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Fabrication techniques for high resolution lens assemblies

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ABSTRACT

This paper presents the fabrication and assembly techniques for high resolution lens assemblies such as the projection lenses used for submicron photolithography. In order to meet the stringent precision and dimensional stability requirements for such lens assemblies, the aluminum lens cells are machined and heat treated in several steps to achieve the required accuracies. Special optical tools and mechanical gages are then used to assemble the lenses into the cells on an air-bearing table.

1. INTRODUCTION

In order to achieve the optimum image quality, the lenses must be assembled to very tight axial and decentration tolerances, and then must retain these tolerances under shock, vibration, and large temperature variations. The conventional lathe assembly method[1] of mounting the lenses in a barrel with spacers and retainers requires machining the lenses and all the mechanical parts of the assembly to very tight tolerances to achieve the required precision alignment of the lenses. This means that each set of lenses, spacers and the barrel have to be custom machined and matched, making this method very expensive for production quantities. Moreover, this design provides a very limited thermal compensation between the barrel and the lenses.

A number of other methods[2,3] proposed for high precision lens assemblies require machining of the spacers and lens seats with the expensive lenses in-place, and then bonding the lenses to the cells. The ability to disassemble the lens from its cell is an important consideration, since these components are expensive to fabricate, and cannot be discarded if the assembly does not meet the required centration tolerances.

The fabrication and assembly methods outlined in this paper are based upon the concepts outlined in references 2 & 3, but have the following additional advantages over the previous schemes:

1. The lenses can be machined to loose wedge and diameter tolerances.

2. The cells and spacers can be diamond machined separately without endangering the expensive optics.

3. The resulting assembly provides a high degree of thermal compensation, dimensional stability and resonance.

4. The lenses can be disassembled, if needed, from the cells without damaging any parts, and then can be reassembled to achieve the required centration accuracy using the same set of parts.

2. FABRICATION OF LENS CELLS

A typical lens cell is shown in figure 1. The lens seat, the two faces and a gaging cylindrical surface (GCS) are diamond machined in a single set up. This results in a cell with the lens seat and GCS being concentric and coaxial. This common axis of the cell is orthogonal to the two faces, which are parallel to each other. These machining features are used during the assembly process described in the next section. The lens cells are made from wrought aluminum alloy (6061-T4 or T6) because of its low density, good thermal conductivity and its ability to be diamond machined. The required precision tolerances and dimensional stability can be achieved with the following heat treatment and machining steps:

1. Rough machine to 0.050" over final dimensions.

2. Solution heat treat at 970°F ± 10°F for 30 minutes. Quench immediately into a 20-25% solution of polyalkylene glycol and water. Vigorous air-free agitation of about 100 FPM of solution is required during the quenching phase.

3. Precipitation heat treat at 350° ± 10°F for 6 hours, and air cool to room temperature.

4. Machine with light progressive cuts to final dimensions. The surfaces to be diamond machined should be finished to 0.010" over the final dimensions.

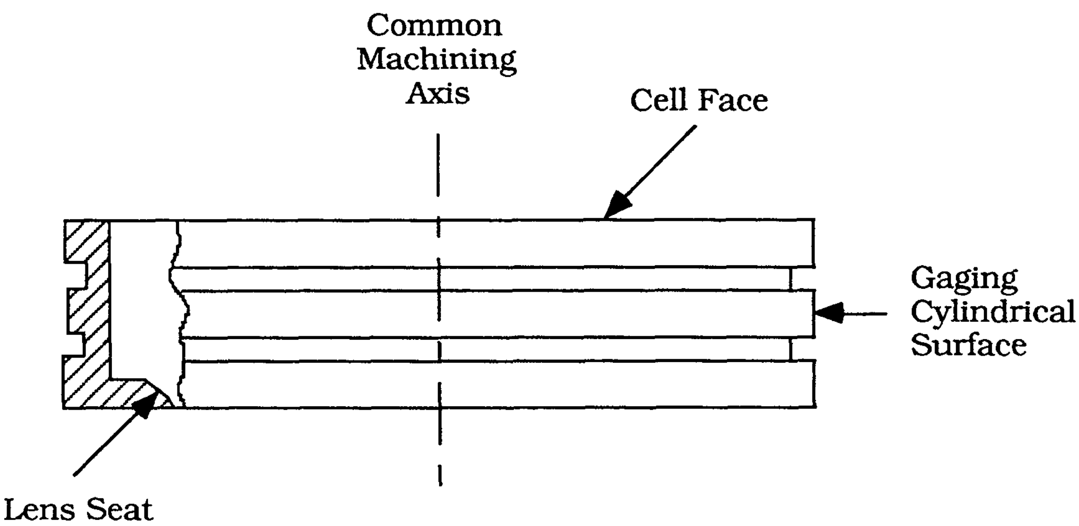

FIGURE 1: Diamond Machined Lens Cell

5. Stress relieve at 320° ± 10°F for 6 hours, and cool to room temperature in still air.

6. Thermally cycle a minimum of 3 cycles from -100°F to +212°F with 30 minutes soak at both temperatures, and 15°F/minute rate of temperature change.

7. Diamond turn the lens seats, cell faces and the GCS to the required dimensions and tolerances.

Due to the precision tolerances required for these cells, the diamond machining and inspection environments must be maintained to within 0.5°F of the operating temperature. Also, the cells must be temperature stabilized before machining and measurement, and handled with white gloves to prevent finger-printing and the change of size due to body temperature.

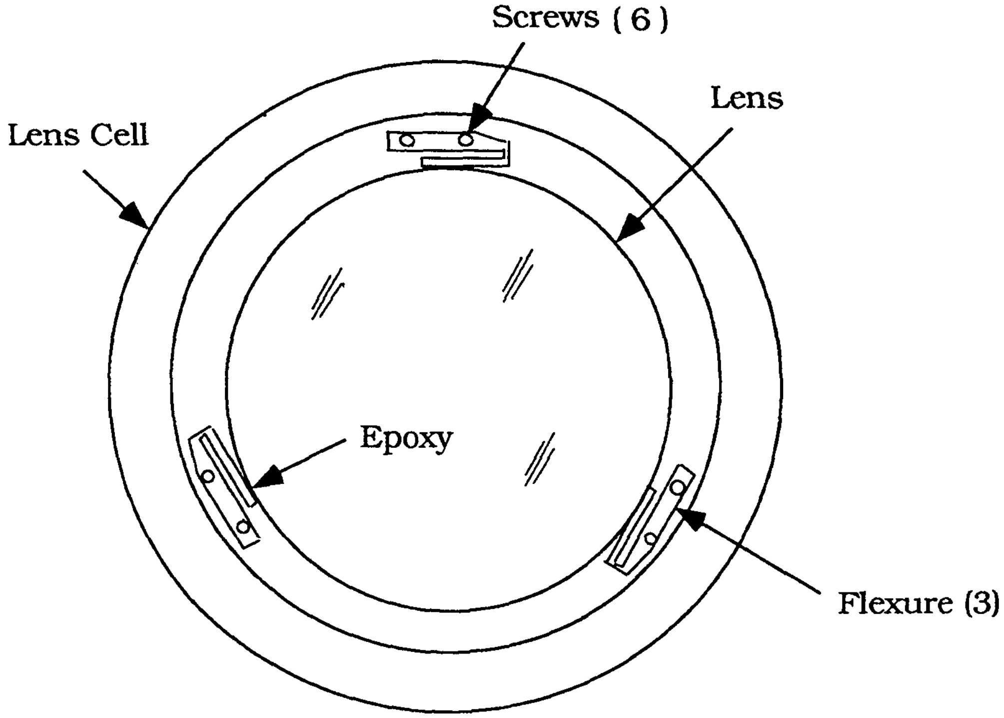

FIGURE 2: Lens Assembly

3. LENS ASSEMBLY METHOD

A typical lens assembly is shown in figure 2. The lens is secured to the cells with 3 equally spaced flexures, which are very compliant radially but stiff in all other directions. Each flexure is mounted to the cell with 2 screws. The assembly tooling and technique is schematically shown in figure 3.

The spin axis of the air bearing defines the "master" axis for centering the cells and lenses on a single common axis.

The flexures are assembled to the cell, and then it is placed on an air-bearing table (ABT). The cell is centered on the spin axis of the ABT by using fine screw adjustments mounted to the table, while monitoring the wobble of the GCS with an air or capacitance gage. Next, the lens is placed on its seat. The surface in contact with the seat is automatically centered by virtue of the seat being diamond machined coaxial with the GCS. In order to center the top surface of the lens, its wobble is monitored with an air gage or optically[3] while the lens is moved laterally on its seat by 2 fine adjustment screws, 90° apart. Once the lens is centered, it is bonded to the flexures and left on the air bearing table until the epoxy is sufficiently cured. A room temperature setting epoxy or a UV-curing epoxy can be used depending on the edge thickness of the lens, and the allowable surface distortion.

This technique can be used to mount either a single lens or multiple lenses in a cell depending on the diameters of the lenses. In order to make a multiple lens assembly, the single lens assemblies are stacked and centered by merely monitoring the wobble of the GCS on each cell, and then the cells are bonded together as shown in figure 4. The correct axial spacing can be obtained either by machining the cells to the correct thickness, or by using the spacers between the cells.

If a lens is found to be decentered or distorted after the epoxy has cured, it can be disassembled from the cell by removing the screws holding the three flexures to the cell. This disassembly process does not pose any risk of damage to the cell or the lens. The assembly process can then be repeated with the same set of parts to obtain the correct centration.

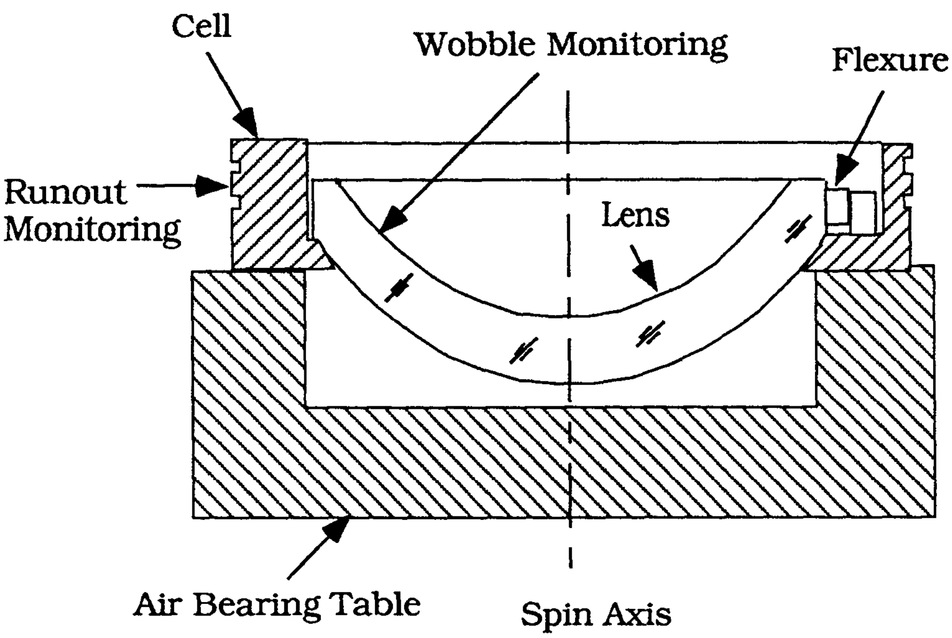

FIGURE 3: Assembly of Lens in the Cell

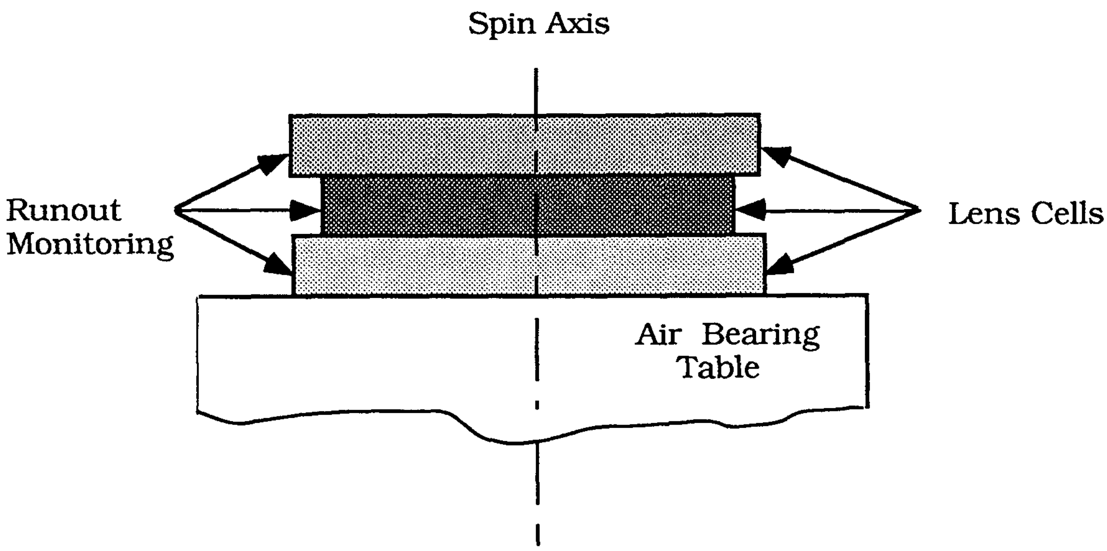

FIGURE 4: Assembly of Lens Cells

4. CONCLUSION

The fabrication and assembly techniques presented in this paper are especially suitable for those application requiring the lenses to be assembled to very precise tolerances. This method allows us to use aluminum and steel parts, and still obtain high degree of thermal compensation and dimensional stability. The lenses can be machined to loose tolerances, and then assembled to micron level accuracies. The assembly method is particularly suitable for making lens assemblies in large quantities, and minimizes the number of expensive cells and lenses that are likely to be damaged or rejected for not meeting the required assembly tolerances.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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