Area Selective Chemical Vapor Deposition of Gold by Electron Beam Seeding

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Gold is a key metal in microelectronics due to its low resistivity, resistance to electromigration and chemical inertness making it an excellent choice for stable and reliable electrical contacts. Chemical vapor deposition (CVD) is a technologically significant option for fabricating gold contacts or other metallic functional structures. CVD utilises the thermal decomposition of precursor molecules in a gaseous state. Molecules reaching the surface are thermally decomposed, leaving the central metal atom on the surface. If the decomposition is favored kinetically or thermodynamically on certain surfaces compared to others, the ensuing variation in reaction rates can be exploited for area selective deposition.

This work presents a novel maskless patterning technique that enables area selective CVD of gold [1]. A focused electron beam is used to decompose the metal-organic precursor $Au(acac)Me_2$ locally [2], thereby creating an autocatalytically active seed layer for subsequent CVD with the same precursor. The procedure can be included in the same CVD cycle without the need for clean room litho-graphic processing. Moreover, it operates at low temperatures of 80 °C, over 200 K lower than standard CVD temperatures for this precursor, reducing thermal load on the specimen.

Given that electron beam seeding operates on any even moderately conductive surface, the process does not constrain device design. This is demonstrated by the example of vertical nanostructures with high aspect ratios of around 40:1 and more. Written using a focused electron beam and the same precursor, these nanopillars exhibit catalytically active nuclei on their surface. Furthermore, they allow for the first time the precise determination of the local temperature increase caused by the writing of nanostructures with an electron beam.

To summarise, this work presents a new, technologically powerful and easy to implement approach to area selective gold deposition. The low temperature necessary makes it highly suitable for processing innovative flexible devices that rely on heat-sensitive polymers, including flexible electronics and flexible solar cells. In addition, the maskless direct write seeding is possible on 3D architecttures, which provides the potential to fabricate nanostructures or localized electric contacts on intricate 3D devices.

[1] A. Tsarapkin, K. Maćkosz, C. S. Jureddy, I. Utke, and K. Höflich, ArXiv:2312.00653 **[cond-mat.mtrl-sci]** (2023).
[2] I. Utke, P. Swiderek, K. Höflich, K. Madajska, J. Jurczyk, P. Martinović, and I. B. Szymańska, Coord. Chem. Rev. **458**, 213851 (2022).

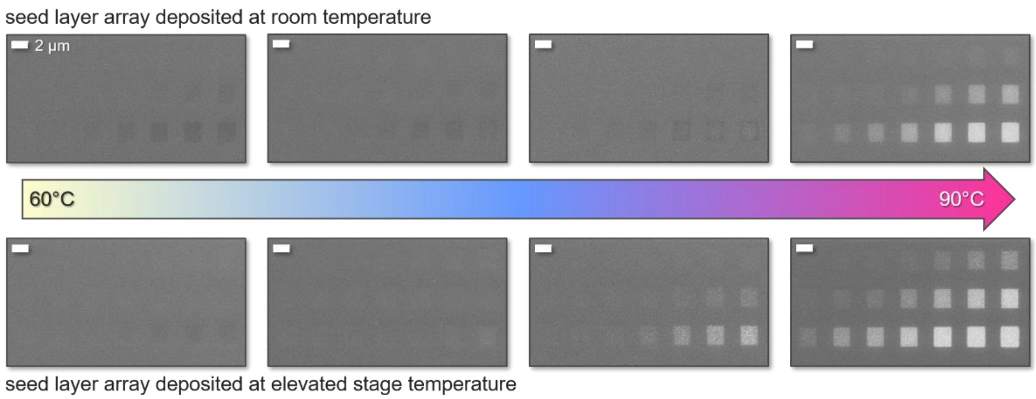

Figure 1: Temperature dependence of area selective autocatalytic film growth. A seed layer is deposited using a focused electron beam to locally decompose the precursor on a substrate at room temperature (top row) or at elevated substrate temperatures (bottom row). After seeding the precursor is decomposed autocatalytically at the deposited Au nuclei without further electron beam assistance. SE micrographs show the resulting gold films at different substrate temperatures.