Enhancement of the Performance of Ring Laser Gyro using Silane Compound

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***Abstract*— Ring Laser Gyro (RLG), in its original form is insensitive to small rotation rates. This insensitivity occurs because of the coupling between the two counter propagating travelling waves, having a very low frequency difference. The main reason of coupling between the waves is due to the scattering from the surfaces of optical components like mirrors and prisms, being used for the turning of the lasers. The scattering from the surfaces is directly related with the level of surface roughness as well as Sub Surface Damage (SSD) generated during the polishing of optical components. This paper presents the experimental studies carried out using silane compound as a modifier of polishing powder for achieving the super polishing of fused silica glass. It has minimized the surface roughness and in turn coupling effect between the counter propagating waves, enhancing the performance of the RLG**

***Keywords*— RLG, Surface Roughness, SSD, Silane compound**

I. Introduction

Many advanced hard and brittle, and difficult-to-machine materials such as silicon, optical glass and ceramics are used for industrial applications. Out of such hard and brittle materials, silicon is the fundamental substrate for most integrated circuits (ICs) and over 90% of semiconductor devices are fabricated on Si wafers. Different abrasive processes such as grinding and lapping leads to deterioration of the surface. Although ductile or partial ductile regime grinding [1] of silicon can be achieved [2], polishing plays a vital role to attain the required surface quality. Chemical-mechanical polishing process allows for effective reduction of the surface damage to obtain super-smooth surface in fabrication of electronic devices [3-6]. Also it does not deteriorate the glass or wafer geometry. This method permits for cost-saving production of efficient microprocessors in multi-layer technique by high material removal rate (MRR) and outstanding surface planarization through synergistic effect between the mechanical grinding and the chemical corrosion.

The abrasive particles in the slurry affect the quality of surface finish of silica substrate to a great extent. The selection of abrasive particles in the slurry must be strictly controlled to avoid the scratches, haze and other defects. In order to achieve the super smooth surfaces considering the requirement of RLGs, there have been several attempts to modify the surface of abrasive particles for minimizing the scratches by increasing the settling time and coagulations time with respect to their pH values. Characteristics like surface charge, reactivity of surface and hardness can be changed by coating with a layer of different chemical compositions. To polish a fused silica glass substrate ceria–polymer composite particles in slurry are being used. Various papers published for improving the dispersion stabilization like zinc oxide nanoparticles by Tang et al. [7], modified zinc oxide nanoparticles with poly-methacrylic acid (PMAA) in aqueous system. Lei et al. [8-10] reported that the modified Zinc Oxide abrasive exhibited good dispersibility, lower surface roughness and less scratches. This paper presents the effects of silane modified ceria/ silica nanoparticles on fused silica glass.

II. OBJECTIVE

The surface quality of silica substrate obtained by Chemical Mechanical Polishing may be enhanced by adding suitable modifiers in the abrasive slurry. 3-aminopropyl triethoxysilane (APTES) may be used as a modifier with colloidal silica abrasives for this purpose [11,12]. In this paper, the effect of using 3-aminopropyl triethoxysilane (APTES) modifier on surface finish of silica substrate in chemical mechanical polishing is investigated.

III. EXPERIMENTATION

Experiments were conducted for chemical mechanical polishing of fused silica glass substrate using conventional slurry and slurry consisting of abrasive particles modified with 3-amino propyltriethoxy silane. Five experiments each were conducted using conventional and modified slurries. The experimentation consisted of preparation of slurry, chemical mechanical polishing and measurement of material removal rate and surface quality.

A. Abrasive Material and Modifie

Ultrasol 7H having 30%Colloidal Silica by weight and pH value of 4 was procured from Eminess Technologies USA, 3-aminopropyltriethoxysilane (APTES), 1% by weight obtained from Sigma-Aldrich. All chemicals were used as received without further purification. Purified water having a water resistivity 18 MΩ cm was used. All the sample preparations were done at room temperature.

B. Polishing performance test by conventional polishing

The fused silica glass of 18 x 14 x 6mm was polished using optical polishing Machine as in Fig. 1. The polishing experiments were performed on five samples. After the preliminary operation the glass substrate was subjected to final Polishing using opaline powder on polyurethane polishing pad for about eight hours. Then the glass substrate was tested for its surface roughness by 3 D non contact profiler using White Light Phase shifting Interferometry techniques with the accuracy of 0.1 nm in the Z direction to obtain R_a and R_z roughness heights. The Surface roughness was measured at three different locations on each sample (Fig.2). And the results are summarized in Table 1.

Fig. 1: OPTICAL POLISHING MACHINE

C. Polishing performance test by modified slurry

As mentioned above the similar experiment has been carried out using the modified slurry using APTES and the results of surface roughness is also summarized in Table.1

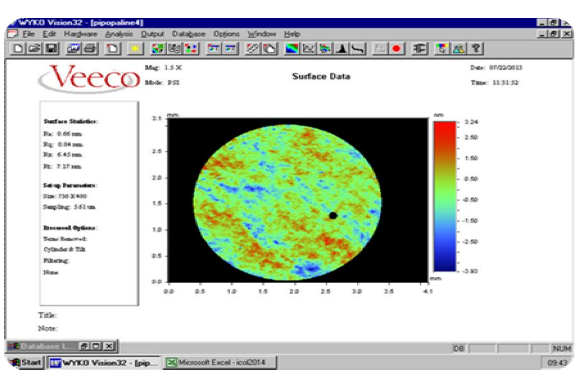

Fig.2 2D SURFACE PROFILE OF THE GLASS SUBSTRATE

Table 1: SURFACE ROUGHNESS VALUES OBTAINED WITH UNMODIFIED AND MODIFIED SLURRY

sample	Unmodified Slurry Roughness(Ra) Location 1	2	3	Avg (Ra)	Modified Slurry Roughness(Ra) Location 1	2	3	Avg (Ra)
1	1.4	0.99	0.8	**1.06**	0.41	0.51	0.53	**0.48**
2	0.69	0.68	0.76	**0.71**	0.64	0.61	0.51	**0.59**
3	0.85	0.66	0.71	**0.74**	0.74	0.65	0.71	**0.70**
4	0.86	0.86	0.66	**0.79**	0.59	0.5	0.52	**0.54**
5	1.05	0.92	1	**0.99**	1.24	0.88	0.55	**0.89**

The surface roughness (R_a) values measured for all the five samples was lower with modified slurry than obtained by polishing using unmodified slurry. The average values of surface roughness obtained with unmodified and modified slurry are plotted in Fig.3.

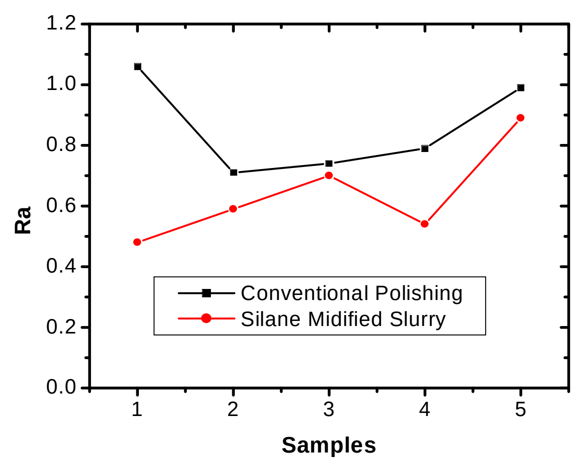

Fig.3 COMPARISON OF SURFACE FINISH OBTAINED WITH CONVENTIONAL AND MODIFIED SLURRY

IV. RESULTS AND DISCUSIONS

The reasons of improvement in surface finish are investigated by observing the variations in abrasive particle properties like change in Zeta potential (using the Master sizer 3000), stabilization time of the slurry and coating onto the particle which has soften the particle.

The measured and average surface roughness values for the five samples are given in Table. 1. WYCO NT 1000 Surface Profiler was used to measure the surface Roughness (R_a) and Peak-to-Valley value (PV) of glass substrate. Scattering which is directly proportional to average roughness value and in turn the Lock in threshold which is related with the equation below states that higher the scattering coupling coefficient, higher will be the lock in threshold. (Fig.4)

$$\Omega_L = \frac{c\lambda}{8\pi A} rCos(\beta)$$

Where *r* is the scattering coupling coefficient, *c* velocity of the light, *A* area of the cavity, λ wavelength of the He-Ne laser and β the Zeta potential.

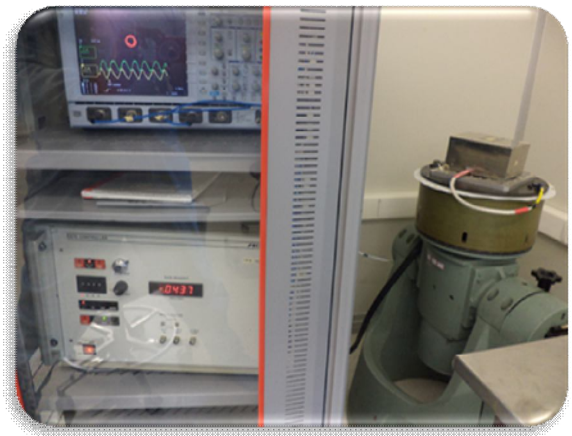

Fig.4 LOCK-IN THRESHOLD MEASUREMENT WITH SILANE COMPOUND

The improved surface roughness of the glass substrate reduced the lock in threshold value which has been experimentally evaluated and shown below in Table 2.

***In turn the improved performance of Ring Laser Gyro*.**

Table 2 THE LOCK-IN DATA OF THE GYROS ASSEMBLED WITH SUBSTRATES PROCESSED IN DIFFERENT FABRICATION METHODS

Process	Lock in threshold
With conventional Polishing	0.2 deg/Sec
With modified Slurry polishing	0.04 deg/Sec

V. CONCLUSION

In this work, the effect of abrasive particle modifier 3APTES on surface finish of glass substrate was observed by chemical mechanical polishing. It was found that there was improvement in surface finish by modification of colloidal silica with silane when compared to conventional polishing process as the soft coating of 3- aminopropyltriethoxy silane on abrasive particles helped to decrease mechanical damage so as to improve surface quality. It improved the surface roughness and in turn lock-in; resulting in to enhancement of performance of RLG.

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