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SELF-ORGANIZED SOFT-HARD INTERFACES: FROM SURFACES TO BIOLOGICALLY INTEGRATED HYBRID MATERIALS

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The biological material systems promise the possibility of developing innovative materials that simultaneously self-assembled, self-organized and self-regulated; characteristics that are difficult to achieve in purely synthetic systems. Proteins play an essential role in fabrication of biological materials due to their diverse functions ranging from structural to biochemical. The ability to mimic any of these functions can be a game changer in designing new biomaterials. There are several challenges in these strategies including replicating the hierarchical organization of biological materials, organization that provides multi-scale structure/property interdependence. The interfacial interactions become critical in tuning the individual components towards the functional needs. There is a need for strategies that can control self-organization at a molecular level and thus provide predictability over the biological and inorganic interfaces. In the recent years, there has been a proliferating interest in creating advanced bio-interfaces resolving protein modulated material surfaces that allow as well as enhance favorable interactions with the surrounding biological systems. Smaller protein domains, i.e. peptides, have been utilized as the key fundamental building blocks to mimic the molecular recognition as the basis of molecular scale interactions. Our approach includes decoding the peptide-material interactions, and using these foundations to develop self-organized and multifunctional hybrid systems. Following Nature's molecular footsteps, we explore tuning molecular interactions at bio-interfaces to create integrated bio-hybrid systems. In this presentation, we summarize our approach, which includes decoding the peptide-material interactions, and using these foundations to have better control specifically at the soft-hard interfaces. We will first describe our chimeric peptide-based approach for titanium and titanium alloys used for skeletal implants. These self-assembling binding motifs in combination with other small bioactive peptide molecules enable us to introduce additional functions encoded within the combined molecule. The resulting chimeric molecule maintains both functions, controlling their surface organization at the implantable material interface while also retaining the desired orientation to present a bioactive signal to the cells to direct their behavior. Our examples will include: i) to utilize antimicrobial peptides in controlling bacteria-surface interactions at the interfaces to prevent biofilm formation and consequent implications such as implant failure due to bacterial infections [1], ii) to direct cell-to-implant interactions by chimeric peptides that are displayed at the material interfaces to achieve guided stem cell differentiation [2]. We will finally describe our fusion protein based approach where engineered peptide tags and nanoparticle based systems are used to generate self-organized biologically integrated hybrid materials. Here we demonstrate modularity of our approach in designing polymer nanofibers integrated with nanoparticles assembled with engineered peptides that are genetically conjugated to photoactive biomarker proteins [3].The selected bio-hybrid composites will be presented in three different categories, their ability for bio-sensing, antimicrobial property and producing integrated mineralized interfaces. The integration of biological building blocks may allow harnessing the extraordinary diversity and protein functions to generate smart bio-hybrid materials for wide range of applications including sensing and tissue engineering applications.

1. *Yucesoy, D., Hnilova, M, Boone, K., Arnold, P., Snead, M.L., Tamerler, C. Chimeric peptides with antimicrobial properties as implant functionalization agents for titanium alloy implants. JOM, 67(4), 754-766, 2015*
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