Wear and Ion Erosion in Spinning Disk Fences made with Al and Torlon

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Abstract: Wear effects are evaluated in spinning wheel wafer fixture components made from Al and Torlon materials exposed to high current ion beam exposures and over 350,000 wafer moves over extended time periods. Metrologies used include: (1) optical and SEM microscopy (surface texture changes), (2) optical profilometry (wafer wear and ion erosion), (3) RBS (chemical composition and accumulated ion dose), (4) TOF-SIMS and ICPMS (elemental contamination on wafers). In addition, we present in-line data on reduced wafer chipping with Torlon replacing Al fences.

Keywords: Torlon polyimide, wafer fences, fixed restraints, wear resistance, optical profilometry

I. INTRODUCTION

Several decades after they were designed, many spinning wheel end stations continue in service in high current implanters. In the meantime, requirements for significant reductions in metallic contamination levels has driven the development of non-metallic replacements for end station components in positions exposed to heavy dose ion beams [1]. One key area for non-metallic components is as replacements for metal (usually Al alloys) "fence" or "finger" structures on the outer radius of the wafer positions in spinning wheels. These fences not only need to function in high ion dose environments with minimal erosion, dimensional change and contamination risk but also need to provide reliable wafer restraints under high centrifugal forces.

High-strength polymer Torlon is widely used in high performance parts where wear resistance and mechanical strength are required [2]. Torlon is available in a variety of formulations based on a polyamide-imide core molecule (Fig. 1) with general high performance from cryogenic temperatures to above ≈260 C. Torlon parts are especially notable for high tensile strength, lubricity (low coefficient of friction) and wear resistance to metals and other hard materials abrasion [2].

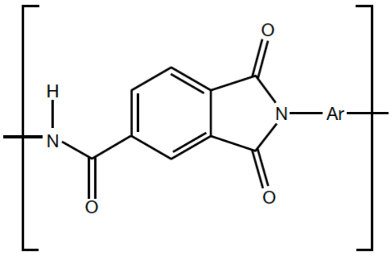

Fig. 1. Structure of Torlon polyamide-imide polymer.

A practical design for the use of high-strength polymer Torlon wafer fences is shown in Fig. 2 for use in GSD (Gyroscopic Spinning Disk)-type spinning wheels. The Torlon part replaces an Al alloy component. Corresponding fixtures for fixed restraints in AMAT-9500-type spinning wheels are shown in Fig. 3.

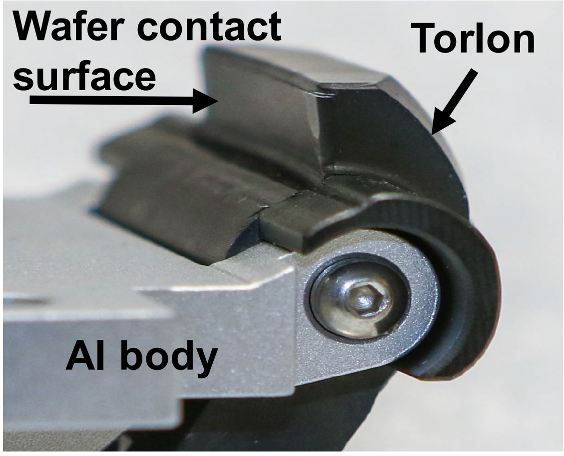

Fig. 2. Photo a Torlon fence assembly for a 200 mm GSD disk.

Fig. 3. Photo of fixed restraints for AMAT-9500-type 150 (left) and 200 (right) mm spinning wheels.

II. IMPLANTATION CONDITIONS

Torlon wafer fixturing components were exposed in high-volume 200 mm IC production environment for over a year. Torlon parts were used in wafer wheels processing ≈350,000 wafer moves, or ≈27,000 wafer contacts per fence unit. The estimated accumulated exposed dose, primarily As ions, was well over 10^{20} As/cm^2.

RBS measurements (Fig. 4) from the top surface of heavily implanted Torlon fence part confirmed the high dose As exposure.

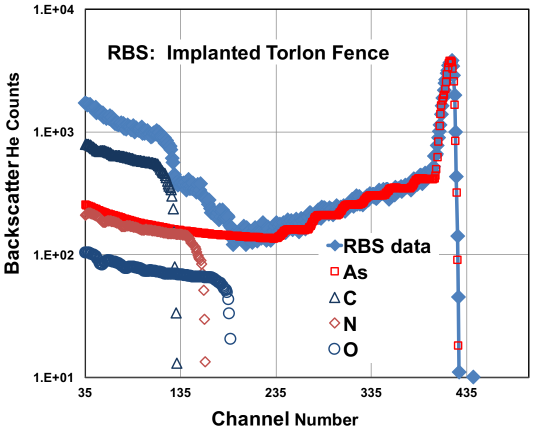

Fig. 4. RBS spectra from the top exposed surface of a heavily implanted Torlon fence part showing a strong As accumulated dose on the surface. Also shown are the C, N and O material components fitted to the total RBS signal.

The RBS measurements were done with 2.275 MeV He^{2+} beams backscattered to a detector at 160° relative to the incident beam. The assumed Torlon density was 1.15e23 atoms/cm^3. The Torlon and implanted As compositions were fitted to the observed backscatter spectrum.

TABLE I. ATOMIC COMPOSITIONS (ATOMIC %) AT VARIOUS DEPTHS IN A HEAVILY AS IMPLANTED TORLON FENCE DERIVED FROM RBS DATA.

	0 nm	50 nm	100 nm
As (at. %)	20.6	10.7	2.2
C (at. %)	62.7	71.2	78
N (at. %)	11.7	13.2	14.8
O (at.%)	5.0	5.0	5.0

The results in TABLE I. show that the C, O, & N concentrations exhibit only slight variations in depth under the high-dose As profile. The statistical uncertainties in the atomic concentrations are ±0.5 % for As and ±5 % for C, N and O. This data indicates that the only matrix element to change relative levels during the yearlong exposure from the Torlon resin composition (Fig. 1) was O, reduced from ≈20 to 5%.

III. IN-LINE RESULTS

A. *Wafer chipping rates*

Wafer edge chipping rates in high volume production lines with Al fences ranged up to 11 wafers per month, with a fleet average of ≈0.5 wafers chipped per tool per month for 200 mm wafers. The estimated tool availability loss was 1.5% for events related to chipped wafers. After installation of Torlon fences, *no* wafer chipping events were reported for an estimated 350,000 wafer moves.

B. *Metallic contamination levels*

The use of hard polymer Torlon fences reduced metal contamination on wafers from levels seen with Al fences. Al levels with Torlon fences measured by TOF-SIMS relative to results with the use of Al fences were 16% near the fence edge and 38% in wafer centers. ICPMS measurements, measured on wafer locations near the fences with Torlon fences, in terms of the percent levels compared to the Al fence data, for a broad range of elements are listed in TABLE II.

TABLE II. METAL CONTAMINATION LEVELS (IN %) ON WAFERS WITH TORLON FENCES MEASURED BY ICPMS REFERENCED TO LEVELS WITH AL FENCES.

Al	Ca	Cr	Fe	Mn	Ni	Na	Ta	Sn	Ti
66	23	29	13	0	0	61	31	62	42

IV. WEAR MEASUREMENTS

A. *Al Fences*

Optical images and wear depth measurements were done with a visible light surface scattering tools (VR-3200 and VK-1100) with dimensional and height resolutions of ≈1 um for cm-scale physical parts [3].

Laser illuminated optical imaging (Fig. 5) of an Al fence part after over a year in service shows considerable grooving at the wafer edge contact as well as photoresist residue build up above the wafer plane.

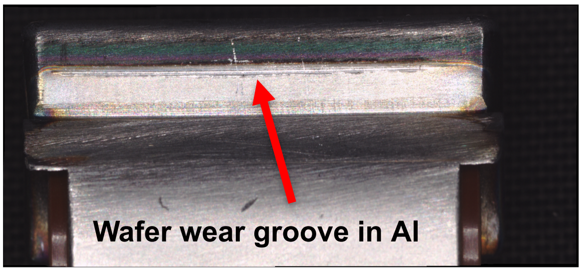

Fig. 5. Optical image (VR view) of wafer edge wear in Al fence with >350,000 wafer moves per disk.

A scanning optical VK profile (Fig. 6) of the Al fence, shows a 14 µm deep groove and a 34 µm high extrusion ridge in the area of the wafer contact. The profile is indicative of plastic deformation and material erosion. The sharp edge of the groove is thought to be largely responsible for the observed wafer chipping/breakage rates.

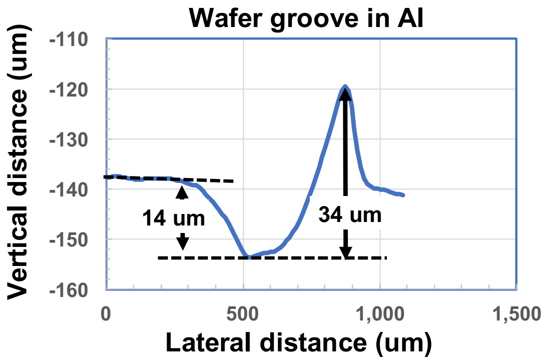

Fig. 6. VK measurement of a wear depth profile at the wafer contact in a heavily used Al fence, groove depth ≈14 µm, with an extrusion ≈10 µm above the level of the original Al surface.

B. Torlon fences

Laser optical imaging and depth measurements on Torlon fence parts after over one year in service showed a distinctly visible wafer contact mark (Fig. 7), however the measured groove depth was only 6.6 µm (Fig. 8).

Fig. 7. VR optical image of wafer mark on Torlon fence after >350,000 wafer moves on disk. The mark is visually distinct under laser illumination but has very little depth, (see Fig. 8).

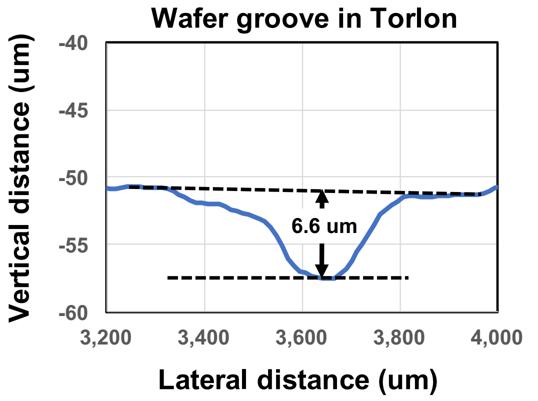

Fig. 8. VK optical measurement of wear depth profile at the wafer contact in a heavily used Torlon fence, ~6.6 µm

Large area optical scans of Torlon part contours showed no evidence of plastic deformation or radial distortion from the original dimensions and shape (Fig. 9).

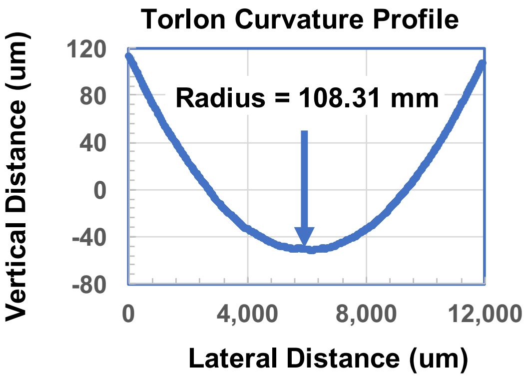

Fig. 9. VR measurement Torlon fence curvature at the wafer contact plane, showing no distortion from the original shape due to extended ion exposure.

V. DISCUSSION

In spite of initial concerns that the use of hard resin "plastic" parts in heavy-use ion implantation environments would lead to melting, ion beam embrittlement, outgassing, mechanical failure, contamination, physical shape distortion or high rates of wear, the present study finds that those fears are unfounded for the case of Torlon wafer fence parts. In addition, the use of robustly designed Torlon wafer fence parts has virtually eliminated wafer chipping and particle contamination from wafer-fence contacts. In addition to these reports on the use of Torlon, fence components made from PEEK materials have been fabricated and tested with similarly satisfactory results as those reported here.

VI. SUMMARY

Torlon parts are excellent for replacing Al fences in spinning wheel end stations in high-volume ion implantation operations. The principal benefits are related to the high wear resistance of Torlon, leading to reduction in wear depths at the wafer contact as well as virtual elimination of wafer chipping due to fence contact. In addition, metal contamination levels are also substantially reduced by the switch from Al to Torlon fence parts.

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