Investigating the effect of surface topography on cell behavior

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INTRODUCTION

Bone implants were first used in the early 20th century, and are now common practice in medicine and dentistry. This is in part due to the increased understanding of osseointegration (OI; the connection between living bone and the surface of the implant). Optimisation of the interface between implant and bone is crucial to the continued development of implant technology.

In this investigation, silicon and titanium surfaces were used to simulate the surface of a bone implant. Human osteoblast (OB) cells were then cultured on these surfaces to determine a relationship between surface roughness and osseointegration.

BACKGROUND THEORY

OB cells are responsible for bone formation in the body [1]. The adhesion of OB cells (and hence OI) on a surface can be described by the Young equation ($0 = \gamma_{SG} - \gamma_{SL} - \gamma_{LG}\cos\theta_C$) and the contact angle (Fig 1).

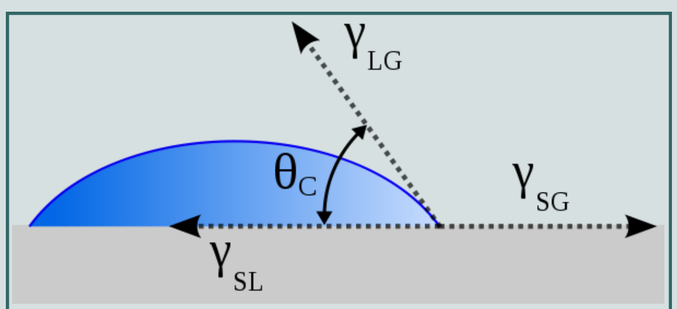

Fig 1: The contact angle θ_C and interphase energies between solid-liquid (γ_{SL}), solid-gas (γ_{SG}) and liquid-gas (γ_{LG}).

Implants are typically made of titanium because it is biocompatible and has similar mechanical properties to bone [2]. Silicon is readily available due to its use in the semiconductor industry and is non-toxic, making it an ideal control material.

Photolithography was used to fabricate the surfaces, a brief account of which is shown in Fig 3. Surface roughness is quantified in a number of ways, but the most useful to get a general idea of surface texture are R_a and R_q parameters:

$$R_a = \frac{1}{n}\sum_{i=1}^{n}|y_i| \qquad R_q = \sqrt{\frac{1}{n}\sum_{i=1}^{n}|y_i^2|}$$

Where n is the number of readings and y_i is the depth/ height from the mean-line for the i^{th} data point.

The expected behaviour of the OB cells is that rougher surfaces should have increased proliferation over extended periods of time [3].

PRE-FABRICATION INVESTIGATIONS

What roughening process to use and what mask plate to use were determined on test samples. Fig 2 shows the pattern to be etched. It was chosen because the 110x110µm squares are sufficient dimensions to be fabricated accurately and still suitable for the cell study. Results from a previous project investigating roughening processes were used.

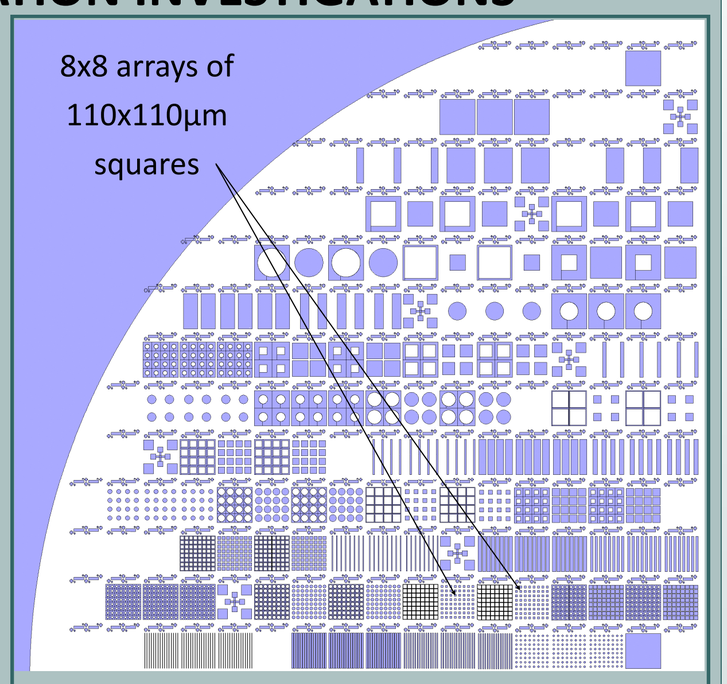

Fig 2: The pattern etched onto each quadrant. Only a quarter of the full mask plate is shown for clarity.

Wafers would be subjected to different amounts of time (15 min, 30 min and 45 min) of the same program to give a gradient in surface roughness.

WAFER FABRICATION

Circular (diameter = 76mm) wafers of silicon were used. Each wafer went through the photolithographic processes outlined in Fig 3. The nickel depth was 200nm and the photo-resist depth 1.3µm. Silicon etching and roughening was done using a Corial 200IL Inductively Coupled Plasma etcher. Nickel etches were done using Aqua Regia acid.

This produced quadrants with the pattern shown in Fig 2 etched into them, each with different surface characteristics (topography and material combinations).

Each quadrant was then characterised using an Ambios XP-100 stylus profilometer to measure etch depth and surface roughness. Optical images were obtained using a Polylite Reichart Microscope at 20x magnification. Atomic Force Microscopy (AFM) was also used in the characterisation.

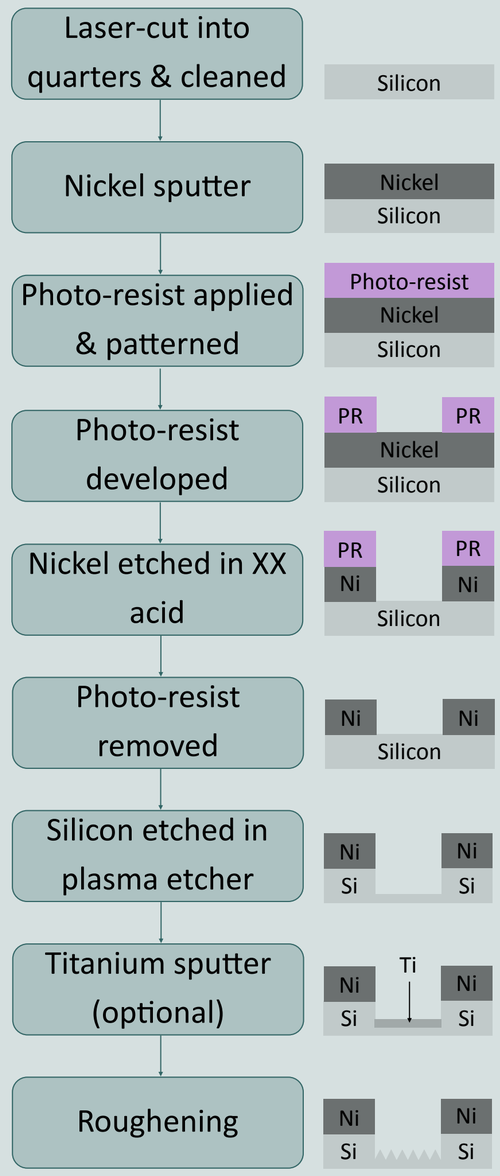

Fig 3: Flow chart describing the fabrication process for the wafers. Surface layers are presented for clarity and are not to scale.

RESULTS

For comparison purposes, Fig 4 shows images captured at 20x magnification of two different roughening process lengths (30 min and 45 min). The etch depth in each case was 29.6µm (30 min) and 32.0µm (45 min). AFM characterisation has not yet been completed.

Fig 4: Optical images at 20x magnification of the roughened silicon surface having undergone 30 min (left) and 45 min (right) of the roughening process.

CONCLUSION

A set of wafers have been fabricated which have been sent to the collaborators for the cell-study portion of the investigation. Predictions of the OB cell response will be confirmed when the cell-study is complete.

REFERENCES & ACKNOWLEDGEMENTS

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