# Nanokompozitinių deimanto tipo amorfinės anglies dangų su sidabro nanodalelėmis abliacija femtosekundinio lazerio interferenciniu lauku

# Ablation of amorphous diamond-like carbon nanocomposite films with embedded silver nanoparticles by femtosecond laser interference field

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Plasmonics are of great interest and numerous research are dedicated for investigation of localized surface plasmons of metallic nanostructures [1]. By choosing the right concentration and surface structures, plasmonic nanocomposites can be used as broadband anti-reflective and absorbing coatings, high sensitivity sensors, layers to increase efficiency of solar cells [2, 3], etc. Silver has strong plasmonic interactions, but it can easily get oxidised [4]. Thus various attempts are made to prevent this, such as embedding particles in a passivating matrix [5].

In this work we present thin films of silver nanoparticles embedded in amorphous diamond-like carbon matrix (DLC:Ag). The films are patterned employing femtosecond laser interference ablation.

DLC:Ag films were deposited on silicon and quartz substrates employing magnetron sputtering in direct current mode. A mixture of acetylene and argon gas as well as silver target were used. The gas flow of argon was 70-80 sccm, while of acetylene – 5.4-11.7 sccm. The supply current was up to 0.15 A and voltage up to 420 V. The deposition time varied between 178 s and 321 s.

One-dimensional (1D) periodic structures in DLC:Ag films were ablated using Yb:KGW femtosecond laser pulses (pulse duration 290 fs). Second harmonic laser wavelength of 515 nm was chosen for the microfabrication. The laser beam was separated into two using diffractive element and then overlapped with 4f lens system into one spot on the surface of the sample to create the interference pattern. The system was calibrated so that each of these beams would have the same power to get high interference contrast. The pitch of the pattern was altered by changing the angle of the incidence. To find best parameters of microfabrication the laser fluence was varied from 1 mJ/cm$^2$ to 27 mJ/cm$^2$. The number of pulses was increased from 1 000 to 125 000 to observe the effect of accumulation. The total area of ablated pattern was $300 \times 300$ $\mu$m$^2$. For each pitch, the total of 25 patterns with different micromachining parameters were created.

The ablated structures were investigated using scanning electron microscope (SEM, Hitachi S-4800) and helium ion microscope (HIM, Zeiss ORION NanoFab). From the microscope images (fig. 1) it was confirmed, that pitches of 1D structures are 1.32 $\mu$m, 0.80 $\mu$m and 0.58 $\mu$m, respectively.

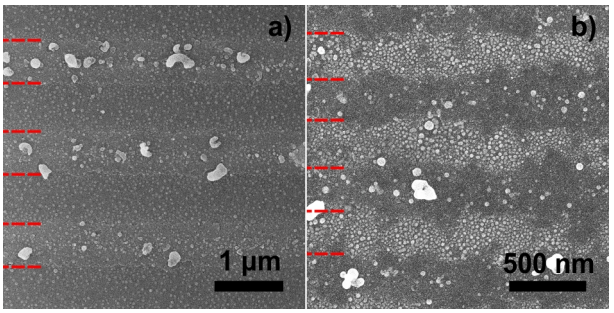


Figure 1. a) HIM image of 1.32 $\mu$m pitch 1D structure in DLC:Ag with 6.5 at.% silver content. Micromachining parameters: 1 mJ/cm$^2$ fluence, 27 000 pulses.
b) SEM image of 0.58 $\mu$m pitch 1D structure in DLC:Ag with 15.3 at.% silver content. Micromachining parameters: 1 mJ/cm$^2$ fluence, 1 000 pulses.

It was determined, that 27 mJ/cm$^2$ fluence is too high for ablation for all pitches, since all of the surface is affected and where are no visible lines of nanoparticles on the surface. 17 mJ/cm$^2$ fluence is too high for smallest pitch (0.58 $\mu$m) structures for the same reason. While for the bigger pitches at this fluence the structure is only visible after using 1 000 pulses ablation. The one-dimensional periodic structures are more pronounced in thin films with higher silver content (15.3 at%). In conclusion, femtosecond laser ablation by interference field is suitable for fabricating one-dimensional periodic structures of silver nanoparticles in amorphous diamond-like carbon matrix.

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*Keywords: silver nanoparticles, femtosecond laser ablation, interference field, helium ion microscopy*

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