Nanowire Synthesis on catalyst arrays produced with electron beam induced deposition

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The locally confined preparation of surfaces for nanowire synthesis is reported in this presentation. Metal particles are commonly used as catalyst for the synthesis of nanowires and nanotubes [1,2]. The metal particle size, area density and distribution has been recognized in numerous studies as determinative for the chemical vapor deposition of the nanowires and nanotubes.
Gold nanoparticles are used as catalyst for the synthesis of silicon nanowires grown by vapour-liquid-solid (VLS) deposition from silane. Carbon nanotubes have been synthesized by the catalytic decomposition of a carbon containing species such as carbon monoxide or ethylene over a supported metal catalyst such as iron or cobalt.
By using the maskless, resistless method of focused electron beam induced deposition (FEBID) we have accomplished the local deposition of catalytic metals on the nanometer-scale. With this locally confined CVD process a focused electron beam of an electron microscope was utilized to fabricate the metal structures. With the technique of FEBID it is possible to produce nanoparticles on real three dimensional structured substrates such as tips and trenches. Volatile organometallic precursor gases such as Dimethly-gold-acetylacetonate and Iron pentacarbonyl were introduced into the electron microscope and decomposed on the sample surface by the electron beam. With FEBIP small structures with a size below 1 nm have been reported [3]. The ability to deliberately control the catalyst geometry allows to influence the surface diffusion and the deposition rate.
Area depositions, dot array depositions and vertical depositions of catalytic metal will be presented (Fig. 1). Depositions in trenches and on tips will be shown as well. The effect of simultaneous introduction of precursor gas and an additive gas like water vapour or oxygen will be discussed. The deposition parameters for optimisation of material purity and the deposition rate will be discussed. The deposited catalyst structures have been successfully used as substrate for a subsequent synthesis of nanowires and nanotubes (Fig. 2). Synthesis was found to be restricted to the area covered with FEBID-deposited catalytic metal. The volume of the catalytic metal particles and the chemical composition necessary for the synthesis of the nanowires will be defined.
The synthesis of silicon nanowires confined to the previously deposited gold structure is shown in Fig 1 and Fig 2. The application of iron and cobalt nanoparticles fabricated by FEBIP for carbon nanotube deposition is discussed and examples are given.

[1] Hafner, J.H., Bronikowski, M.J., Azamian, B.R., Nikolaev, P., Rinzler, A.G., Colbert, D.T., Smith, K.A., Smalley, R.E., Catalytic growth of single-wall carbon nanotubes from metal particles, (1998) Chemical Physics Letters, 296 (1-2), pp. 195-202.
[2] Moisala, A., Nasibulin, A.G., Kauppinen, E.I. "The role of metal nanoparticles in the catalytic production of single-walled carbon nanotubes - A review" Journal of Physics Condensed Matter 15 (42), 3011 (2003)
[3] Van Dorp, W.F., Hagen, C.W., Crozier, P.A., Kruit, P., In situ monitoring and control of material growth for high resolution electron beam induced deposition, J. Vac. Sci. Technol. B 25 (6), 2210 (2007)

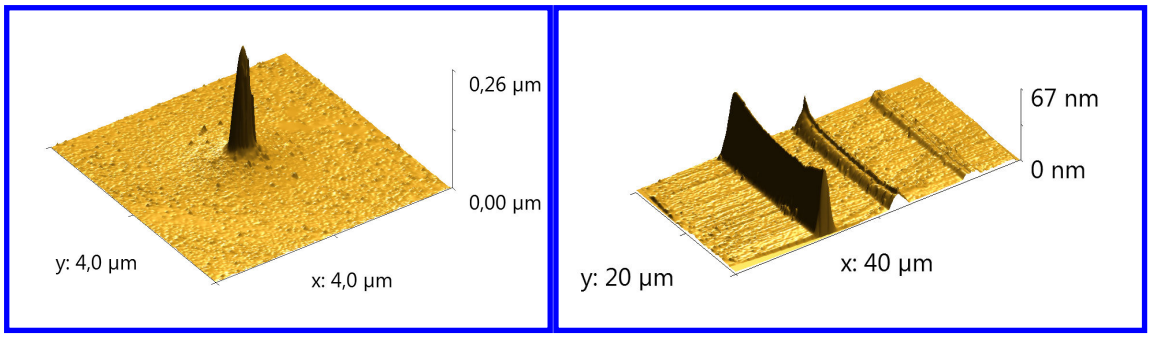

Fig. 1. AFM images of FEBID gold structures (left) dot deposition, (right) deposited lines

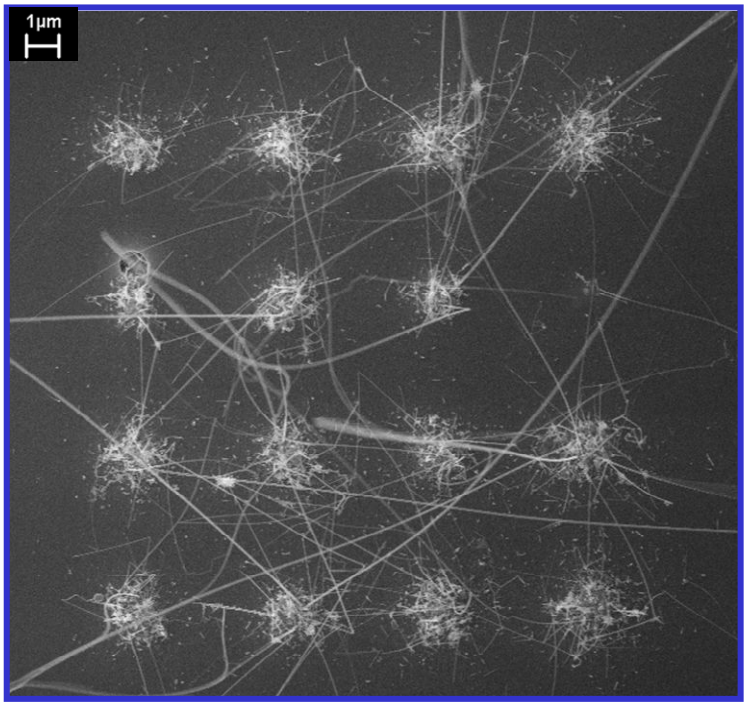

Fig. 2. FEBIP deposited catalyst array after silicon nanowire growth