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New Areas of Research and Applications for GaN

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The properties of semiconductor materials can be modified in a controlled fashion or even new characteristics may be brought to light by building hybrid 3D nanoarchitectures. The goal of this presentation is to review the research efforts undertaken over the last years to develop novel bio-inspired hybrid 3D nanoarchitectures based on binary compounds such as GaN, ZnS, ZnO, TiO_2 etc. One of the most promising 3D nanoarchitectures proves to be the so-called aero-GaN or Aerogalnite, which represents the first artificial material exhibiting dual hydrophobic-hydrophilic behaviour, its characteristics being close to those inherent to a biological cell membrane. The Aerogalnite consists of gallium nitride hollow micro-tetrapodal structures with nanoscopic thin walls, the inner surface being covered by an ultrathin film of zinc oxide [1]. The lateral faces of GaN tetrapods were found to show hydrophobic properties, while the free end of the arms – hydrophilic ones. This new result was achieved in close collaboration with other research groups (see [1] and https://physicsworld.com/a/hydrophobic-or-hydrophilic-aero-gallium-nitride-is-both/).

Approaching each other hollow GaN tetrapods floating on the water surface leads to the formation of waterproof rafts showing impressive stretching and cargo performances. The interaction between tetrapods resembles the interaction of fire ants forming live rafts on the water surface which enable the insects to survive during floods [2, 3].

The elasticity and stretching performances of self-assembled aero-GaN membranes were studied using communicating vessels. It was found that the aerotetrapods of gallium nitride interact with each other on the water surface until a consolidated membrane forms. The membrane is elastic and can be used as a separation barrier between liquids, avoiding direct contact and mixing, but keeping the gas exchange due to a very high degree of porosity. We found that the membranes can withstand liquid droplets hundreds of times heavier than the membrane [1].

It was found that aero-GaN platelets with the thickness of 1-2 millimeters exhibit impressive shielding capabilities against electromagnetic radiation in a wide range of frequencies including Gigahertz and Terahertz ones [4, 5]. The shielding effectiveness in the frequency range from 0.25 to 1.37 THz exceeds 40 dB, which places Aerogalnite among the known best Terahertz shields.

We succeeded in preparing liquid marbles using GaN aero-tetrapods. In order to explore the aero-GaN liquid marble properties, different deviations from the spherical symmetry were induced during the fabrication process. It was found that aero-GaN based liquid marbles exhibit energy-efficient long-term translational movement for several hours and fast velocity of rotation up to 750 rpm [1]. The rotation speed and the time decay of spinning liquid marbles are highly dependent on their weight. The lighter liquid marbles show higher rotation speed, while the heavier ones are characterized by a much higher inertia keeping the spinning for a longer time [6]. The rotation of liquid marbles is highly dependent on the specific architecture of the enveloping shell consisting of GaN hollow microtetrapods with dual hydrophilic – hydrophobic properties and the deviations from the spherical shape leads to behavioral changes of the marbles. It was found that elongated liquid marbles exhibit pulsed rotation, attaining the same maximum speed of rotation at each pulse, after which the speed of rotation drops down sharply. This phenomenon was described by using a simple analytical model which takes into account the uplift of the marble and formation of water columns underneath during the spinning process. When the rotation speed increases the marble tends to detach from the water surface, which leads to interruption of the propulsion mechanism and consequently the marble drops on the water surface and continues the rotation at much lower speed [6].

In the plenary report, results of investigation of architectures based on Ga_2O_3, ZnS, TiO_2 will be presented as well and the areas of possible applications of these aero-materials will be discussed.

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