Self-Healing Nano-Textured Vascular Engineering Materials

Alexander L. Yarin

University of Illinois at Chicago
Department of Mechanical and Industrial Engineering, University of Illinois at Chicago, 842 W. Taylor Street, Chicago 60607-7022, USA

The nature-inspired self-healing strategies have been explored in biomimetic engineering designs with a goal of repairing structural damages or facilitating the anti-corrosion protection by means of systematic transport of healing materials, which can be cured and polymerized at the damaged sites. Microscopic capsules filled with healing agents, which were proposed first, are certainly viable and require no external energy to trigger the healing process. However, a material layer with such capsules is inherently thick due to the bulky-sized microcapsules. A different approach with a much smaller confinement for the healing materials and a capability of multiple healing is desired. Here we overview the efforts of our group and the other research groups toward development and testing of nano-textured vascular self-healing materials and discuss the state-of-the art in the field of such materials, which emerged to mimic multiple natural materials, for example, those characteristic of our own body (e.g. skin and bones healed by means of vascular system).

The relevant healing agents, and the basic physico-chemical phenomena characteristic of self-healing materials and composites based on them will be discussed, as well as such fabrication methods of the key elements of the vascular system of modern nano-textured engineering self-healing materials as electrospinning (including co-electrospinning and emulsion spinning) and solution blowing (including coaxial solution blowing and emulsion blowing). Some other approaches based on hollow fibers, etc. are also mentioned.

Self-healing materials are expected to be capable of self-restoring their mechanical properties, e.g. stiffness, toughness, adhesion and cohesion. It is tremendously important to heal the invisible and practically undetectable fatigue cracks, which endanger airplanes, and multiple other composite-made vehicles and constructions. Nano-textured vascular self-healing can also prevent or delay delamination in composites on ply surfaces. Therefore, the results which elucidate fundamental mechanical tests (e.g. tensile, fatigue and blister tests, as well as the impact test) and performance of nano-textured vascular self-healing materials in such tests are discussed in detail. They demonstrate the degree to which such materials are capable of restoring their stiffness, toughness, and the adhesion and cohesion energies.

Another field where nano-textured vascular self-healing materials are extremely desirable is the anti-corrosion protection. Numerous corrosion protection approaches have been suggested, including the cathodic protection method, the anti-corrosion paint coating method, etc. However, the toxicity of the chemical paints and other problems related to the cost, as well as to the environment, remain as serious concerns. Accordingly, the bio-inspired vascular self-healing techniques have been recently explored as alternative approaches for prevention corrosion. In particular, we discuss in detail the extrinsic self-healing based on nano-textured vascular nanofiber networks and demonstrate successful performance of such materials in healing cracks in the anti-corrosion protection layers. The results reveal that this approach to anti-corrosion protection holds great promise due to its economically and industrially feasible features.

MSc-1977 (in Applied Physics), PhD (in Physics and Mathematics)-1980, DSc (Habilitation, (in Physics and Mathematics)-1989. Affiliations: The Institute for Problems in Mechanics of the Academy of Sciences of the USSR, Moscow (1977-1990); Professor at The Technion-Israel Institute of Technology (1990-2006; Eduard Pestel Chair Professor in Mechanical Engineering at The Technion in 1999-2006); Distinguished Professor at The University of Illinois at Chicago, USA (2006-present); Fellow of the American Physical Society. Prof. Yarin is the author of 4 books, 12 book chapters, 335 research papers, and 10 patents. Prof. Yarin was the Fellow of the Rashi Foundation, The Israel Academy of Sciences and Humanities, and was awarded Gutwirth Award, Hershel Rich Prize and the Prize for Technological Development for Defense against Terror of the American-Technion Society. He is one of the three co-Editors of "Springer Handbook of Experimental Fluid Mechanics", 2007, and the Associate Editor of the journal "Experiments in Fluids".

Email: ayarin@uic.edu