Electronic Supplementary Material (ESI) for RSC Advances.

Supporting information

to

Optimized Inkjet-Printed Silver Nanoparticle Films: Theoretical and Experimental Investigations

Sreeman Mypati, Shankar R. Dhanushkodi, Michael McLaren, Aristides Docoslis, Brant A. Peppley, and Dominik P.J. Barz*

Department of Chemical Engineering, Queen's University, Kingston, ON, K7L 5L9, Canada

E-mail: dominik.barz@queensu.ca

Design of Experiment coded variables

For a Design of Experiment (DOE) with factors (independent variables) having different units and order of magnitudes, it is preferable to code them so that the values have a generic level. For a two level-three factor central composite design (CCD), the levels of interest are located around the center level as indicated in Figure S1.

The respective coded variables for the three factors used in this study are given in Table S1.

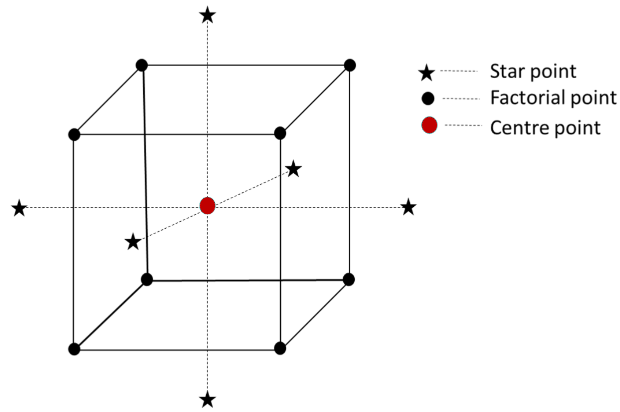

Figure S1: Circumscribed central composite design

Table S1: Coded variables of the factors (sintering parameters)

Factors	**-1**	**0**	**+1**	**-1.633 (-α)**	**1.633 (+α)**
Temperature T/°C	180	230	280	148	312
Time t/min	30	60	90	11	109
Layers n/-	3	6	9	1	11

The factor levels are coded as -1 (low), 0 (center), +1 (high), $-\alpha$ (star point -1) and α (star point +1) while the responses (dependent variables) are the resistivity ρ and thickness H. Note that a full two level factorial design provides only statistical information within the range of factors and does not include the quadratic terms. Using a CCD gives information beyond the level range by considering star points. These levels are outside the factorial range both above and below the median and are computed using the α distance from the center point according to

$$\alpha = \left(M \frac{1 + \frac{n_{sc}}{n_s}}{1 + \frac{n_{cc}}{n_c}} \right)^{\frac{1}{2}} \tag{1}$$

Here, M is the number of factors in the design and n_{sc}, n_s, n_{cc} and n_c are the number of center points in the star portion, star points, center and non-center cube points, respectively. Further information is available for example in Ref.[1]

Transformation of data

Initially, the analysis of variance (ANOVA) is performed using the experimental data. It is observed that the resistivity data is not normally distributed. To increase the effectiveness and applicability of the statistical analysis, a Box-Cox normality plot [2] is obtained to find the correlation coefficient (λ = -1 for resistivity; λ = 1 for thickness). The λ is used as the exponent for the transformation of the measured data. Table S2 shows the experiments that are performed according to the DOE along with the measured and predicted responses.

Table S2: Experimental design table for the sintering factors and measured and predicted responses.

Factors			**Thickness**		**1/Resistivity**	
Temperature T	Time t	Layers n	Measured	Predicted	Measured	Predicted
°C	min	-	μm	μm	$\cdot 10^9$ $(\Omega\cdot\text{m})^{-1}$	$\cdot 10^9$ $(\Omega\cdot\text{m})^{-1}$
180	90	9	6.84	7.71	0.029	0.027
280	90	3	2.66	2.83	0.04	0.04
230	60	6	5.77	5.32	0.039	0.036
230	60	6	5.73	5.32	0.038	0.036
180	30	3	3.54	3.18	0.0004	0.0017
280	30	9	7.19	7.36	0.044	0.049
280	30	3	2.88	2.91	0.037	0.034
280	90	9	6.96	7.43	0.043	0.043
180	30	9	7.55	7.78	0.03	0.025
230	60	6	5.92	5.4	0.036	0.041
180	90	3	2.84	3.26	0.035	0.032
230	60	6	6.03	5.4	0.035	0.041
230	109	6	6.13	6.11	0.035	0.037
230	11	6	5.54	6.11	0.023	0.023
230	60	11	9.56	8.76	0.046	0.044
230	60	6	5.53	6.11	0.039	0.037
230	60	1	1.14	1.22	0.029	0.029
312	60	6	7.04	6.77	0.043	0.041
230	60	6	5.79	6.11	0.037	0.037
148	60	6	7.82	7.34	0.004	0.008

References

(1) Montgomery, D. C.; Runger, G. C.; Hubele, N. F. *Engineering statistics*; John Wiley & Sons, 2009.

(2) Sakia, R. The Box-Cox transformation technique: a review. *The statistician* **1992**, 169–178.