Experimental Observation of Carbon and Carbon-Metal Nanotoroids and New Carbon-Metal Superstructures at Nanoscale

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ABSTRACT

We report on experimental observation (by AFM, STM and HRTEM methods) of nanotoroids for both carbon and carbon-metal superstructures produced by methods of arc discharge and laser ablation. Size of superstructures is ~ 10 nm for carbon and ~ 30 nm for carbon-metal (outer diameter), with inner diameter ~ 1/3 of the total. We also discovered carbon-metal nanocapsules with shapes like nanodisks, reminiscent of human erythrocytes, and sizes ~ 30 nm. The influence of pressure, humidity and temperature was investigated. Effect of reversible transition of topology (sphere - toriod) on the same sample were oserved depending on external parameters. New types of topologically closed carbon and carbon-metal nanostructures are discovered. We also discuss some technological aspects of the growth of such toroidal nanostructures.

Keywords: carbon, metal, nanoclusters, nanotoroid, superstructures.

We report experimental observation (by AFM, STM and HRTEM methods) of nanotoroids for both carbon and carbon-metal superstructures produced by methods of arc discharge and laser ablation. Size of superstructures is ~ 10 nm for carbon and ~ 30 nm for carbon-metal (outer diameter), with inner diameter ~ 1/3 of the total.

Initial observation of toroids were made for pure carbon, but gradual increase of metal to some optimal concentration dramatically increased the yield of toroidal structures. The influence of pressure, humidity and temperature was also investigated. Also effects of reversible transition of topology (sphere - toroid) (Fig. 1. - 5.) on the same sample were observed depending on external parameters.

The possibility of such structures was discussed earlier [1, 2], but we also discovered carbon-metal nanocapsules among toroids, with shapes like nanodiscs, reminiscent of human erithrocites. Changing concentrations and metals (Mo, Cr, etc.) leads to differences in shapes and sizes of superstructures.

Therefore, new types of topologically closed carbon and carbon-metal nanostructures are discovered, with the theoretical model presented elsewhere [3, 4]. We also discuss some technological aspects of the growth of such toroidal nanostructures.

A continual model of topologically closed carbon and carbon-metal nanostructures is presented. This model considers mechanical properties of chemical bonds and external pressure of gas phase. A sequence of transitions for various topological forms of possible superstructures is described for continuous growth of external pressure (from

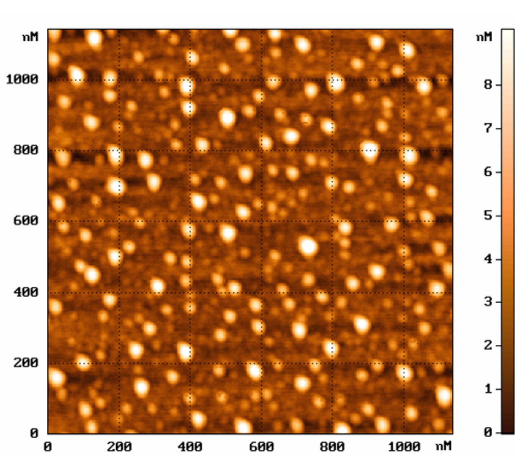

Fig. 1. AFM Image spheroidal of metal-carbon superstructures

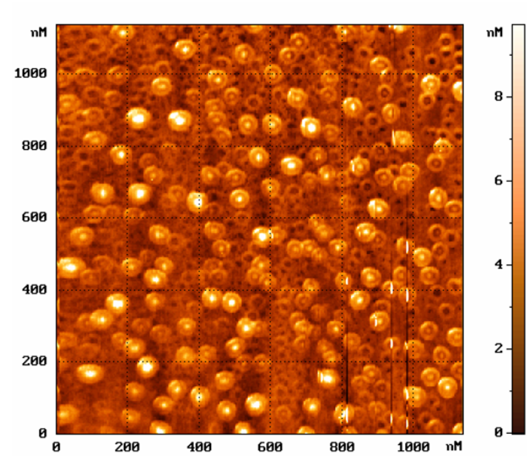

Fig. 5. AFM Image toroidal of metal-carbon superstructures

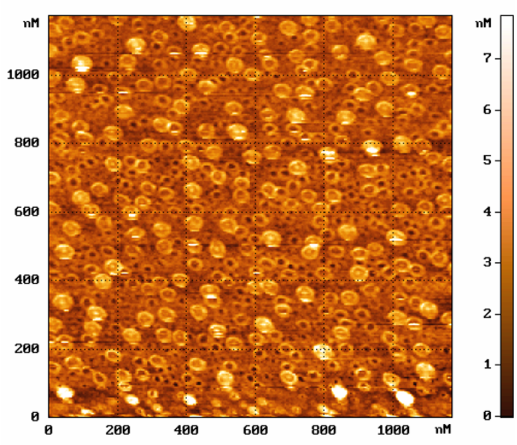

Fig. 2. AFM Image toroidal of metal-carbon superstructures

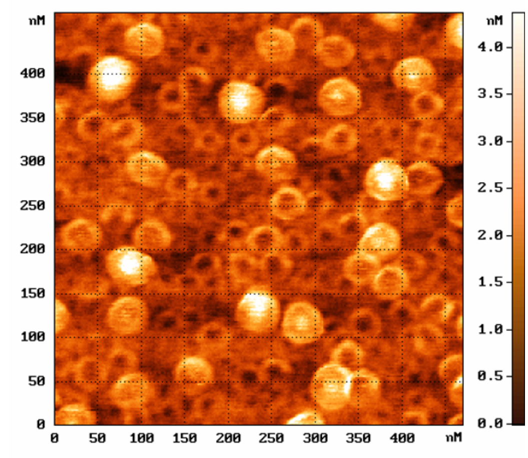

Fig. 3. AFM Image toroidal of metal-carbon superstructures

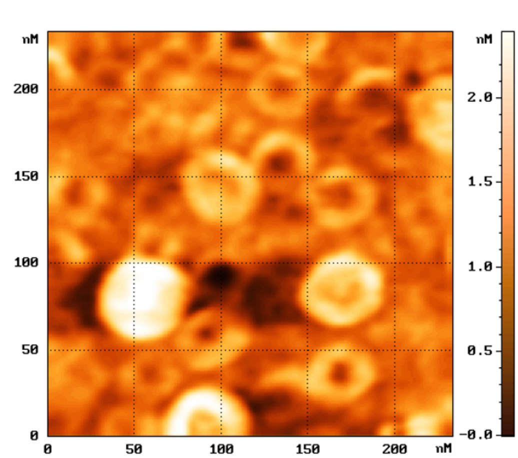

Fig. 4. AFM Image toroidal of metal-carbon superstructures

vacuum to atmospheric): from sphere to slightly pressed shape, then via growing negative curvature of “anti-caps” to toroidal structures and then via flattening and thinning of toroids and growth of their diameter to nanorings (“crop-circle” structures [5]). We also present some technological details of the growth of such toroidal nanostructures and discuss a number of possible applications. We believe that the very facts of existence of optimal carbon-metal concentrations and specific external parameters for production of nanotiroids and other superstructures should have important implication for theoretical understanding of superstructure formation.

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