# Conductive top layer for e-beam lithographie for all e-beam resists (Electra 92)

ALLRESIST

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## Motivation:

The precise writing of patterns by means of electron beam lithography is generally unsuccessful on insulating substrates such as quartz or glass. The reason is the charging of the substrates during electron irradiation, since charges cannot be dissipated due to the insulating properties of the substrate. The problem can be circumvented by vapour deposition of a thin metal layer.

**Idea:** Development and use of conductive, soluble polymers which are applied thinly onto various e-beam resists, dissipate electrical charges during exposure and can subsequently be removed easily and completely. These polymers are also highly suitable for SEM pictures and dissipate the disturbing electrical charges also in these applications.

## Objective and work plan:

Conductive polymers like polyanilines are usually completely insoluble. Within the scope of the works however, a polyaniline was functionalized such that it now readily dissolves in water. From this polymer, resist samples were produced:

| | |
|---|---|
| Film thickness: | 30 – 100 nm |
| Coating: | on all known e-beam resists |
| Crosslinking: | no crosslinking; dose < 5000 µC/cm² |
| Removal: | easy, residual-free removal with $H_2O$ |
| Conductivity: | ~10 S/m |
| Shelf life: | > 24 month |

Electra 92 was coated on different e-beam resists and removed with water after irradiation. The requirements with regard to resolution and quality of the structures were also on insulating substrates fully met.

## Reference process with CSAR 62 and Electra 92:

| | |
|---|---|
| Substrate: | Glass 24 x 24 mm |
| Adhesion: | AR 300-80, 4000 rpm, 10 min, 180 °C hot plate |
| Coating CSAR 62: | AR-P 6200.09, 4000 rpm, 8 min, 150 °C hot plate |
| Coating Electra 92: | AR-PC 5090.02, 4000 rpm, 2 min, 90 °C hot plate |
| E-beam irradiation: | Raith Pioneer; 30 kV, 75 µC/cm² |
| Removal Electra 92: | 2 x 30 s water, dipping bath |
| Development CSAR 62: | 60 s AR 600-546 |
| Stopping: | 30 s AR 600-60 |

**Result:** At a CSAR 62 film thickness of 200 nm, squares with an edge length of 30 nm could reliably be resolved on glass.

## Conductivity and shelf life

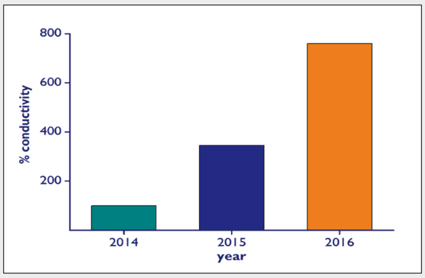



Diagram 1

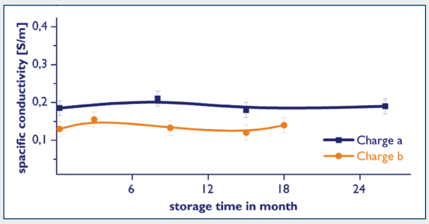
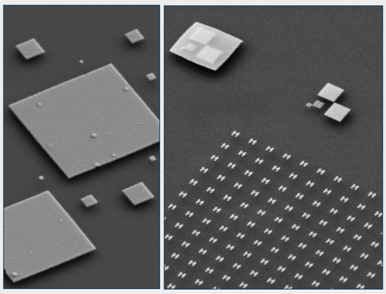



Diagram 2

Due to the optimization of synthesis and purification procedures of the polyaniline, the conductivity of AR-PC 5090 could be increased eightfold within the last 2 ½ years. (This is more than sufficient for all e-beam applications, see diagram 1). Already the first-generation polyaniline (2014) demonstrated that the conductivity properties remain constant over at least two years (see diagram 2).

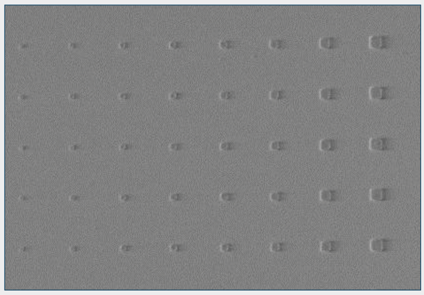
## Electra 92 for SEM pictures



Gold nano structures embedded in an insulating polymer matrix

Recent studies by University of Stuttgart (4th Physical Institute and Research Center SCoPE) demonstrated that the conductive coating Electra 92 represents a good alternative. If this resist is applied onto highly electrically insulating polymers or glass, still a high-quality imaging of nanostructures with SEM is possible.

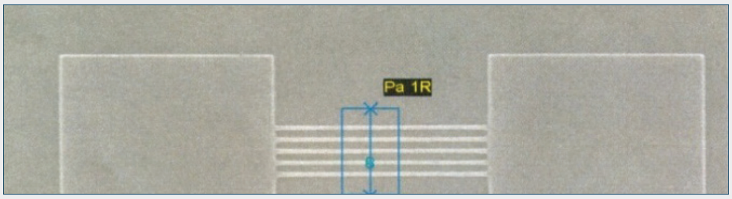
## CSAR 62 on glass



30 – 150 nm squares of CSAR 62 on glass

The combination of CSAR 62 with Electra 92 offers the best options to realise complex e-beam structuring processes on glass or semi-insulating substrates like e.g. gallium arsenide. The excellent sensitivity and highest resolution of the CSAR are complemented harmoniously by the conductivity of Electra (for process parameters, see Reference Process).

## Electra 92 with HSQ on quartz

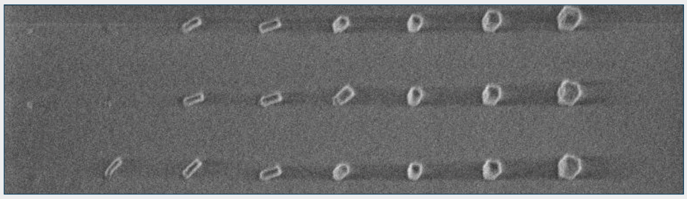



20 nm bars of HSQ, prepared on quartz AR-PC 5090.02

After a coating of Electra 92 on an HSQ resist, even this resist can be patterned on a quartz substrate with very high quality. The HSQ resist (20 nm thickness) was irradiated with the required area dose of 4300 µC/cm².

AR-PC 5090.02 was subsequently completely removed within 2 minutes with warm water and no residues could be detected. After development of the HSQ resist, the structures with high-precision 20 nm lines remained.

## Electra 92 on AR-N 7700 on glass



60 – 150 nm squares (100 nm height) on glass with AR-N 7700.08 and AR-PC 5091.02

Novolac-based e-beam resists possess other surface properties than CSAR 62 or PMMA. For this reason, AR-PC 5091.02 was designed with a different solvent composition. E-beam resist AR-N 7700.08 was at first spin-coated on glass, dried, coated with Electra 92 and baked at 50 °C. After irradiation, the Electra layer was removed within 1 minute with water and the e-beam resist then developed. The resulting resolution of 60 nm is very high for chemically amplified resists.

## Summary and outlook:

The synthesis and purification of the conductive polymer was optimized for Electra 92. Two Electra 92 versions exist for different resist surfaces:
- for PMMA resists, CSAR 62, HSQ et.al.: AR-PC 5090.02
- for novolac-based resists AR-N 7000 et.al.: AR-PC 5091.02

After exposure, an easy and residue-free removal with water is possible. The conductivity under high vacuum conditions can be specified with approximately 10 S/m and is thus in the upper range of semiconductivity. For the applications investigated here, this value was always sufficient. Particularly noteworthy is the long-term stability of Electra 92. After more than 2 years in storage, conductivity, coating properties and solubility practically remained unchanged. Outlook: Work is currently in progress concerning the direct patterning of Electra to manufacture conductive tracks with a two-layer system.

As of: Sept. 2016