Transition Metal Dichalcogenides as Cell Culture Platforms

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Transition metal dichalcogenides (TMDs), such as WS_2 and MoS_2, have been widely explored for their utilization as two-dimensional (2D) semiconducting nanomaterials with unique electronic, mechanical, and catalytic properties. A multitude of research has been pursued to integrate these unique properties of TMDs into a diversity of biomedical applications, including drug delivery, therapeutics, biosensors and bio-imaging. Although cytotoxicity studies have been performed on TMDs, cell-substrate interactions of TMDs are not well reported in literature and require further study to illuminate the influence of TMDs on the adhesive interactions of biological cells and the subsequent incorporation of these nanomaterials for potential biological applications.[1-6]

In this work, WS_2 and MoS_2 are grown via chemical vapor deposition (CVD) on SiO_2 substrates and seeded with human fibroblast cells. Cell culture is similarly performed on SiO_2 substrates without TMD, as TMD-free control samples to compare the effects of TMD presence on the adherence of fibroblast cells. After culturing, the cell-substrate interactions are probed after 24 hours using a methyl violet staining. To perform dimensional metrology and analysis, optical microscope images were collected and postprocessed using thresholding and noise filtering algorithms to segment individual cell bodies (n = 50-60 cells/sample). Cells that were either in contact with other cells or not fully in the field of view were discarded from analysis.

Cellular morphometric features (cell area, eccentricity) were computed from the segmented cell outlines. Upon determination of the corresponding mean and standard deviation values, unpaired t-tests were performed on the mean values of cell area and eccentricity, whereas F-tests were performed on the variances, as shown in Figure 1. It was observed that the presence of TMDs improves the cellular adhesion and viability on the cytotoxic SiO_2 substrate. Cells adhered on SiO_2 were significantly smaller and more eccentric than those in the presence of TMDs, confirming this observation; furthermore, cell morphology was determined to be more elongated on MoS_2 than WS_2. Though there was no significant difference determined between the mean cell area between MoS_2 and WS_2, statistical significance was determined for their variances, indicating a significantly larger range of cell areas for the WS_2 sample.

Current experiments being performed include cell culturing on patterned TMDs grown in controlled arrays. TMD patterns only on predefined locations are created via photolithography on a SiO_2 substrate and subsequent lift-off followed by physical vapor deposition (PVD) of MoO_3 or WO_3 prior to CVD growth. Thus, cell-substrate interactions between biological cells and TMDs will be quantitatively analyzed in relation to differing TMD area of coverage, layers, and porosity to probe the causal relationship between the measured TMD substrate properties and cell attachment.

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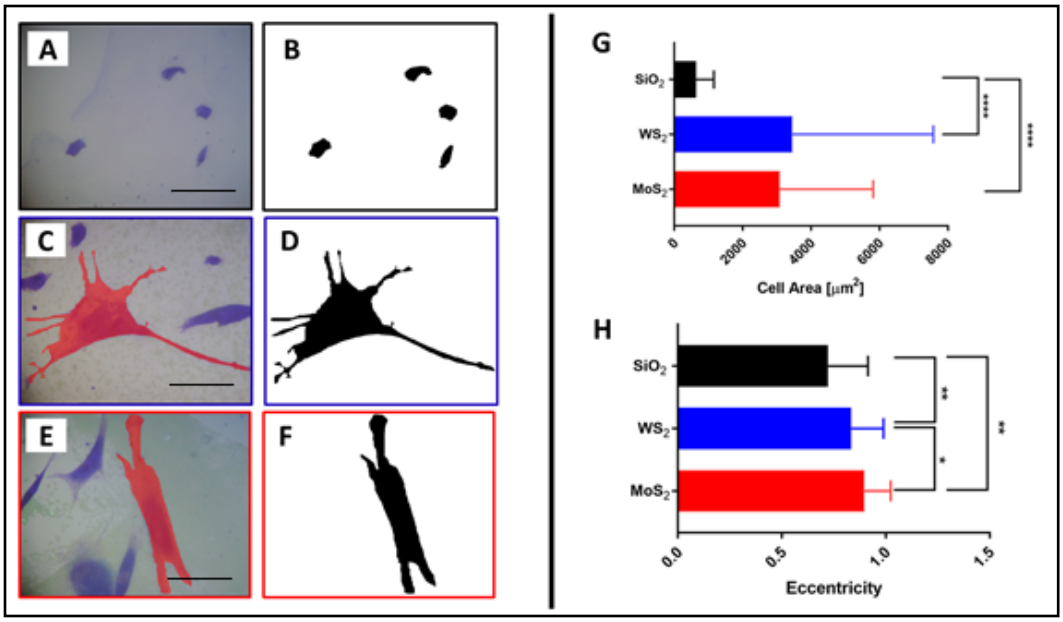

Figure 1: Analysis of Morphometric Features: Representative optical microscope images of fibroblast cells cultured on A) SiO_2, C) WS_2 on SiO_2, and E) MoS_2 on SiO_2, scale bar = 100 μm; cells that were either touching other cells or spanning beyond the field of view were discarded from analysis. Representative B&W threshold images shown for fibroblast cells cultured on B) SiO_2, D) WS_2 on SiO_2, and F) MoS_2 on SiO_2; graph of morphometric features, including G) Cell Area and H) Eccentricity, with statistical significances shown; mean ± s.d., n =50-60 cells (per sample), *P≤0.05, **P≤0.01, ***P≤0.001, ****P≤0.0001.