

Surface Engineering of Polymer Eyewear Frame via Ceramic Tumbling: Optimizing Surface Roughness for Enhanced Coating Adhesion

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BACKGROUND OF STUDY

PA12 Polymer Eyewear

Operator-Dependent
Relying on Operator's Experience, High Variability

Inconsistent Finish
Peeling, Grainy Texture Surface and Micro-Scratches

Unknown Roughness Control
Lack of Quantitative Data between Roughness (Ra) & Tumbling Parameters

Limited Literature Data
Limited Studies on Established Tumbling Parameters and Surface Roughness



Reworks and Rejects
High Defect Rates Leading to Costly Reworks

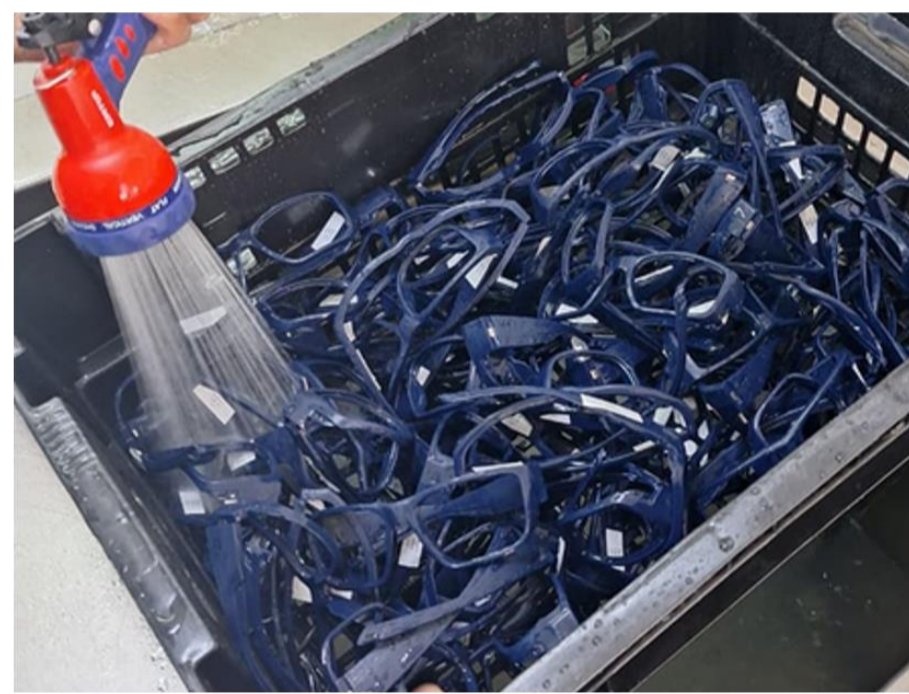
METHODOLOGY

1.0 Sample Preparation

- Injection moulded PA12 frames
- Trimming of part lines (frame & temple)

3.0 Pre-coating

Ultra-sonic Cleaning

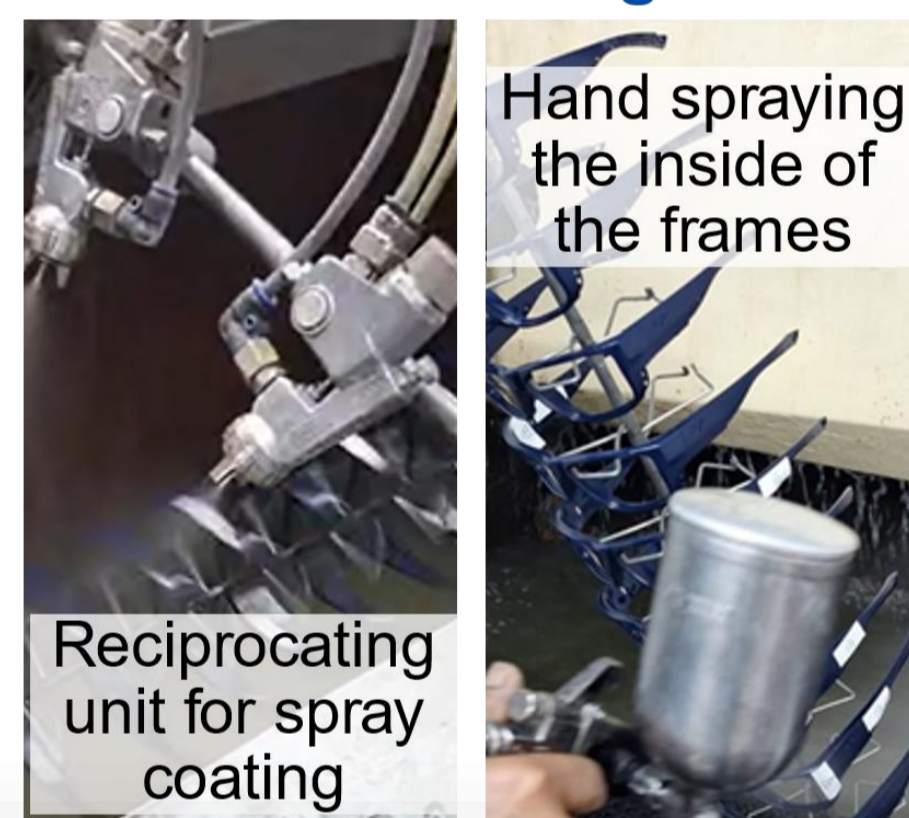


2.0 Tumbling & Labelling

Centrifugal Drying Basket

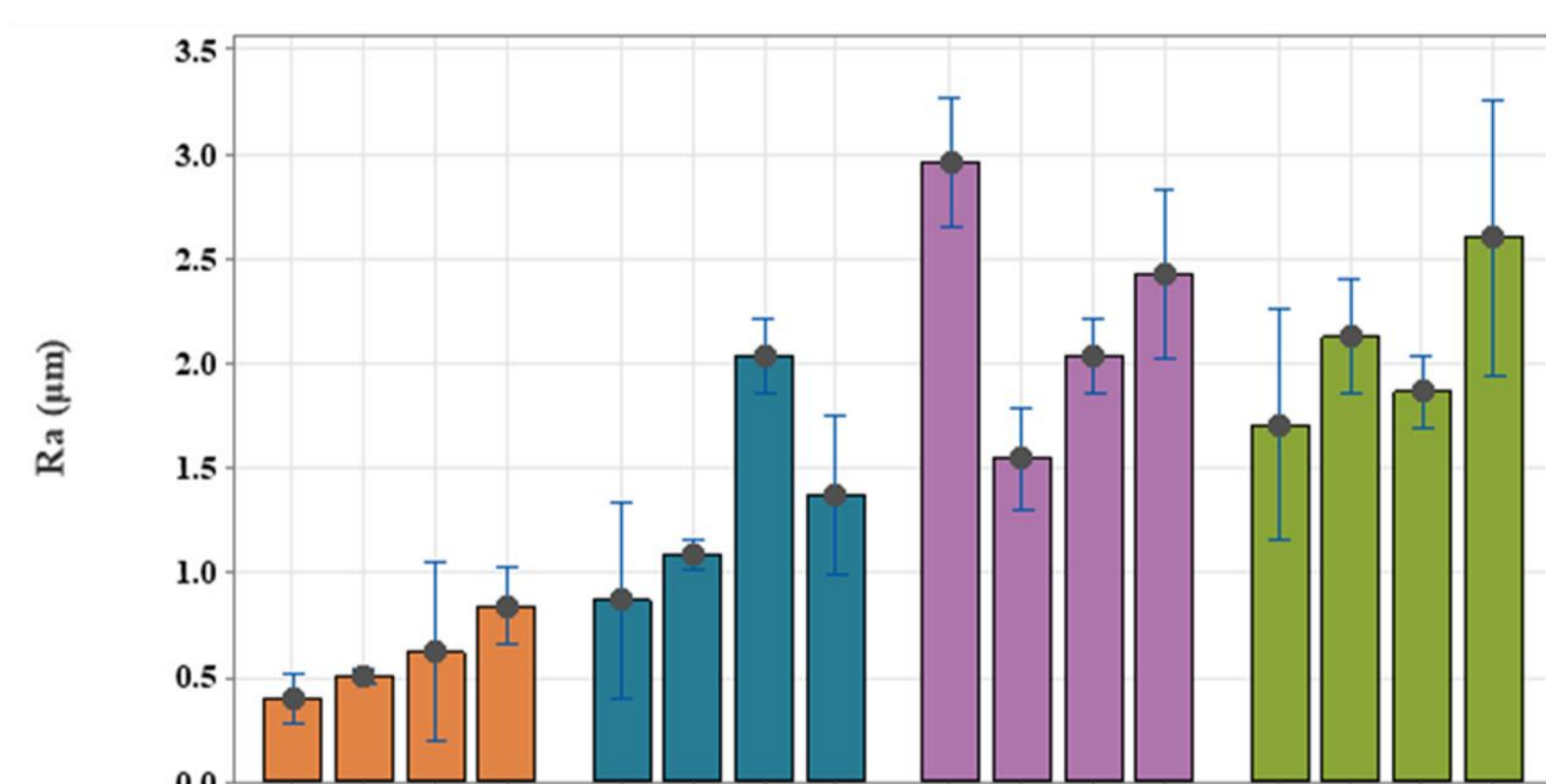


4.0 Coating

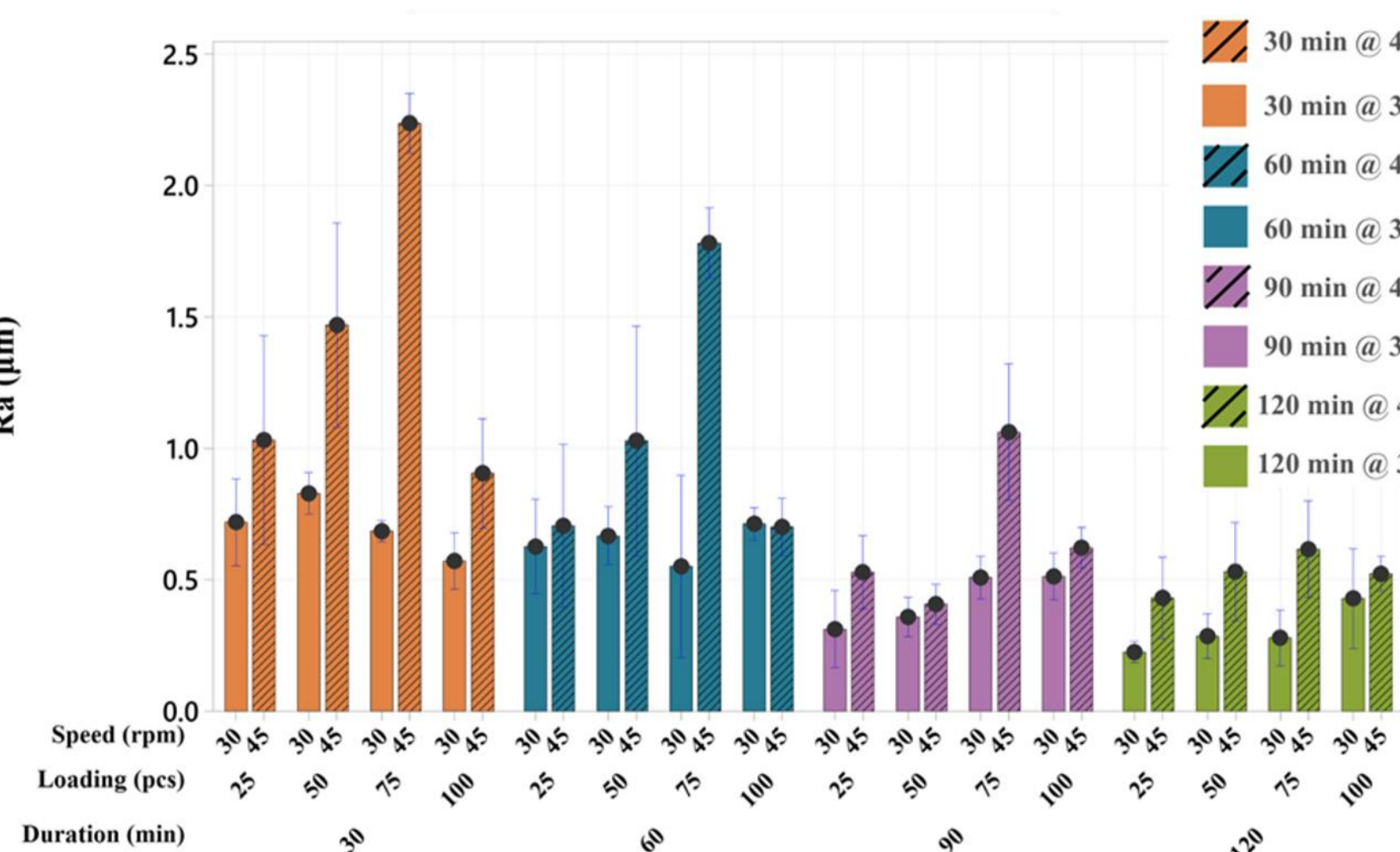


Mean Surface Roughness, Ra (µm) VS Tumbling Parameters

Wood Media Tumbler



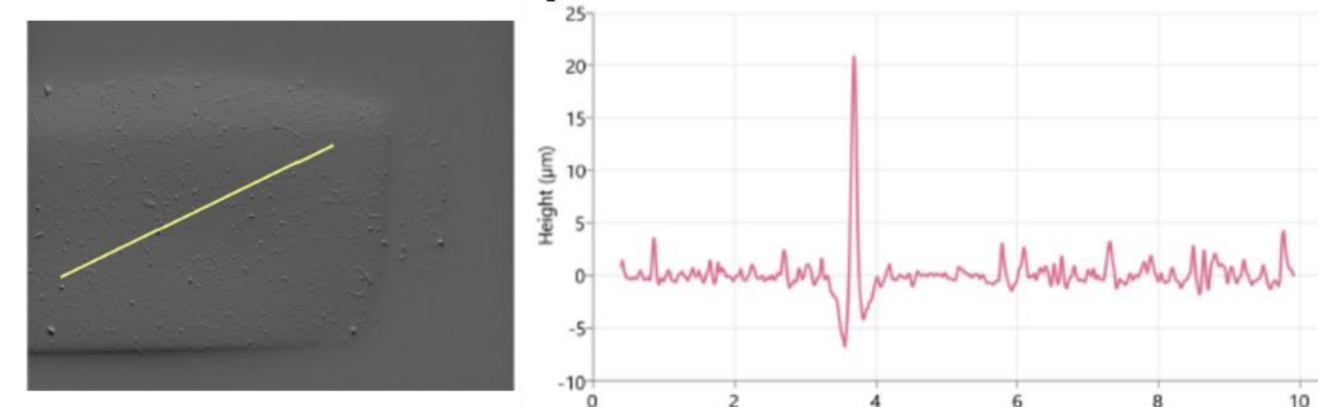
Ceramic Media Tumbler



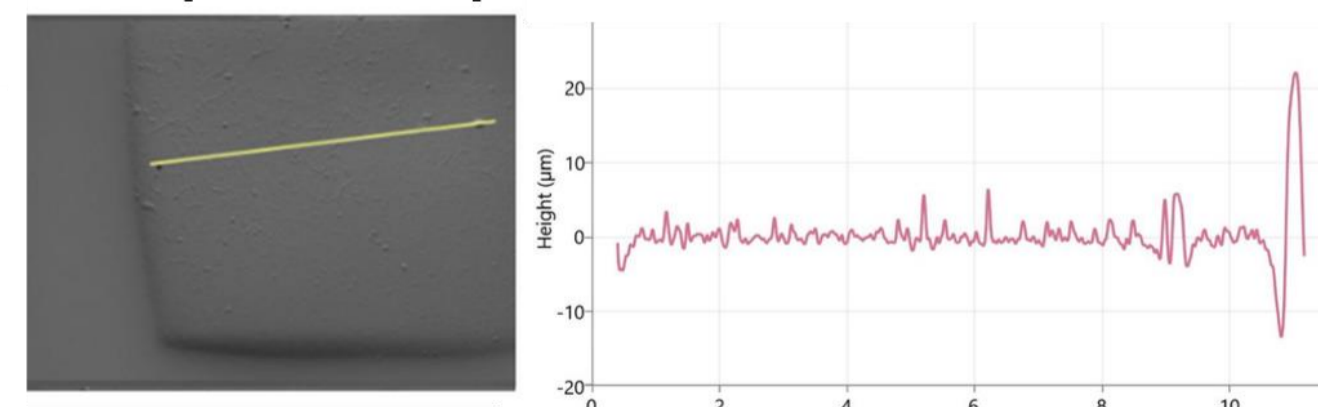
ANALYSIS OF RESULTS

GelSight Roughness Analysis - Ceramic Media

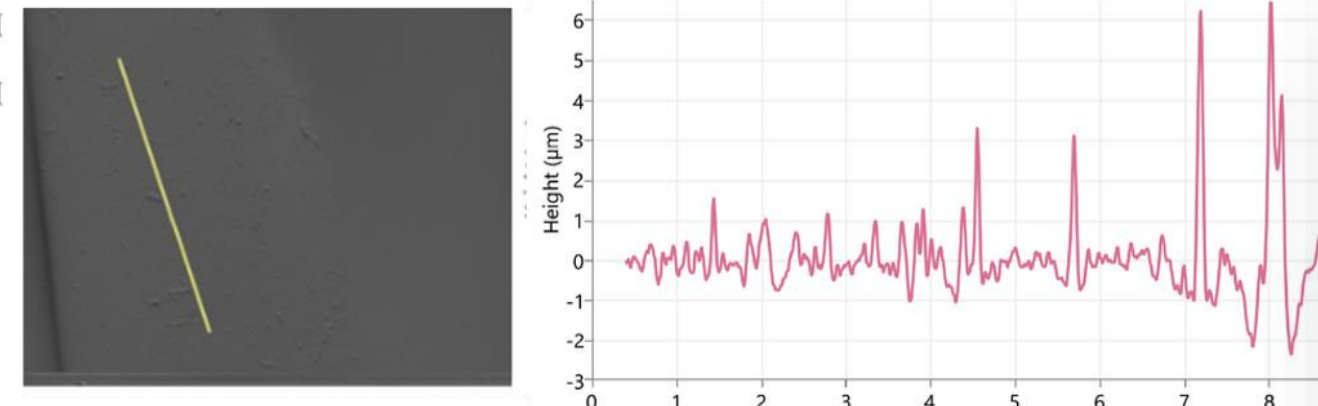
Untumbled Sample



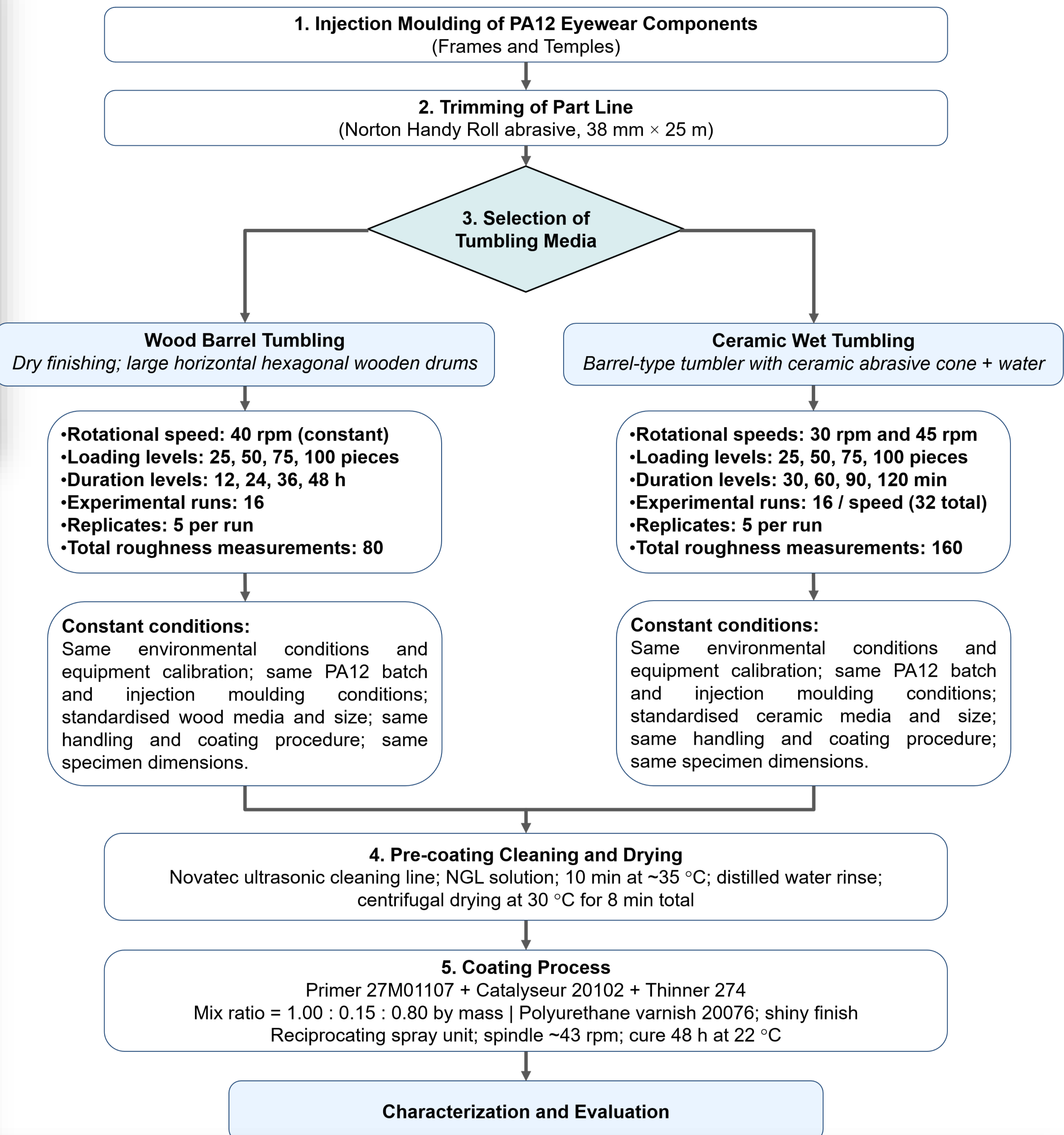
50 pcs at 45 rpm at 30 min



50 pcs at 45 rpm at 120 min



FACTORIAL DESIGN OF EXPERIMENT



EVALUATION

A. Cross-Hatch Adhesion Test
ASTM D3359 Method B
6 x 6 lattice; 3 test locations

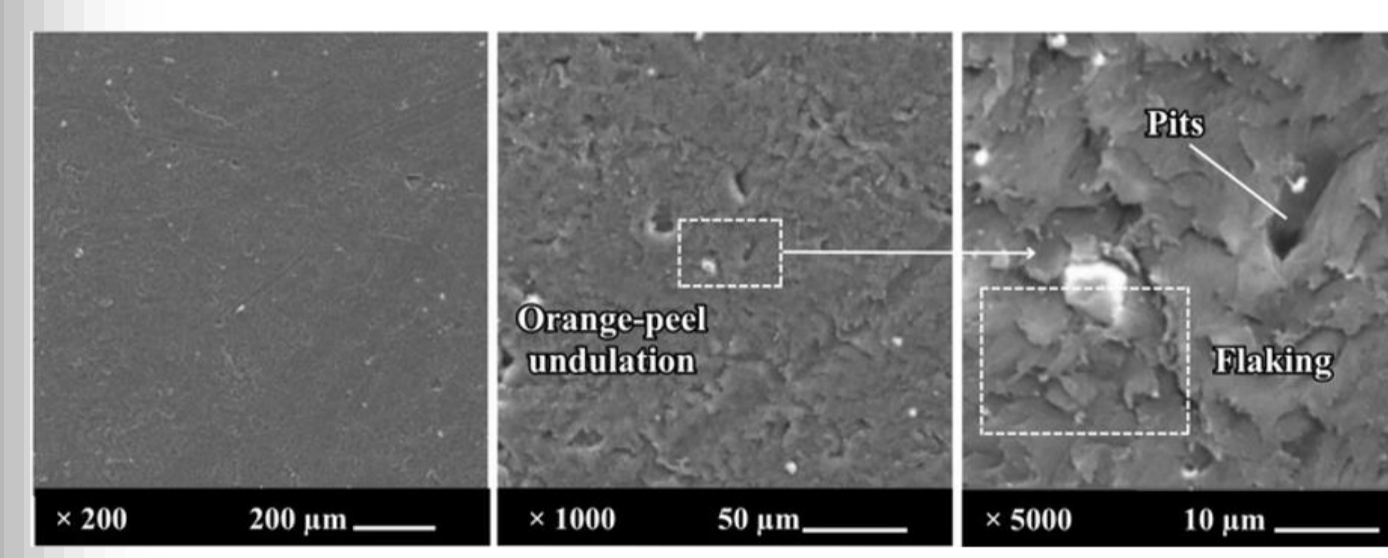
B. Surface Roughness Measurement
GelSight tactile profilometry
ISO 4287 Outputs: Ra and Rz;

C. Scanning Electron Microscopy (SEM)
Tescan Vega 3 Au/Pd sputter coating
ISO 16700 (200x to 5000x)

D. Visual Inspection
ISO 13076 800 ± 100 lux; Viewing Distance 25-45 cm; Zones A, B, C

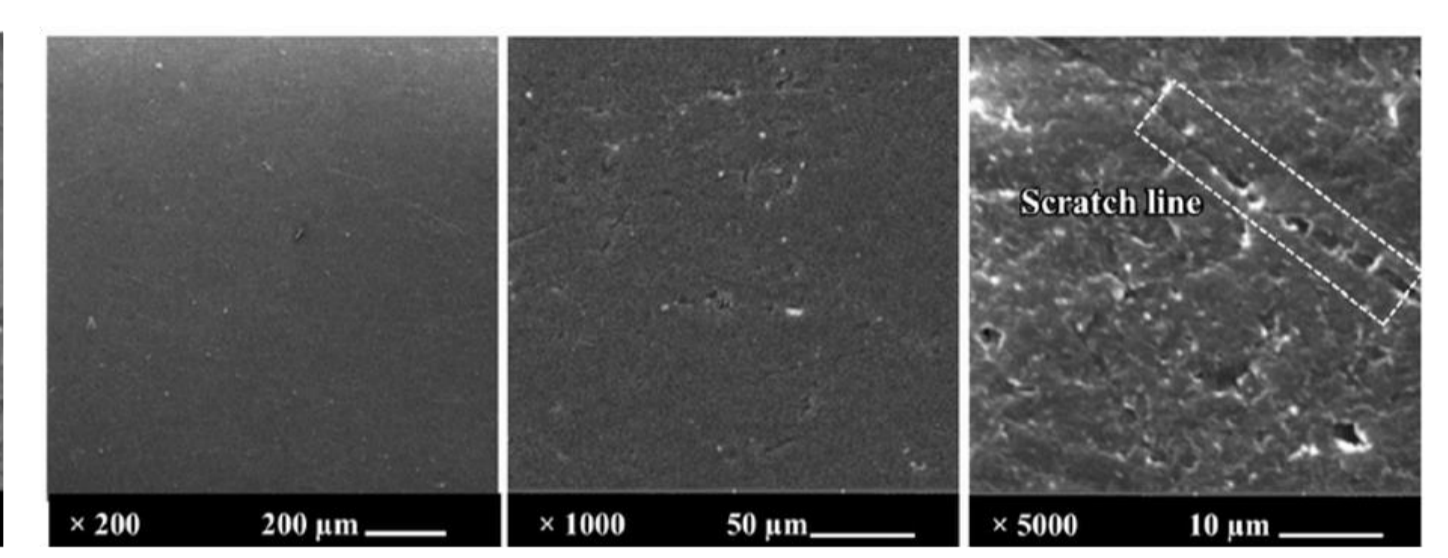
Ceramic Media

50 pcs at 45 rpm at 30 min

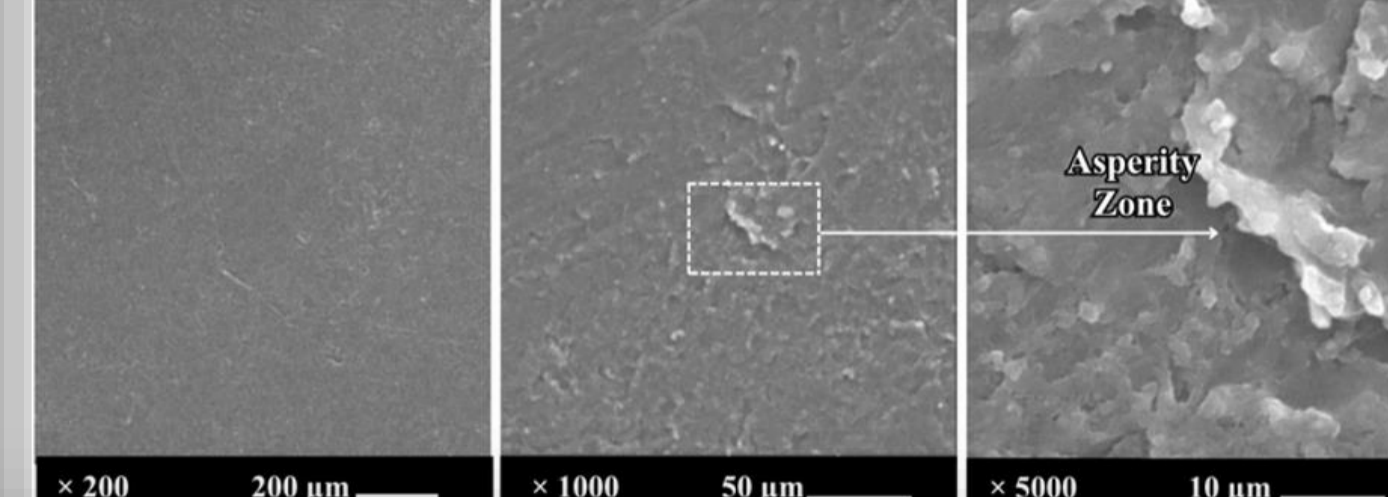


Wood Media

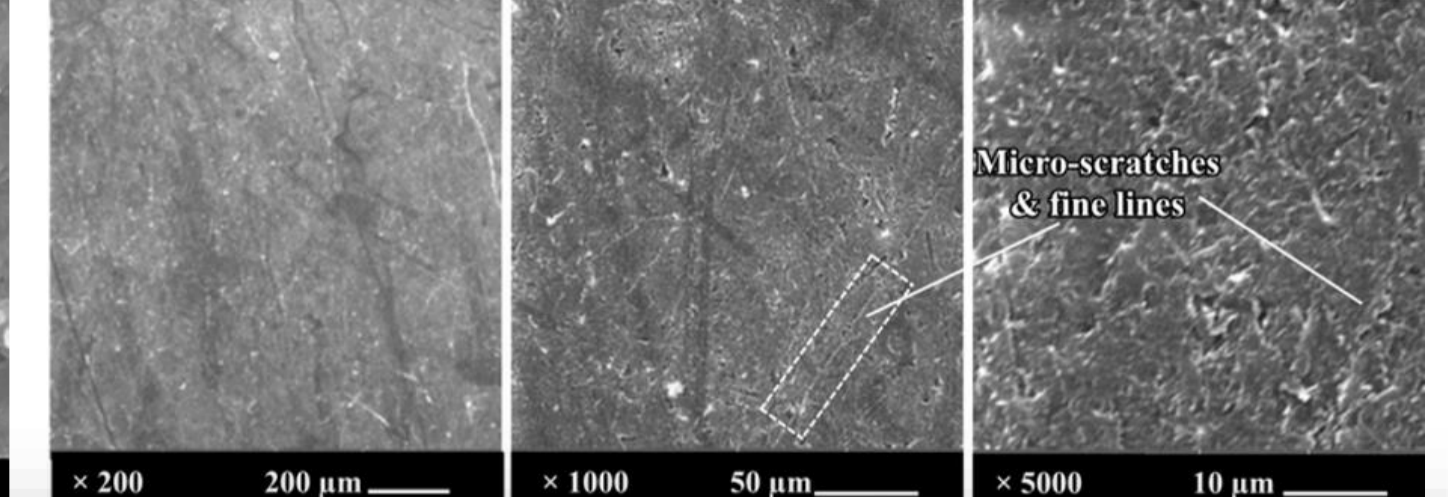
24h with 25 pcs



50 pcs at 45 rpm at 120 min



24h with 100 pcs



SUMMARY OF KEY FINDINGS

- Wood media produced smoother and more consistent surface texture while Ceramic media resulted in more aggressive abrasion.
- SEM analysis confirmed reduction in surface defects at longer durations
- GelSight results showed consistent trends in Ra and Rz measurements
- Optimal surface finish achieved within Ra range ≈ 0.6 – 1.2 µm
- Optimum Tumbling Conditions**
 - Ceramic at 45 rpm for 60 – 90min with 25 – 50 pcs
 - Ceramic at 30 rpm for 30–60 min with 50 – 100 pcs
 - Ceramic tumbler at 30 rpm with 75 pcs for 30-45 mins then in wood tumbler for 12 hours.