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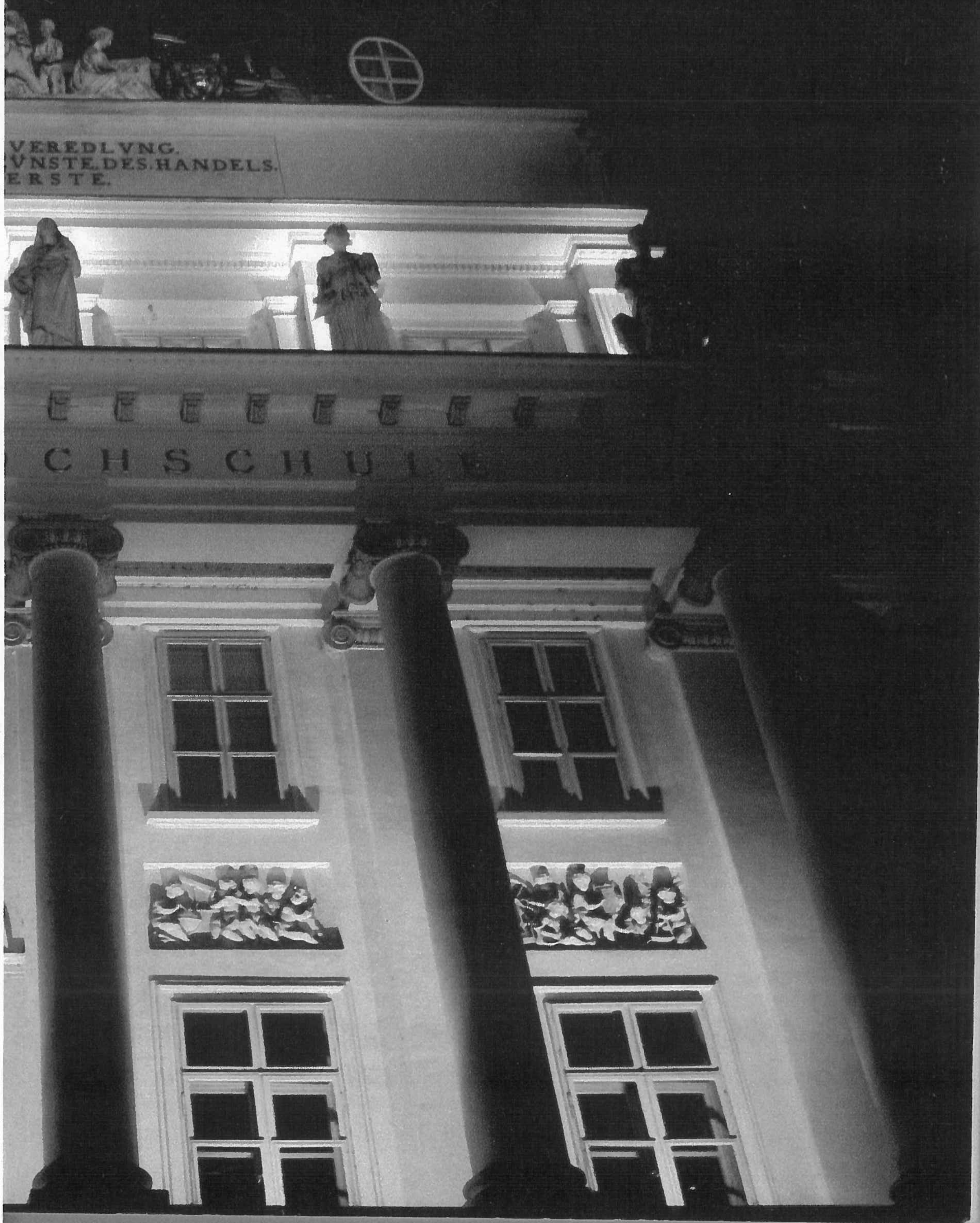

POSITION CONTROL OF NANOWIRES USING A FOCUSED ION BEAM

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The vapor-liquid-solid (VLS) nanowire synthesis requires seed particles, which act as a catalyst and define both, diameter and position. Gallium droplets can be used as an alternative to the commonly used Au in order to avoid trap states [1]. We present the growth of GaAs nanowires at defined positions by implantation of Ga with a focused ion beam (FIB) system, which does not require lithographic steps and therefore avoids potential contamination of the growth facilities [2,3]. Epitaxial growth of semiconductor nanowires at defined positions opens new opportunities for the integration of optoelectronic devices with conventional silicon technology.

Gallium droplets nucleation

The Ga droplets in Figure 1 were deposited on Si (100) substrates in a molecular beam epitaxy (MBE) under ultra-high vacuum (UHV) conditions. The deposited material with an equivalent Ga layer thickness of 3.7 nm forms droplets with an arbitrary distribution on the Si surface of the wafer, which is heated to 600 °C. After this nucleation process and an annealing time of 60 s the vapor liquid solid synthesis (VLS) of nanowires is started in the MBE with a Ga growth rate of 0.09 µm/h under an As flux of 5e-7 torr and leads to the formation of GaAs nanowires shown in Figure 2.

Figure 1 Arbitrary deposited Ga droplets on Si (100) in a molecular beam epitaxy system

Figure 2 GaAs nanowire growth in the VLS mechanism under ultra-high vacuum conditions

Positioning of droplets and wires

The approach, presented in this work, is based on implanted gallium ions in a small field with a diameter of 80 nm with a FIB at 30kV acceleration voltage on a well-defined position on the Si (100) wafer. After this step, the wafer sample was annealed for a time of 10 minutes at a temperature of 600 °C. This causes the diffusion of the ions to the surface and form small Ga droplets which can further act as a catalyst for the VLS growth mechanism (see Figure 3).

Figure 3 Focused ion beam implanted and by annealing formed Ga droplets at defined positions on Si

Figure 4 GaAs nanowire growth after annealing the implanted Ga in a MBE system

As shown in Figure 4 the VLS synthesis of nanowires takes place exactly at the spots, which were defined by Ga ion implantation. In between the nanowires, some polycrystalline GaAs is formed uncatalytically. We will optimize the growth conditions in order to suppress such parasitic growth and to increase the yield of positioned nanowire arrays.

Conclusion

We present a strategy for the positioned growth of semiconductor nanowires by implanting catalyst material with a FIB system. This presents a key ingredient for the integration of GaAs nanowires with Si for optoelectronic devices. We will extend this concept to other semiconductor materials in future.

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