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Low-cost, high-performance, single-crystal-like device layers and controlled self-assembly of nanostructures within device layers for wide-ranging energy and electronic applications

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For many energy and electronic applications, single-crystal-like materials offer the best performance. However, in almost all cases, fabrication of single-crystal form of the relevant material is too expensive. In addition, for many applications, very long or wide materials are required a regime not accessible by conventional single-crystal growth. This necessitates the use of artificially fabricated, large-area, single-crystal-like substrates suitable for heteroepitaxial growth of the relevant advanced material for the electronic or energy application in question. In this talk, details of the fabrication of such substrates will be provided. Heteroepitaxial growth of nanolaminate multilayers and devices on such substrates using a variety of deposition techniques such as pulsed laser ablation, sputtering, e-beam evaporation, MBE, MOCVD, and chemical solution deposition will be reported upon. Application areas that have been demonstrated via the use of such artificial substrates include – oxide high-temperature superconductors, semiconductor materials (Si, Ge, GaAs, CdTe and Cu₂O), ferroelectrics (BaTiO₃), multiferroics (BiFeO₃), etc. In addition, strain-driven self-assembly of second phase nanomaterials at nanoscale spacing has been demonstrated within device layers. Control of heteroepitaxy in lattice-mismatched systems and the effects of strain on self-assembly will be discussed. Such heteroepitaxial device layers on large-area, single-crystal-like artificial substrates are quite promising for a range of electrical and electronic applications.

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Cell loaded hydrogels as advanced bioinks for 3D printing

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Three-dimensional bioprinting is the process of extruding cells with or without the addition of materials in a precise spatial arrangement towards tissue substitutes. Yet bioprinting bears some limitations, mainly the selection of materials to be used as bioinks. Among others, bioinks must be able to mimic native tissue microenvironment and protect cells from the shear-stress to which they are submitted during printing process, without compromising the resolution, shape and stability of the tissue construct. These features are common for injectable hydrogels, which are 3D hydrophilic networks that facilitate oxygen, nutrients and growth factors diffusion and partially mimic tissue physical characteristics. Some examples of natural-derived materials include decellularized tissue, gelatin, fibrin, collagen and alginate. Nevertheless, the gelification kinetic of current proposed bioinks is impairing the printability of tissue constructs. Pectin can be considered a novel and versatile biomaterial as its favorable properties, including swelling, degradation, cell immobilization, and binding or release of bioactive molecules can be tailored by the crosslinking mechanisms and agent. Herein, an innovative injectable pectin hydrogel encapsulating human adipose stem cells is proposed. Gelation kinetics, viscosity and shear-thinning properties could be finely tailored by controlling pH, pectin concentration and gelifying methods. Gelification time of the developed hydrogels ranged from seconds to 20 minutes, accordingly with the adopted conditions, therefore offering a suitable time window to prevent the collapse of the gel post-printing. Additionally, the obtained viscosity is within the range of the different bioprinting techniques, namely inkjet, orifice-free and extrusion. Their injectable potential was confirmed through rheological analyses. Upon extrusion through 20G and 25G needles, cells encapsulated within pectin hydrogels were viable and kept their stemness capability up to 7 days after extrusion, indicating that the presence of 3D pectin hydrogels protects cells from damaging during the printing process. In this sense, a ready-to-use and inexpensive pectin hydrogel is herein proposed as a bioink for 3D bioprinting tissues.

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