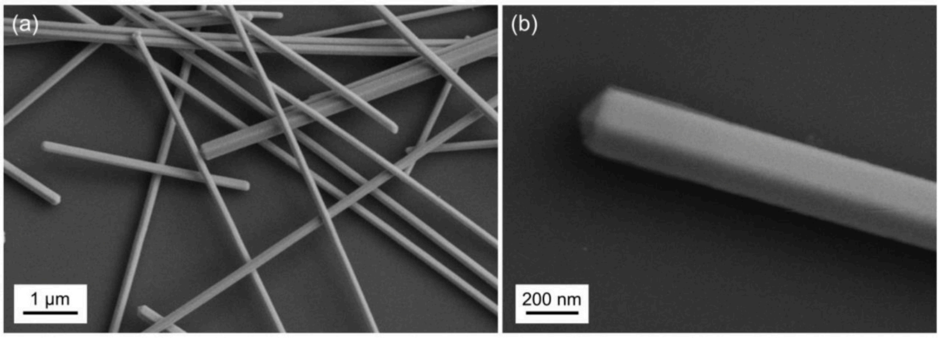
A DELICATE PROCEDURE

Studying the effects of atmospheric-pressure plasma treatment on silver nanowire networks

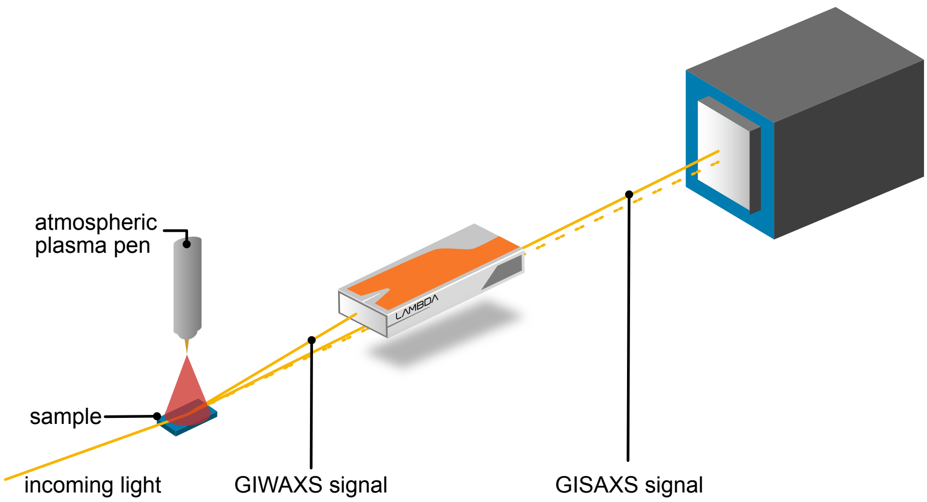
Silver nanowires can serve as conductive channels in elastic materials, facilitating the development of new, 3D-printable technologies such as flexible optoelectronics. In order to realize complex resistor designs, the electrical properties of these potent filaments need to be carefully tuned. One tool that allows for the treatment of silver nanowires is atmospheric plasma. It consists of a gas of charged particles at atmospheric pressure and is very effective at cleaning surfaces by oxidation or ablation of contaminants. However, it can also change the structure of the silver nanowires themselves – and ultimately destroy them. Treatment of silver nanowires with atmospheric plasma is thus a very delicate procedure. In order to apply it in a controlled fashion, scientists seek to understand exactly which structural and electrical changes it induces.



Scanning electron microscopy images of (a) a silver nanowire network and (b) a single silver nanowire.

EXPERIMENTAL SETUP

A team of researchers from Germany investigated the effects of atmospheric plasma treatment on a network of silver nanowires using an array of different methods. They started off with a nearly contaminant-free silver nanowire network, in order to investigate which structural changes the plasma etching would impose on the wires themselves. With field-effect scanning electron microscopy and X-ray photoelectron spectroscopy, they obtained images of their sample after every treatment step. In addition, in situ grazing-incidence small and wide angle scattering (GISAXS and GIWAXS) experiments were conducted at the Micro- and Nanofocus X-ray scattering (MiNaXS) beamline P03 at PETRA III, DESY. The GIWAXS signal was recorded with a LAMBDA 750k camera. **"The position of the GIWAXS detector was chosen so that both the primary signals of the silver crystals and the signals of the silver oxide that formed during the plasma treatment could be resolved simultaneously. The compact detector design and the small pixel size of 55 µm are very advantageous for this"**, explained Matthias Schwartzkopf, who designed the study.



RESULTS

Setup	PETRA III, DESY (Germany), P03 beamline
Camera	LAMBDA 750k Si detector
Resolution	786,432 pixels with 55 µm
Acquisition frequency	10 Hz
Photon energy	12.8 keV

The researchers treated their silver nanowire network with an atmospheric plasma pen for up to 26 seconds and observed the electrical and structural changes: During the first phase, the initially pentagonal silver nanowires assumed a more rounded shape. This structural change was associated with a very minor increase in resistance, which means that very controlled adjustments could be made during this phase. In phase II, resistance changed more rapidly, but still controllably, as silver oxide formed on the nanowires. The last phase was associated with increased melting and destruction of the silver nanowire network. Building upon those measurements, the researchers simulated the electrical response of the silver nanowire network to plasma etching with a theoretical model. Their work suggests that the electric properties of silver nanowire networks can be engineered with atmospheric plasma.

GIWAXS signal recorded with the LAMBDA 750k after six seconds of plasma treatment. The upper two rings stem from the nanowires, the bottom ring from the forming silver oxide.
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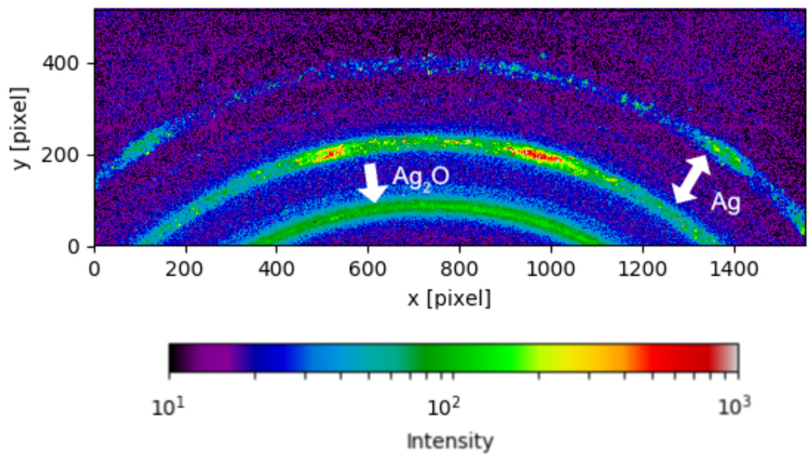

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