Spontaneous stress-induced erythrocyte deformation and lysis through nanopillar substrate topology

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Abstract

Cellular biomechanics is an expanding area of research and application where it probes the mechanical response of diseased cells, provides physical cell separation based on cell properties, and underpins cellular behaviour under imposed shear stresses[1]. Additionally, mechanical cell behaviour in microfluidic devices is playing an increasingly important role in the development of blood-borne disease diagnostics[3] such as sickle-cell anaemia and malaria which reduce erythrocytes (RBC) deformability, which may impact on transport within the microcirculatory system. We have previously shown the integrity of bacterial cells in contact with nanopillar array surfaces to be significantly disrupted through deformation stresses and engulfment into the surface[2]. Cell lysis forms an important haematology platform in diagnosis and condition monitoring including accessing intracellular haemoglobin, DNA and RNA. Here, we detail the physical response of erythrocytes to this nanoarchitecture and foreshadow its potential in microanalysis. We identify the physical interaction brought about by the spatial convergence of the topology a nanopillar array substrate (black silicon) and that of the erythrocyte cytoskeleton. This provides spontaneous stress-induced cell deformation, rupture and passive lysis in a time from immobilization to rupture of ~3 min. and without external chemical or mechanical intervention. This mechano-responsive surface topology provides highly active yet autogenous RBC lysis and a prospect as a front-end platform technology in evolving micro-fluidic devices for cellular analyses[4].

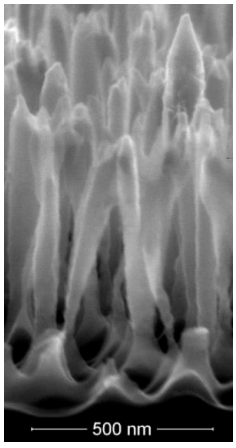

Fig 1

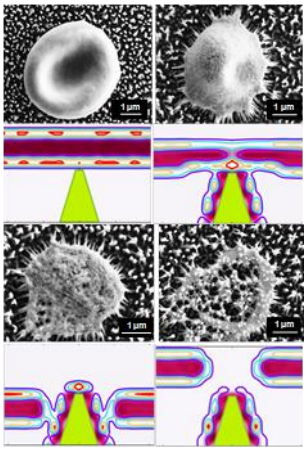

Fig 2

Figure 1. SEM image of bSi nanopillar arrayed surfaces (side view).

Figure 2. Morphological alteration of erythrocytes interacting with nanopillar surfaces (SEM images) and Single Chain Mean Field density profile lipid bilayer in contact with arrayed nanopillars.

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(2) E. P. Ivanova, J. Hasan, H. K. Webb, et al. Nat. Commun., 2013, 4, 2838.

(3) R. Fan, O. Vermesh, A. Srivastava, B. K. H. Yen, et al. Nat. Biotech., 2008, 26, 1373-1378.

(4) V. T. H. Pham, V. K. Truong, D. E. Mainwaring, et al. J Mater. Chem. B, 2014, in press.