Structured Surfaces

– the new paradigm in surface metrology

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Outline

- Overview of surface metrology
- What is the new paradigm?
- What are structured surfaces?
- How to classify structured surfaces?
- How to evaluate structured surfaces?

Overview of Surface Metrology

- 1940s
  - Mechanical instruments with 2RC analogue filter
- 1960-1970s
  - Digital instruments with mean line filter system
- 1980s
  - Larger range instruments (for form and texture measurement), started sound mathematical based approach
- 1990-2000s
  - Areal surface instrumentation (Optical, Stylus and AFM) and a well-defined characterisation system

1990's & 2000's

Dedicated Areal Surface Measurement Instruments

0.01 Nanometer — 25 millimeter

Atomic Force Microscopy

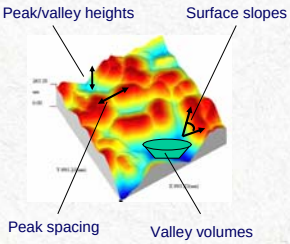
Coherence-correlation Interferometer

Optical Interferometer

Precision Contacting Stylus

1990's & 2000's

Areal Surface Characterisation: Terms, Definitions and Parameters



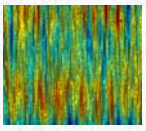
- Field Parameters

  Uses all the available data from the texture surface, which includes the S-parameter and V-parameter sets
- Feature Parameters

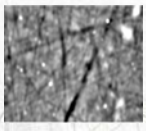
  Uses only data from previously identified segments from the texture surface.

Stochastic Surface Characterisation

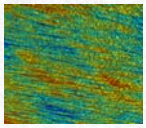
Honed



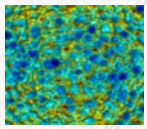
Ground



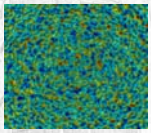
Polished



Hand polished

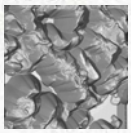


EDM

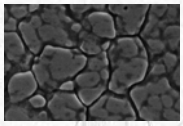


EPI wafer

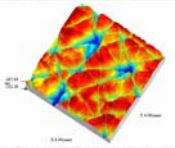
Stochastic Surface Characterisation



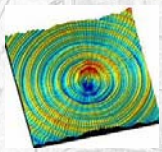
Grounding wheel surface



Steel sheet surface



Biological surface



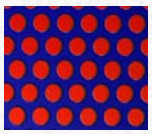
Diamond turned optical surface

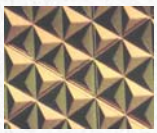
Metrology Faces

—New Type of Surfaces

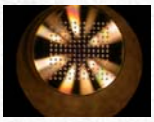
- Surfaces derived from:
  - Micro/nano manufacture technology
  - Ultra precision engineering
- Surface characteristics:
  - Simple or **freeform** shapes
  - **Micro/nano** dimensional/geometric deterministic pattern features

New Types of Surfaces

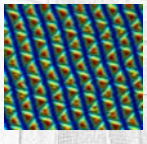




Optical de-pixelators



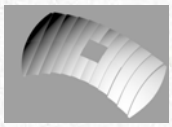
Micro-lens mold



3M Abrasive Paper

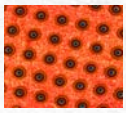
New Types of Surfaces

High beam freeform reflectors

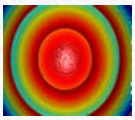


Freeform reflector of fog lamp

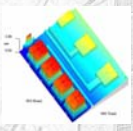
V-grooves

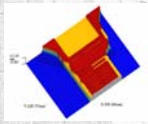


Laser Zone Texture



Fresnel lens

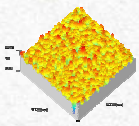




MEMS/MST Devices

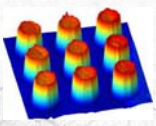
What Is the New Paradigm

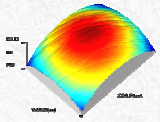
— in Surface Metrology



From Stochastic

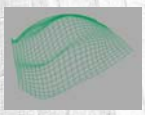
To Deterministic





From Simple Geometry

To Freeform



What Are Structured Surfaces

- Surface texture with deterministic patterns are called "**structured surfaces"** and include:
  - Non-rotationally symmetric patterns and linear patterns
  - Tessellations
- Characterisation of structured surfaces

  From

  Statistics of a cloud of points

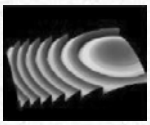
  To

  Statistics of predefined surface features

How to Classify Structured Surfaces

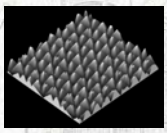
It is proposed to classify structured surfaces into two types according to surface characteristics:

Type 1



Fresnel lens

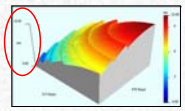
Type 2



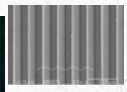
3M Abrasive Paper

Type One: Patterned Surfaces

- **Surfaces that include steps, edges and facets.**
- An example is the Fresnel lens that is used to focus the light in lighthouses and in some modern car headlights.

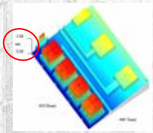


Fresnel lens



V-grooves

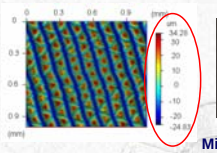
Fog lamp



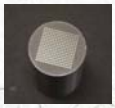
MST Device

Type Two: Tessellated Surfaces

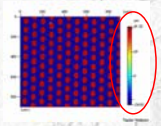
- **Surfaces that have a tessellated pattern, that is, a repeated structure over the surface.**
- **An example is a 3M abrasive surface which consists of an array of triangular based micron sized pyramids.**



3M Abrasive Paper



Micro-lens mold



Optical de-pixelators

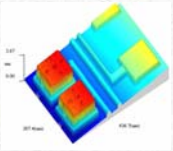
How to Evaluate Structured Surfaces

Initialised two evaluation techniques:

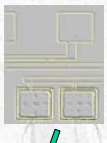
Type 1:
- Edge detection techniques (pattern recognition)
  - To detect the steps and edges which can be used to locate and orientate between the steps or edges.

Type 2:
- Segmentation in the autocorrelation function
  - To determine the unit tile, its geometrical shape and boundary.
  - To generate two translational vectors to provide the relationship between unit and neighbourhood.

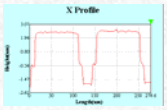
Type 1: Edge Detection Techniques



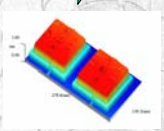
Edge detection:Pattern Recognition Technique



Enclosed contours to define sub-regions to generate a **datum**



Mean Step = 4.25µm



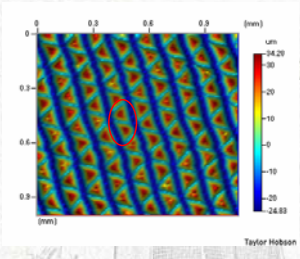
Unbiased step height

Type 2: Tessellated Surface

- Tessellated surfaces have a 'repetitive' filled tessellation
  - A tessellation is a collection of tiles that fills the plane with no overlaps and no gaps.
- The most common tessellations have translational symmetry
  - It can be evaluated by ***a unit tile*** and ***two translational vectors*** which describe the two basic repetitive planar translations of the unit tile.

Type 2: Tessellated Surface

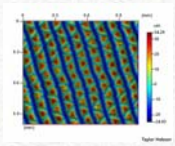
- For example, a tessellation model for the abrasive surface (3M paper surface), has a unit tile consisting of two adjacent triangular pyramids (one the mirror image of the other).



Type 2: Tessellated Surface Characterisation

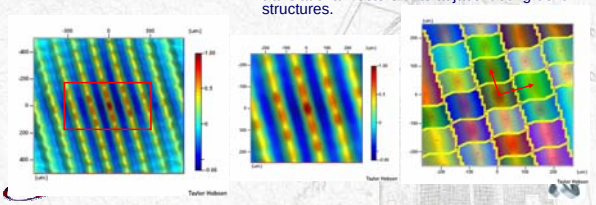
- The areal autocorrelation function combined with segmentation can provide the information for symmetric translation surfaces.
  - the segment around the origin provides the unit tile.
  - from the relationship of the unit tile with other segments it is easy to determine two independent planar translational vectors.

Type 2: Tessellated Surface Characterisation

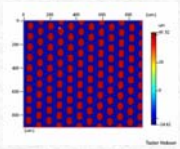


The ***segmented areal autocorrelation function*** of the 3M Abrasive Surface shows:

1. A unit tile (a quadrilateral consisting of two adjacent triangular pyramids at the origin).
2. The relationship between the unit tile and its eight neighbours
3. Two translation vectors.
4. An unit tile can be mapped by the two translational vectors onto adjacent congruent structures.

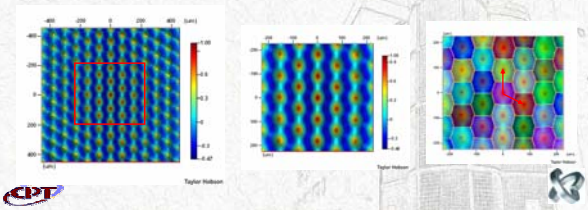


Tessellated Surface Characterisation



An optical de-pixelator:

1. A hexagonal unit tile
2. Six adjacent neighbours
3. Two translation vectors.



Summary

- Overview of surface metrology: **1940-2000's**
- What is the new paradigm? **Structured surfaces, Freeform surfaces**
- What are structured surfaces?
  - **Surfaces with deterministic patterns or tessellated texture**
- How to classify structured surfaces?
  - **Type 1: Patterned Surface Geometry**
  - **Type 2 Tessellated Surface Texture**
- How to evaluate structured surfaces?
  - **Edge detection (Pattern Recognition Technique)**
  - **Segmentation on areal autocorrelation function (obtain a Unit and Two Vectors)**

Structured Surfaces

– the new paradigm in surface metrology

Thank you for your attention

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DAMC Meeting, Cranfield, 11th September 2007