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DEVELOPMENT OF SILVER-DOPED HYDROGENATED AMORPHOUS CARBON FILMS (a-C:H) WITH RESPECT TO THE ANTIBACTERIAL AND MECHANICAL PROPERTIES

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Introduction

The aim of the project is to develop hydrogenated amorphous carbon (a-C:H) films which offer a antibacterial effect and good mechanical/tribological properties. The antibacterial effect should be reached through incorporation of metallic silver nanoparticles into the film.

Experimental

The deposition was done by pulsed DC magnetron sputtering in a Cemecon CC800 unit. The silver-doping was realized by sputtering graphite targets with inserts of pure silver (99,95%). The silver content was varied by changing the size and the number of inserts in the targets. The sputtering was done under a mixture of argon, krypton and acetylene. For better adhesion all a-C:H films were deposited on a chromium nitride interlayer. The influences of bias voltage, target power and the silver content on the mechanical and antibacterial properties were investigated. Ultra-microhardness, atomic force microscope, ball-on-disk, electron microscopy, XPS and SIMS measurements were conducted to obtain the mechanical and chemical properties of the films. The antibacterial properties were investigated by immersion test in tap water and tests based on JIS 2801:2006/ISO 22196. The schematically design of the films and the graphite-silver targets are shown in Figure 1 and Figure 2.

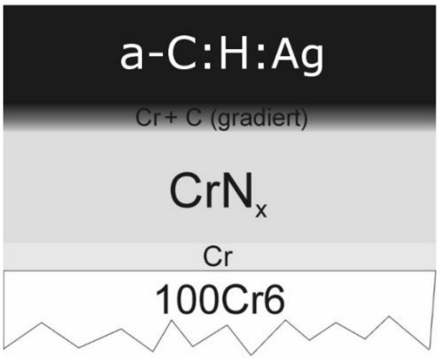


Figure 1: Schematically design of films

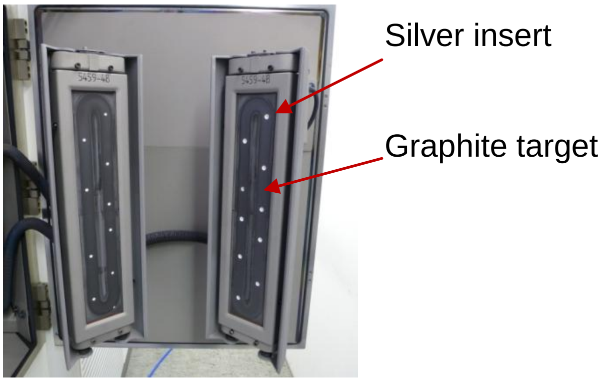


Figure 2: C/Ag-targets in a Cemecon CC800

Results

With increasing target power the films contain more silver while the hardness is slightly decreased (see Figure 3a). The acetylene flow has no significant effect on the silver content while the deposition rate (which is not shown) is increasing and the hardness is decreasing (see Figure 3b). For an increasing bias voltage the films show a lower silver content and a higher hardness (see Figure 3c). When comparing the hardness for films deposited with -100 V and -200 V bias voltage as a function of the silver content, the hardness drops faster for the films deposited with -200 V (see Figure 3d).

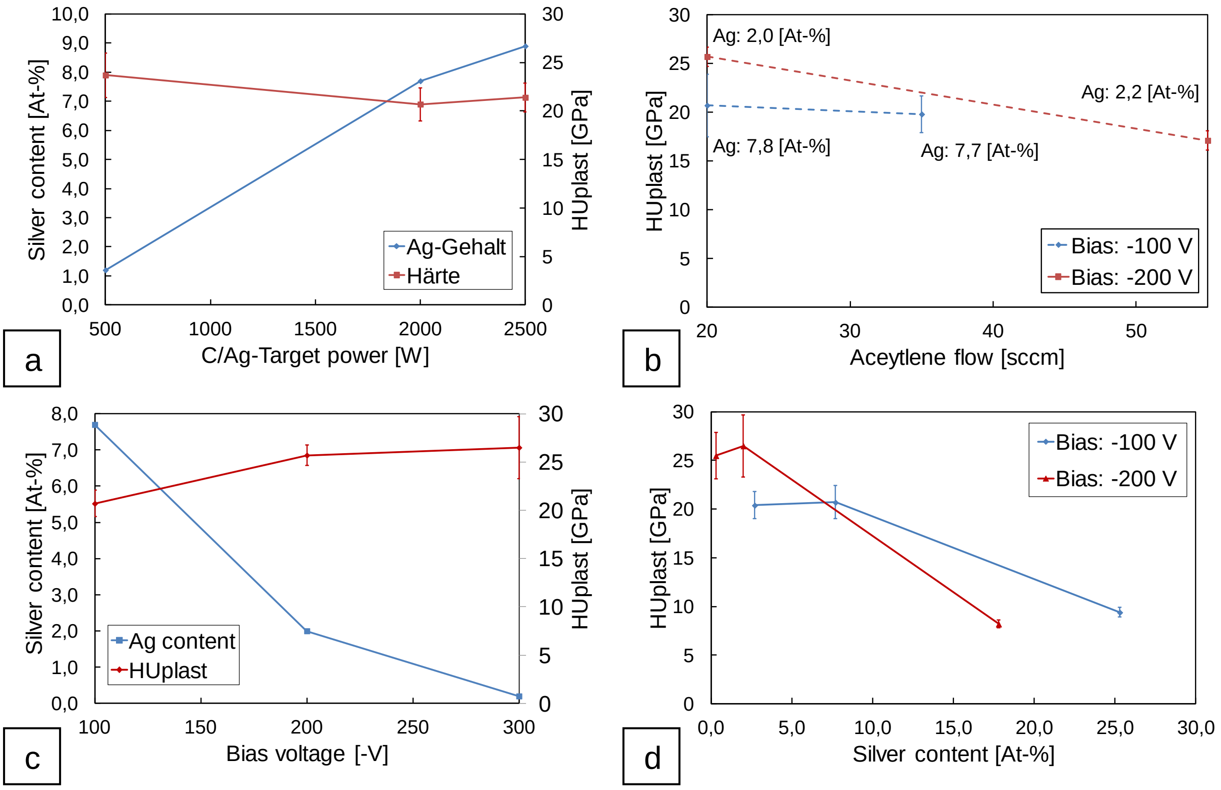


Figure 3: Target power vs. silver content/hardness (a); Acetylene flow vs. silver content /hardness (b); bias voltage vs. silver content/hardness (c); Silver content vs hardness/bias voltage (d)

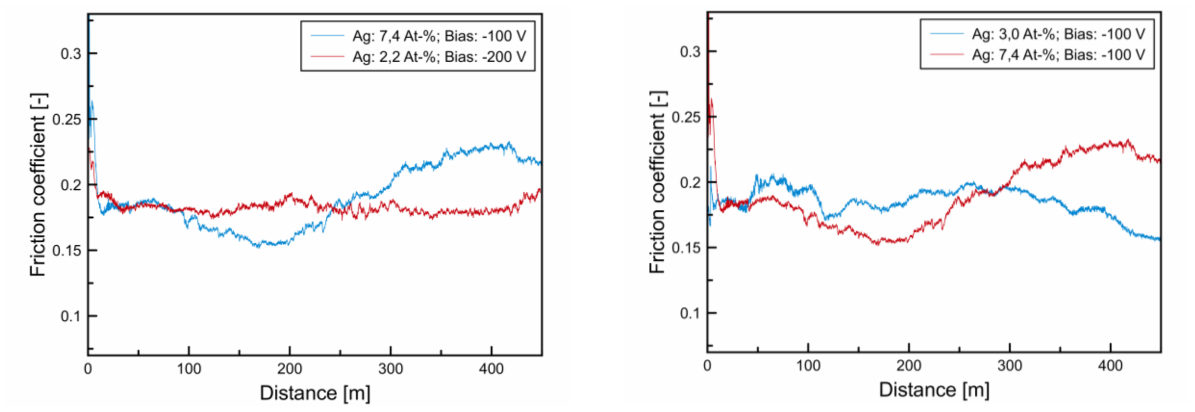


Figure 4: Pin-on-disk tests for different bias voltages and different silver contents

In Figure 4 the friction coefficient for two bias voltages and silver contents are shown. The films with a higher silver content have a higher friction coefficient at the short run-in period after the start of the test. The friction coefficient is for all tests in the same range.

In Figure 5a and 5b FEM pictures of fracture and surface areas for two different silver contents from a-C:H films deposited with a bias voltage of -200 V are shown. On both surfaces silver particles in the nanometer range could be observed. The film with a silver content of 17,8 At-% shows particles with a bigger size which could also be observed in the fracture area. Figure 5c a shows the cross section of a silver doped a-C:H film deposited with -100 V bias. On the surface a thin continuous silver layer is visible. No silver particles could be observed in the fracture area.

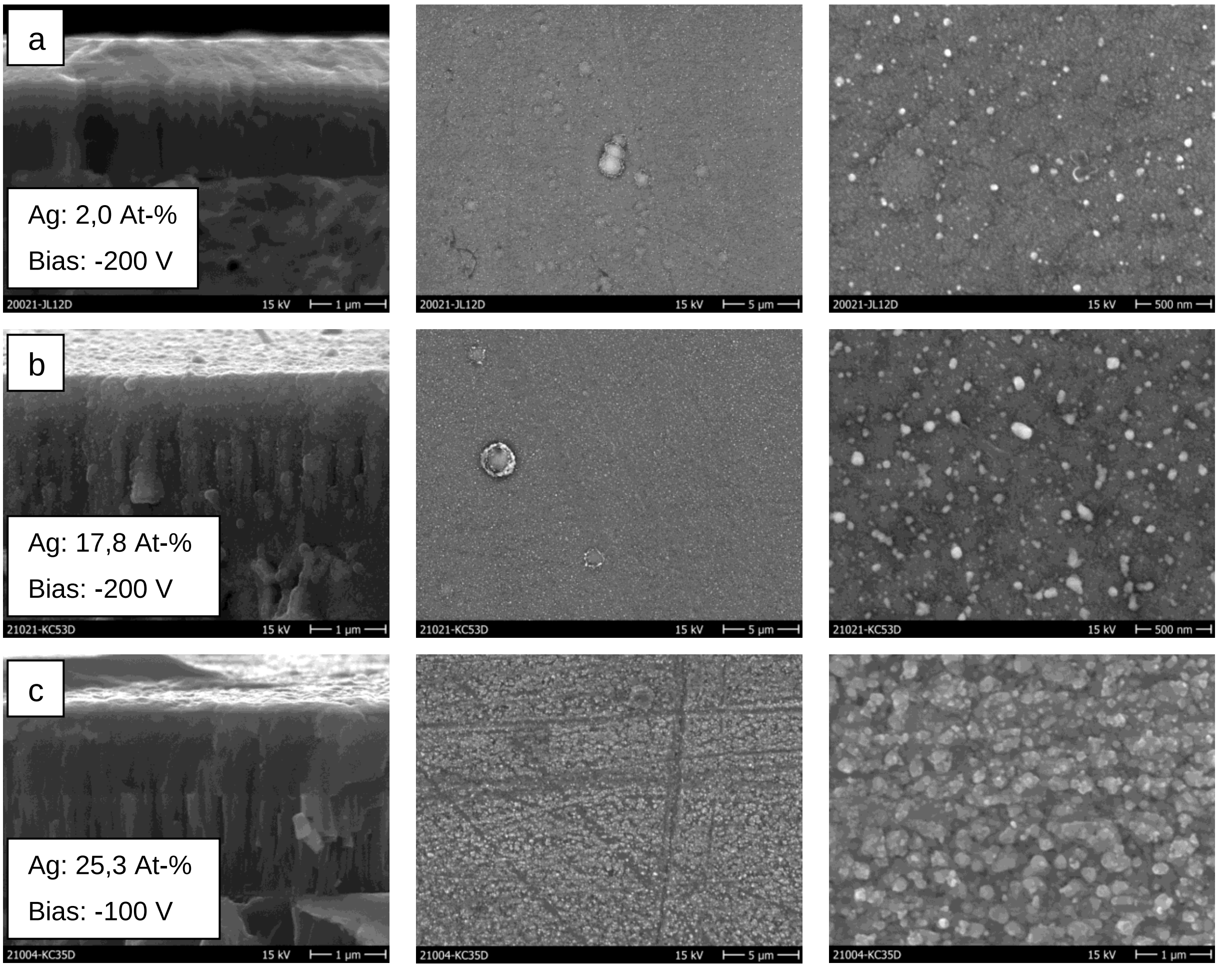
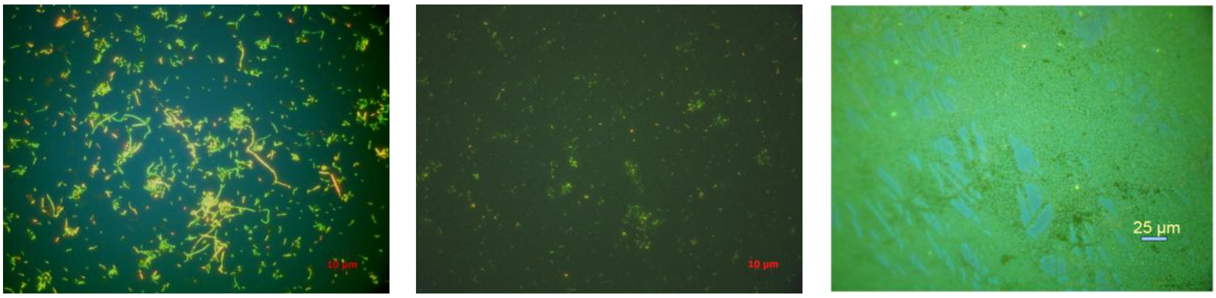


Figure 5: FEM pictures of fracture and surface areas from different a-C:H:Ag films

In Figure 6 the bacteria colonization of the surfaces after immersion tests in tap water is shown. With increasing silver content the colonization is decreasing.



Steel surface (reference) Ag: 7,7 At-%, Bias: -100V Ag: 25,3 At-%, Bias: -100V

Figure 6: Bacteria colonization of steel surface and a:C:H:Ag surfaces after immersion tests in tap water

The tests based on JIS 2801:2006/ISO 22196 show that the films exhibit antimicrobial potential. Higher silver contents show better results. On the film with the highest silver content 100% of the Escherichia coli and 93% of the Micrococcus luteus bacteria were killed.

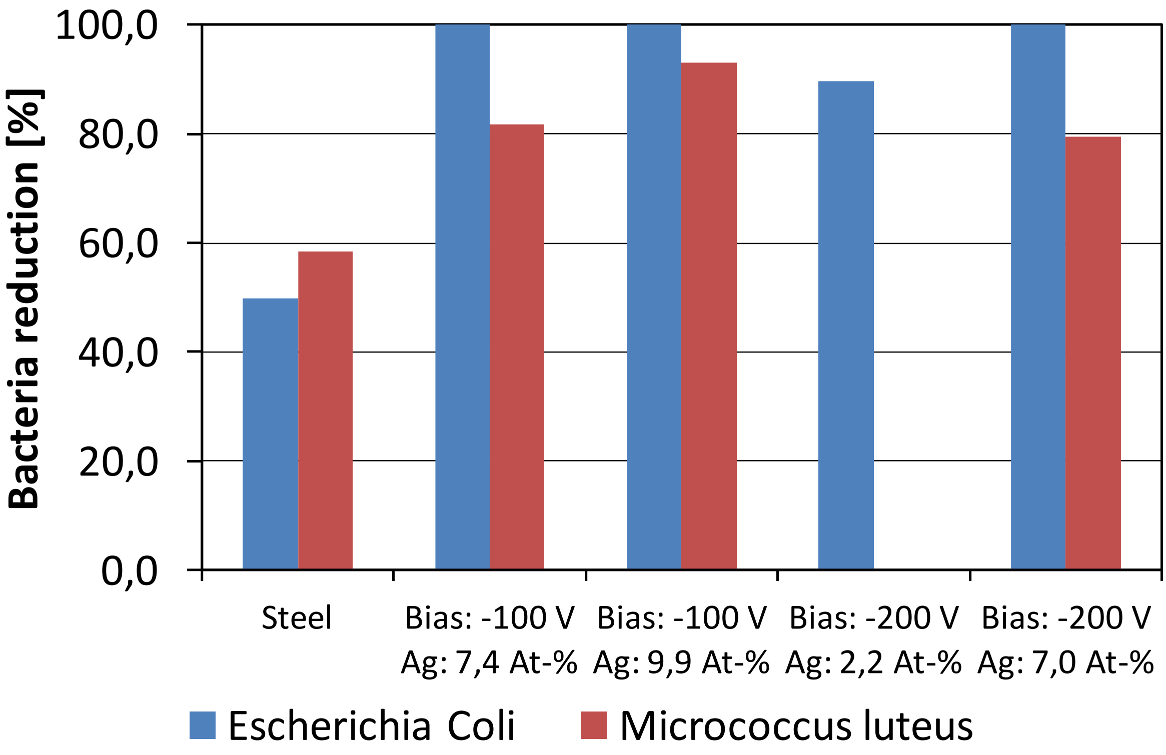


Figure 7: Bacteria reduction for different a-C:H:Ag films

Acknowledge

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