Super finishing / Super polishing of optical glass and glass ceramic substrates for Low losses/ Minimum scattering applications as required for RLG

Mahendra K.Gupta*, G.D. Purna chander, B.V. Rao, K.Rambabu
Research Centre Imarat, Vigyana Kancha (P.O.), Hyderabad - 69
* mkg19662002@yahoo.co.in

ABSTRACT

This paper gives the processing techniques for achieving the super smooth and polished surfaces of optical glass and glass ceramic using loose abrasive optical fabrication techniques. These surfaces has been analyzed for surface roughness using phase shift interferometry. Sub surface damage is analyzed by qualitative measurements of scattering and cosmetic defects measured by using 500X magnification microscope. The shape accuracies are determined using Fizeu interferometer.

Keywords: Surface analysis, polished surfaces, phase shift interferometry, Sub-surface damage.

1. Introduction:

Laser based optical rotational sensors like Ring Laser Gyro (RLG) [1] requires a very high quality of optical components in respect of optical flatness, low transmission, reflection and scattering losses. Transmission and reflection losses can be related to properties of the bulk material as well as the polishing quality of surfaces. Where as the scattering losses are due to the surface roughness, Sub Surface Damage (SSD) and cosmetic defects, which are directly related with the manufacturing techniques.

2.0 Definition of the defects:

It is well known that in order to produce a satisfactory optical surface [2], it is necessary that a surface be free of scratches and have as low an R_a as possible. This R_a measurement is the average distance between the highest and lowest points on the surface perpendicular to the plane of the glass sheet being polished. Thus, accepting that the surface will not be totally flat at the sub micron stage, it is a measure of variation between highest and lowest points. Clearly the lower the figure the better of optical clarity and freedom from distortion.

3.0 Reasons for defect:

A method loose abrasive polishing is used in forming optical parts used in laser optical systems such as Ring Laser Gyro. In this process A blank is grounded and polished using coarse emery powders then lapped and polished using fine ceria powders. This process will cause micro cracks and sub surface damages to the surface. The sub surface damage [3], which contains mainly fractures that have been covered by the polishing re-deposition layer. This subsurface damage may reduce the strength of the final polished part by providing initiating cracks that reduce fracture strength. SSD may provide sites for light-absorbing contaminant to reside. When these contaminants are at or near fracture surfaces, the atoms are more easily ionizable, which can cause larger cracks and fractures. SSD will also modulate locally the electromagnetic field.

4.0 Method of achieving the defect free surface:

4.1. Polishing method

In order to achieve the back scattering as low as possible it is essential to reduce the surface roughness and sub surface damage, which depends upon the processing technique of optical surfaces and raw materials used in generating super smooth surfaces. To provide desired optical quality class DIN Std/Mil Std deep lapping is made [4] i.e. increased material removal is made to lap off the whole crack layer, that has been originated during previous grinding and lapping. These defects are eliminated [3] or minimized in practice by using control sequence of successively gentler grinding and polishing steps, making sure that each step removes enough material to eliminate damage produced by the previous step.

4.2 Possible Methods:

It is possible to generate super smooth/super finishing surfaces various processing techniques such as Loose abrasive polishing, fixed abrasive grain polishing technique [6] Chemical Mechanical Polishing, Deterministic Micro grinding, Chemical etching, Ion plasma etching techniques either individually are combination of these techniques or modification of the individual process.

4.3 Reasons for choosing the current technique

Considering the merits and demerits of various processing techniques the loose abrasive polishing technique was found to be best suitable to our present requirements. The production facility for loose abrasive grinding and polishing technique was already exists with us. It is also observed that some surfaces are generated thorough this method earlier yielded better results.

In loose abrasive polishing technique the parameters to be considered while generating smooth surface are Environmental effects (temperature and humidity), Polishing tools, Abrasive size and slurry formulation. Thus it is very easy to optimize either one are all above parameters and minimal additional machinery is required. The above mentioned technology features result in optical components production labor increase of 10%. However, improved by such a way production process allows to obtain 2 times decrease of internal stresses inside the Optical components material after their optical contact mounting on the sital block and to substantially reduce the back-scattering, that leads to Ring Laser Gyro lock-in threshold decrease [4].

4.4 Slurry Preparation:

In the polishing processes a slurry of abrasive particle in a liquid medium [2], (usually water based), is placed in contact with the surface to be polished and a pad is caused to move across the surface predetermined pattern so as to cause the abrasive in the slurry to polish the surface. Various slurry formulations have been proposed in this paper.

A polishing slurry, useful in optical Chemical Mechanical Planarization (CMP) applications [2], comprises a ceria with a BET (The BET surface area determined by the Brunauer/Emmett/Teller method described in The Journal of the American Chemical Society, 60 page 309 February 1938)) surface are of at least $10m^2/gm$ [2]. In the present work we could establish a process for the production of a ceria slurry suitable for optical polishing which comprises providing ceria slurry with a BET surface area of less than $10m^2/gm$ and milling the slurry until the BET surface area has increases by at least $5m^2/gm$. A process flow for polishing process using three different slurry formulations are shown in **Fig. 2.**

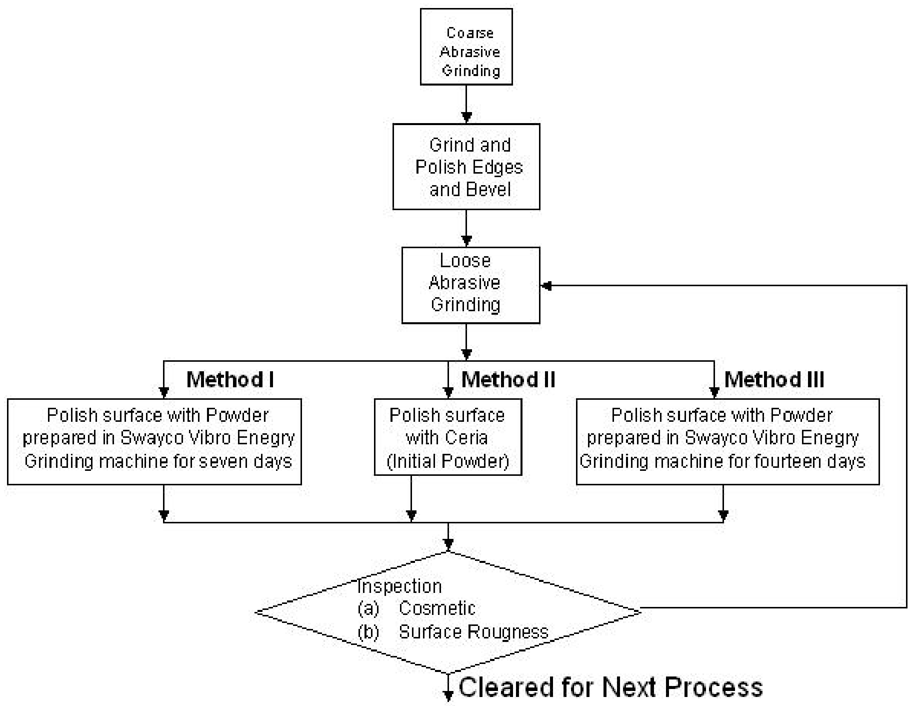

Fig. 2

4.5 Polishing Process

Method-I:. Polishing the surface with directly using commercially available abrasive with optimized De-ionised water mixture, typical grain structure of which is as shown in **Fig. 3**. The polishing yielded a surface with a final roughness, R_a, was 5Å as shown in **Fig.6.**

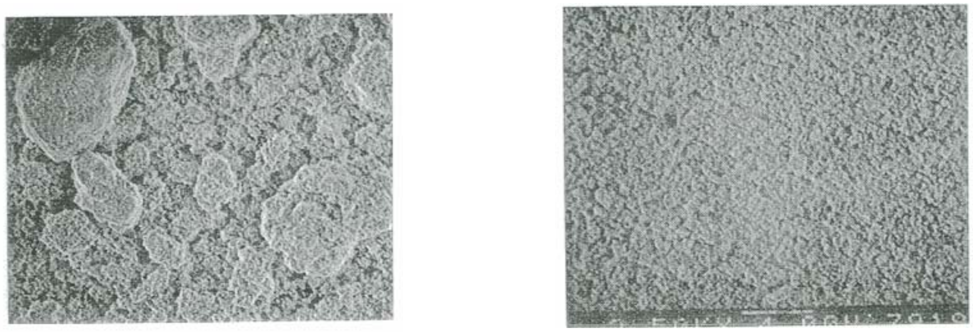

Fig.3

4.6 Method-II: A ceria slurry was made by de-agglomerating optimum amount of commercially available powder in optimum amount of de-ionized water in a Sweco M-18-5 mill,(using five jars), using half inch cylindrical Diamonite low purity Alumina for seven days. Typical grain structure is as shown in **Fig.4.** The polishing yielded a surface with a final roughness, R_a, was 3Å as shown in **Fig.7.**

Fig. 4

4.7 Method-III: A ceria slurry was made by de-agglomerating optimum amount of commercially available Russian powder in optimum amount of de-ionized water in a Sweco M-18-5 mill,(using five jars), using half inch cylindrical Diamonite low purity Alumina for fourteen days. Typical grain structure is as shown in **Fig.4.** The polishing yielded a surface with a final roughness, R_a, was 2Å as shown in **Fig.8.**

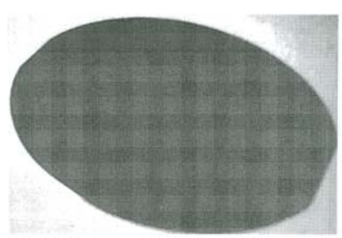

Fig. 5

5.0 Measurement of Defects:

Direct measurement of Sub Surface Damage is tedious. The dimple method [5] is often used as well as wafering methods. Aleinikov showed that SSD is induced by lapping glasses and other brittle ceramics (with hardness 30-fold, fracture toughness 6-fold, and Young's modulus 20-fold) was 3.9±0.2 times Surface Rougness for SiC abrasives (100 to 150µm). Thus indicating that Sub Surface Damage may be estimated from Surface Roughness using non contact measurement methods such as phase shifting interferometer through which we can estimate and control back scattering losses. The surface error is monitored through high precission Fizeau interferometer and surface quality is measured using Nikon Measuring Microscope at 500X magnification. Surface roughness is measured using Veeco NT1000 non contact optical surface profiler.

5.2 Results

We have processed the optical components three different slurrys and analysed their R_a values using Veeco Surface Profiler [7] results are shown in **Fig.6, Fig.7** and **Fig.8**. To inspect cosmetic defects we have used Nikon Measuring Microscope with 500X magnification as shown in **Fig. 9** and **Fig.10**.

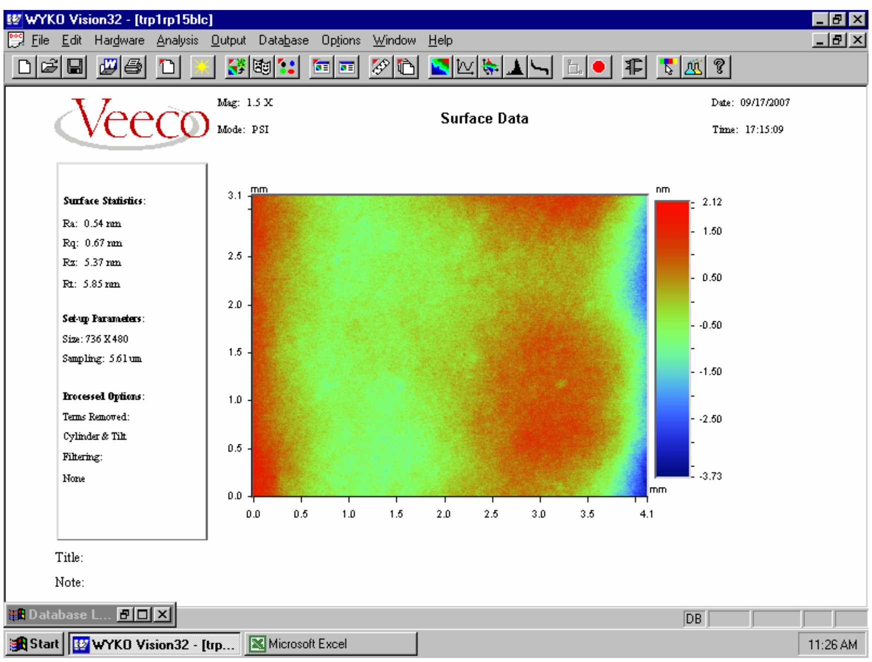

Fig. 6

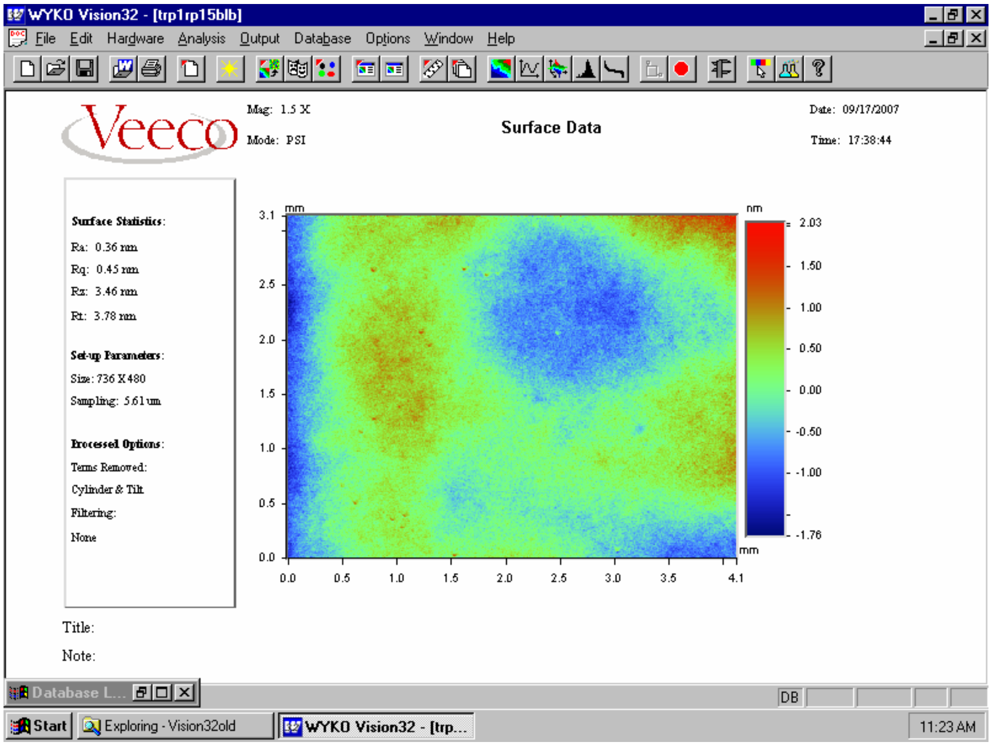
WYKO Vision32 - [trp1rp15blb]
File Edit Hardware Analysis Output Database Options Window Help
Veeco
Mag: 1.5 X
Mode: PSI
Surface Data
Date: 09/17/2007
Time: 17:38:44
Surface Statistics:
Ra: 0.36 nm
Rq: 0.45 nm
Rz: 3.46 nm
Rt: 3.78 nm
Set-up Parameters:
Size: 736 X 480
Sampling: 5.61 um
Processed Options:
Terms Removed:
Cylinder & Tilt
Filtering:
None
mm
3.1
2.5
2.0
1.5
1.0
0.5
0.0
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.1
mm
nm
2.03
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.76
Title:
Note:
Database L...
DB
Start
Exploring - Vision32old
WYKO Vision32 - [trp...
11:23 AM

Fig.7

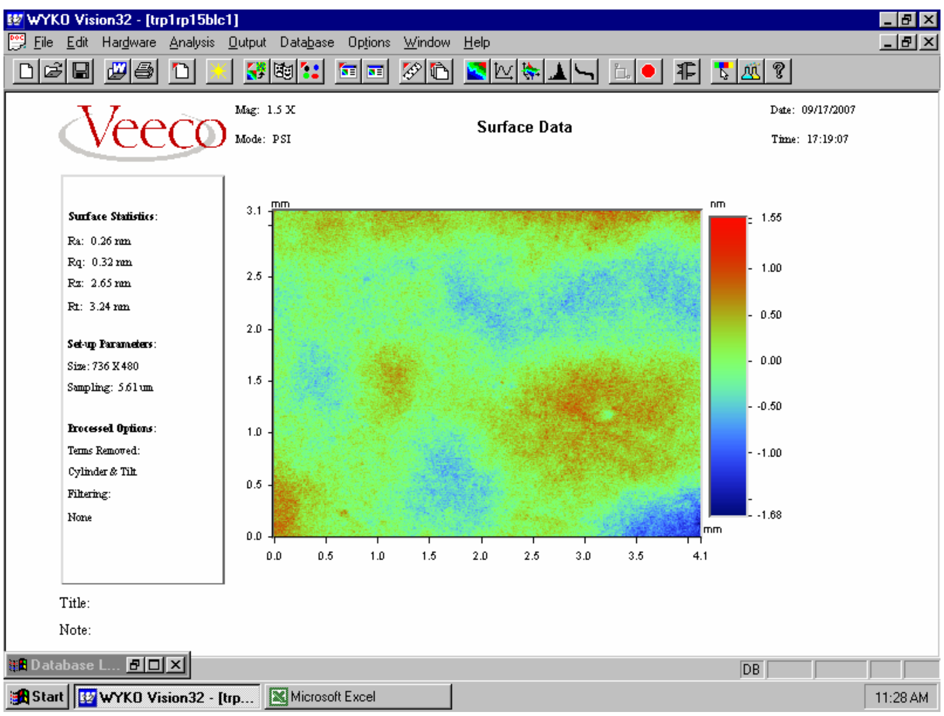
WYKO Vision32 - [trp1rp15blc1]
File Edit Hardware Analysis Output Database Options Window Help
Veeco
Mag: 1.5 X
Mode: PSI
Surface Data
Date: 09/17/2007
Time: 17:19:07
Surface Statistics:
Ra: 0.26 nm
Rq: 0.32 nm
Rz: 2.65 nm
Rt: 3.24 nm
Set-up Parameters:
Size: 736 X 480
Sampling: 5.61 um
Processed Options:
Terms Removed:
Cylinder & Tilt
Filtering:
None
mm
3.1
2.5
2.0
1.5
1.0
0.5
0.0
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.1
mm
nm
1.55
1.00
0.50
0.00
-0.50
-1.00
-1.68
Title:
Note:
Database L...
DB
Start
WYKO Vision32 - [trp...
Microsoft Excel
11:28 AM

Fig. 8

6.0 Conclusions:

Experimental results have been analysed from which we have drawn certain conclusions. There is an improvement in the surface roughness R_a (reducing surface roughness values as discussed in § 2.0) from Method – I to Method-III. It is also observed that cosmetic defects also reduced and followed the same tendency as average roughness values and are shown in **Fig.9** and **Fig. 10.**

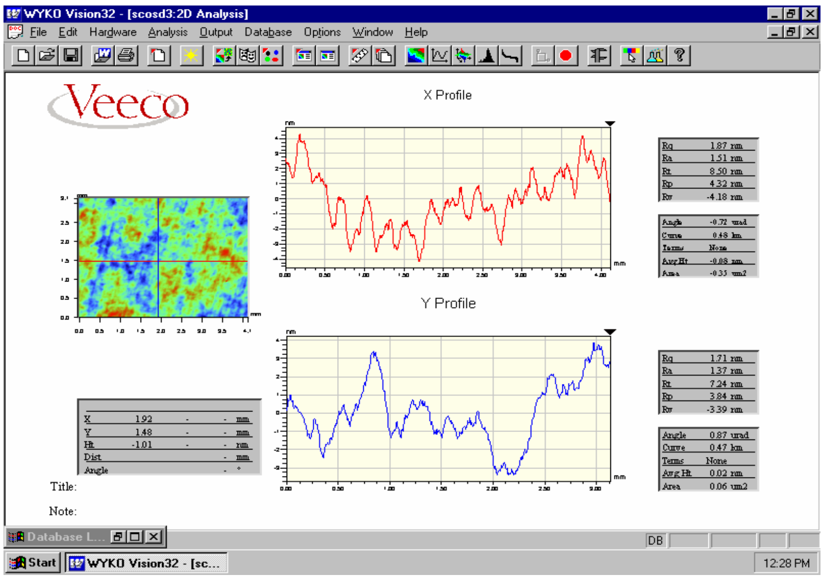

Fig. 9

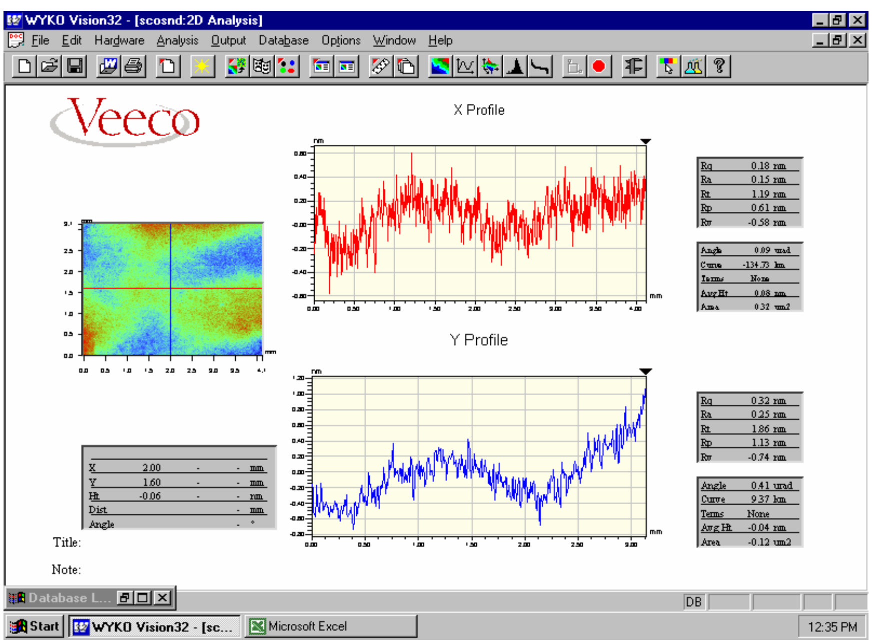

Fig.10

References:

[1] Dr. Frederick Aronowitz, Fundamentals of the Ring Laser , Optical Gyros and Their Application, RTO AGARDograph 339, May 1999.

[2] Garg et al, United States Patent, Patent No. US 6,238,450 B1; Date of Patent May 29.2001

[3] Nicholas et al. United States Patent. Patent No. 6,099,389, Date of patent Aug. 8,2000

[4] Y.V. Bakin, G. N. Ziouzev and M.B. Lioundomirski, Laser Gyros With Total Reflection Prisms, Optical Gyros and Their Application, RTO AGARDograph 339, May 1999.

[5] LLE Review, Volume 73, pp 45-49

[6] Jun Zhang, Kanagawa (JP) United States Patents Publication, Publication No. US 2006/0172663 A1; Pub. Date: Aug 3' 2006

[7] Wyco NT 1000 Users Manual