can see from **Figure 5** that its refractive-index profile is symmetrical.

Figure 5 Refractive-index profile of sample S3



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