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Article / Book Information

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種別(和文)	論文要旨
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（博士課程）
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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

In this thesis, a convenient UV–NIR dual-beam optical tweezer system is developed to precisely manipulate glass microspheres and achieve accurate UV-initiated immobilization in 3D space within seconds *in situ* for the precise assembly of glass pedestal component, achieving the fabrication of a flexible 3D optical router for interlayer communication applications in the 3D photonic networks.

In chapter 2, a customized UV-NIR dual-beam system for the manipulation of glass microspheres in free space was developed. The optical tweezers force distribution was firstly numerically simulated, and the lateral force of the optical tweezers used to manipulate microspheres was then practically measured by Stokes' Law. Up to 16 pN of optical tweezer lateral force could be applied to the microspheres at laser powers below 30 mW, and the force coefficient (Q) exceeded 0.12 which was much close to the theoretical value of 0.1330. The influence of the refractive index and the surface viscosity was discussed, and no significant deviations to the optical force was confirmed which were both less than ~0.3% and therefore ignored during subsequent calculations. The programmable manipulation along the path pre-defined was achieved in defined steps and speeds.

In chapter 3, a customized UV immobilization method for immobilizing the target microsphere in the desired position within seconds was developed. Silica microspheres and slide glasses were processed to coat a MOPS monolayer on the surfaces for photopolymerization of 'click' chemistry. In practice, UV immobilization of silica microspheres on silica substrates was achieved with ~3.0 mW/cm^2 UV laser outlet. The effects of the dipping time in MOPS solutions, MOPS concentration, and photoinitiator concentration were evaluated to obtain an optimized protocol, corresponding to a rapid and reliable UV-induced immobilization within 6s. The single bonding strength of individual MOPS chain was quantified via optical force spectroscopy using the optical tweezers. Each individual MOPS chain could supply 4–6 pN bonding force for immobilization, which corresponded to ~4.5 nN single bonding strength mainly from C-Si bond in MOPS molecules.

In chapter 4, the *in situ* combination of manipulation and immobilization methods in the former two chapters was effectively achieved. Arbitrary complex structures were successfully assembled and collected for observation by both optical microscope and SEM. The structure accuracy was measured and a standard deviation of 0.14 μm could be realized which meant 60 nm corresponding error in gap space. The minimum position error could be less than 0.01 μm, corresponding to only 4 nm error in gap space. A functional triangular pedestal structure was designed and assembled as a component of an interlayer router to flexibly control the gap space between the micro-resonator and waveguide for interlayer communication in 3D photonic networks.

In chapter 5, the tellurite glass thin film with a composition of $76.5TeO_2$-$13.5Nb_2O_5$-$10B_2O_3$ was prepared by glass blowing technique. The film could be firmly bonded on the silica or silicate glass substrates by the direct bonding method. The UV-O_3 treatment was applied to increase surface -OH density for MOPS coating. The water contact angle was measured for both bulk glass and thin film, and a great increase of hydrophilia from ~ 42 to ~ 7 degrees was achieved. Two same peaks in ~ 2850 cm^{-1} and 2915 cm^{-1} of the ATR-FTIR spectra for bulk glass was observed compared to the silica control group, indicating the successful -OH modification and MOPS monolayer coating on the tellurite glass.

In chapter 6, a novel 3D optical router structure was developed, constructed by a triangular pedestal on the tellurite thin film waveguide with a Nd^{3+} doped tellurite glass micro resonator on it. The tellurite glass thin film with a composition of $76.5TeO_2$-$13.5Nb_2O_5$-$10B_2O_3$ was fabricated and bonded on the silicate cover glass. The triangular pedestal was directly assembled on the MOPS monolayer coated tellurite thin film. 10~50 μm Nd^{3+} doped tellurite glass micro resonators were fabricated by the localized laser heating technique and placed on the pedestal by the micro vacuum manipulator. The immobilization

process was optimized considering the low transmittance in UV band of the film to successfully bond silica microspheres on films INVERTEDLY.

In chapter 7, the optimal parameters of structure morphology of the 3D router for three representative communication wavelengths were discussed. The coupling performance was measured to evaluate the fabricated 3D optical router for interlayer communication in 3D photonic networks. The emission light in micro resonator would be considerably coupled into the waveguide by this router structure and propagated horizontally with favorable optical loss. The coupled emission light in the waveguide had obvious directivity of was observed along horizontal orientation, which propagated horizontally with small longitudinal divergence. Counter-clockwise resonated emission light would also be coupled and propagate along reversed direction horizontally. The periodic resonance peaks were obviously observed within emission band around 1040~1080 nm. The wavelength separation was around 1.2 nm, corresponding to the $3.2*10^{11}$ Hz free spectral range. The relationship between the excitation power and the emission peak intensity was measured, showing ~300 mW saturation and 2.16 mW threshold power.