Cavitation engineered 3-D networks and their application in active surface construction

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The amazing electrical, optical, mechanical and drug delivery properties of material, including those based on silicon, carbon and metal, discovered in last decades arose interest in a huge class of hierarchically ordered 3-D networks. The large energy and climate related value of these materials increases fundamental research interests. As long range application of 3-D networks is in focus, there is a strong demand for their green and inexpensive production. Here, we present a potential approach: a process yields 3-D networks with complex structure and such advanced characteristics as unique electronic properties, bright luminescence, defined roughness and porosity, and improved mechanics.

Formation of 3-D surface networks is possible due to controlled consequences of cavitation-assisted processes on a surface (Fig.) in the presence of surfactant, monomers or polymers in solution and of their interactions in dependence on the reactor parameters. As an important result, fundamental models of pronounced sonochemical pathways are established

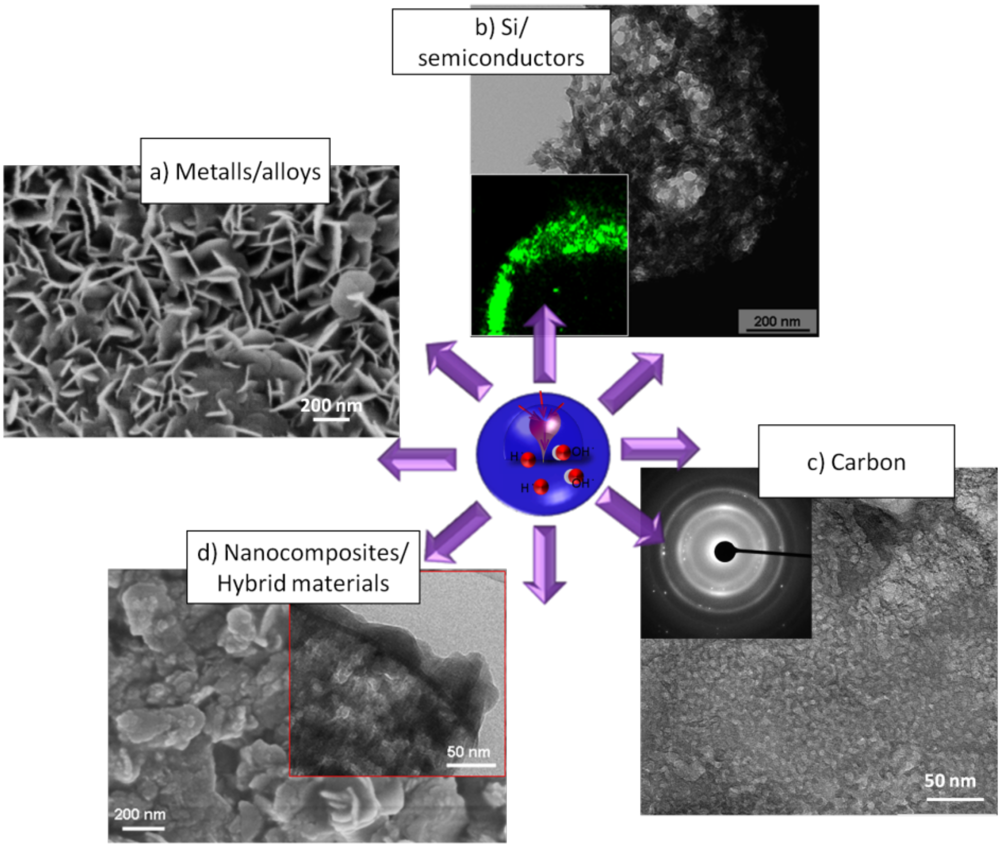

Fig. Materials with different properties after sonochemical treatment: a) SEM image of sonochemically formed magnesium sponge; b) TEM image of porous silicon formed in water–alcohol solution in the presence of a hydrogen donor. The inset shows its micro-confocal photoluminescence; c) TEM image of graphite after ultrasonic modification in the presence of surfactant. The inset shows its electron diffraction; d) SEM and TEM images of formed hybrid magnesium/polypyrrole structure in ethanol + pyrrole solution. Frequency of 20 kHz; I_{ac} = 40-60 W cm^{-2}, except for the case of carbon (c) where I_{ac} was less than 20 W cm^{-2}

for some cases and effectively used for surface complex design and hierarchically ordered 3-D network organization [1-8].

Sonochemistry at solid surfaces is still poorly understood. Bubbles are created by high pressure gradients and large flow rates in liquids near a solid surface. The collapse creates locally extreme pressures and temperatures as well as shock waves and a liquid impinging on the surface. This efficient and "green" tool for the formation of new surfaces with 3-D porous hierarchically ordered networks has very high potential but, on the other hand, has not been explored to the level it deserves. The advantages of sonochemistry in the modification of materials are: (i) potential of performing chemistry and physics at high temperature but with a reactor near room temperature, (ii) highly nonequilibrium structures can be made which meets the demands of technology as well as scientific interest; (iii) the approach does not require additional reagents or treatment.

In the work we demonstrate the application of the sonochemical approach for fundamental process modelling and the formation of new materials, especially with improved functionality, taking as examples four different types. In particular in Fig. examples of the consequences of cavitation assisted modification of the project related materials are given : 1) metals and alloys (for example Mg or Al); 2) semiconductors (Si); 3) carbon; 4) composite/ hybrid materials. Moreover, in our department, the consequences of ultrasonic-assisted glass treatment, polymer, oxides have been intensively analysed.

The connection between different types of materials is their similar 3-D organization (roughness, porosity) due to use of metals as „hard reactive templates" and polymers as „soft template". Moreover 3-D structure organistaion can be contlolled through sonochemical reactor conditions (T, p, solvent, intensity and duriation of sonication). Thus use of the same template under various reactor conditions can broad viarity of surface organistion.

Referances

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