Technical Brief

High-Precision Linear Rail Application for Semiconductor Manufacturing

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As geometries in semiconductor manufacturing shrink, the measurement of device features during wafer processing is becoming even more critical to prevent scrap and the resulting lost revenue. Highly accurate, reliable metrology equipment can ensure that precision processes such as etch and deposition perform within tolerance by allowing operators to identify problem areas quickly and make machine adjustments immediately to avoid yield losses.

The linear guide system used in metrology equipment is critical to overall machine performance, and can be adversely affected by even minute movements or slight pivoting of the guide about its axis. Any deflection or clearance within the linear guide can reduce accuracy, and any roughness in the movement of the load-bearing elements can cause inaccuracy in the machine output, even when driven by highly sophisticated motion controllers.

As a result, the most commonly used products for metrology applications have traditionally been systems without recirculating components, such as cross roller slides (Fig. 1) or air bearing systems. However, the lack of recirculating components in the cross roller slide also leads to stroke limitations (typically 600mm or less) as well as reduced load capacity and rigidity. While air bearing systems do not have the stroke limitations of cross roller slides, they require expensive air supply systems and are more complex to install and set up. Metrology equipment suppliers and their customers could eliminate time and cost by considering high-accuracy linear guides, such as the Bosch Rexroth High-Precision Ball Rail® System.

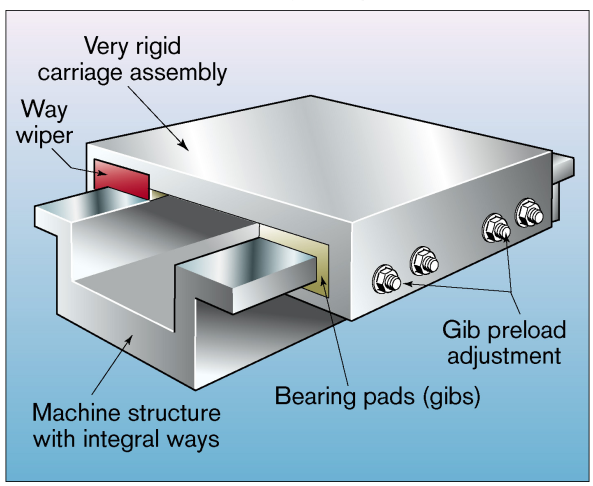

Figure 1

Linear guide accuracy depends on many factors: the trueness of the rail on which the runner block or bearing travels, the raceways inside the bearing

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through which the balls or rollers travel, as well as the flatness of the rail mounting surface, and a host of other factors. But among high-performance linear bearings, the most important area of refinement is the smoothness of ball recirculation inside the runner block as it travels along the rail.

To make linear guides meet the accuracy requirements of metrology applications, the solution is to alter the geometry of the recirculation pathways and eliminate roughness at key transition points. Rexroth's High-Precision Ball Rail System overcomes these limitations by optimizing the recirculation of the balls inside the runner block, providing extremely smooth motion and accuracies ranging between 4 and 6 microns. Because the Ball Rail System makes this performance so repeatable, it's now possible to compensate for such minor deviations in the control of a precision machine, enabling achievement of near-perfect accuracy.

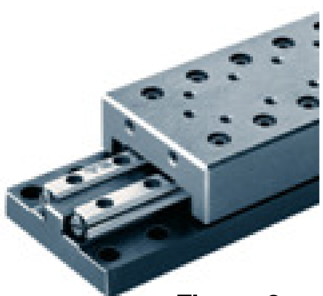
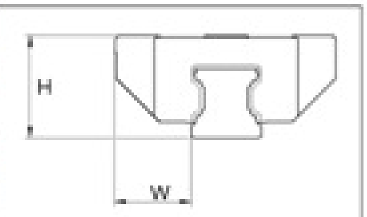


Figure 2

Normally, accuracy measurements in linear guides are defined by the height and the width variation, as measured from the middle of the runner block (Fig. 2). However, measurement of height and width alone do not account for any pivoting of the bearing about the X, Y or Z axis. In other words, although the height or width of the bearing may be extremely accurate when measured from the middle of the runner block, there may be some inaccuracy about the center line of the bearing due to ball pulsation—causing the bearing to rotate slightly about its axis. These movements are known as pitch, roll, and yaw. (Fig. 3)

Tolerance		
Accuracy Class	Height[1]	Width[1]
Standard - N	±100(μm)	±40(μm)
Standard - H	±40(μm)	±20(μm)
Standard - P	±20(μm)	±10(μm)
High Precision- XP	±11(μm)	±8(μm)
High Precision- SP	± 10(μm)	±7(μm)
High Precision- UP	± 5 μm)	±5 μm)



[1] *Tolerence – any bearing at any position on the rail*

Figure 3

What can be done to minimize pitch, roll, and yaw? There are three key transition points in a typical linear bearing where a reduction in roughness can lead to dramatic improvements in performance. They are the entry zone, the load zone (where the ball is actually under load), and the exit zone.

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The entry zone is the point just before the ball enters the load zone. At this point the ball is circulating through the end of the bearing and is rounding some critical radii before it re-enters the load zone. (Fig. 4) As it passes these points, the rotation of the ball can be affected by surface roughness and contact angles inside the bearing, creating friction as well as additional unwanted motion.

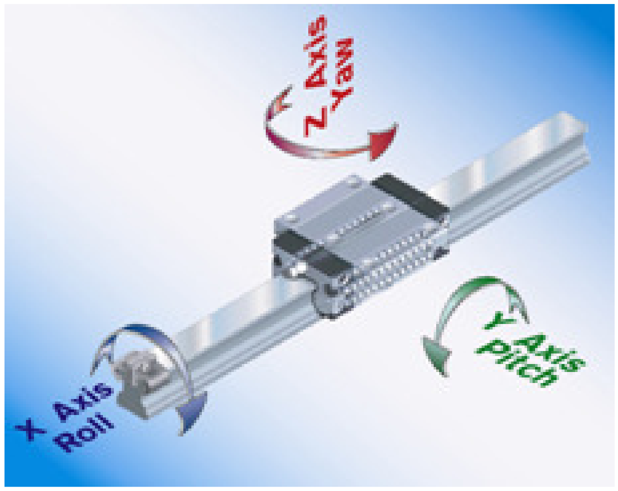

Figure 4

In the load zone, the ball is rotating, and motion is typically consistent with uniform ball spacing. But as it approaches the exit zone, it goes from a point of load to no-load and is shot out of the load zone into the end of the bearing. This exit zone area is characterized by inconsistent ball spacing and ball-to-ball contact due to balls being shot from the load zone. Interactions in each of these key transition points lead to ball pulsations that can be felt when moving the bearing by hand. These ball pulsations ultimately cause rocking motions that affect the overall smoothness of travel and can be problematic for high accuracy metrology, scanning, and optical equipment.

High-Precision Ball Rail solves the problem

Bosch Rexroth's High-Precision Ball Rail system has overcome these limitations by optimizing ball recirculation to provide extremely smooth motion as the balls circulate in the bearing raceways. This is accomplished through the use of a steel insert and relief zones that dampen the ball entry forces at the ends of the bearing. (Fig. 5) This dampening eliminates the rough

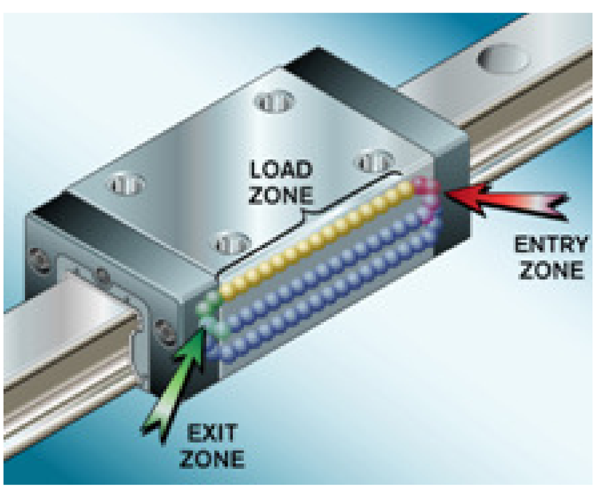

Figure 5

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motion and rolling of the ball rail system about its axis and creates not only accurate height and width dimensions, but also reliable linear motion about all axes. Rexroth tests show a 60 percent reduction in pitch, roll, and yaw compared to standard linear guide systems. (Fig. 6)

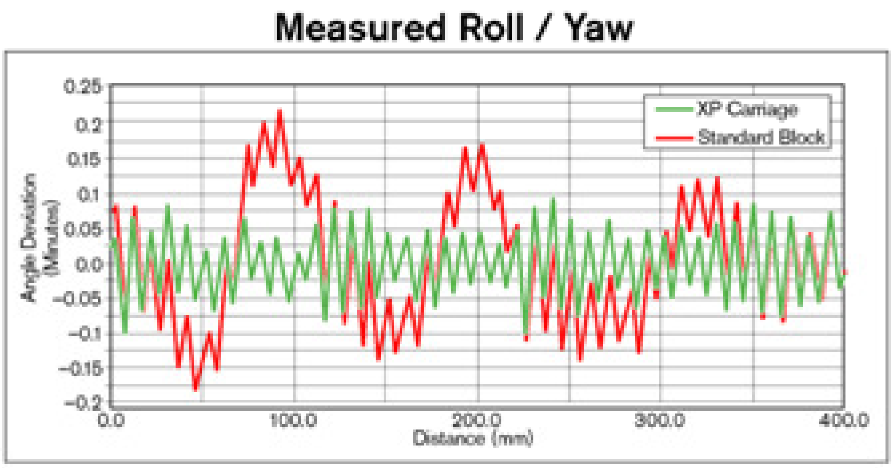

Figure 6

With the emergence of super-precise linear guides such as Rexroth's High-Precision Ball Rail system, designers and machine builders in the metrology, scanning, and optical equipment markets have new options for linear motion within their machines. High-precision linear guides can now help these companies avoid the performance limitations of cross roller slides and the complexity and cost of air bearing systems, while retaining the accuracy and reliability that wafer manufacturers require.

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