Physical Modeling of
Side Wall Deposition by Inclined Electron Beam Evaporation

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Three-dimensional nanostructures like bars, fins and holes are essential design features in modern semiconductor processing to overcome traditional design limits and achieve More-than-Moore device density. Inclined electron beam evaporation is commonly applied for material deposition on these nanostructures to reach conformal step coverage on side walls. These thin films could serve as seed layers for electroplating, applied for p-contacts of GaAs diode bars[1], air bridges for source pads or through substrate VIA contacts in GaN transistors[2,3]. Depending on the exact nanostructure forms, shadowing can be a challenge for decent step coverage. Both experimental and modeling results show an improvement in conformality by optimizing inclination angles[4–6].

In this study, a physical model ís developed to predict the step coverage on the side walls of different structures by inclined evaporation. We will present our model based on several general conditions: a. the evaporation is under high vacuum (below 10^{-5} mbar); b. evaporation beam is perpendicular to the wafer by 0° inclination (**fig. 1**): c. wafers are rotated during evaporation; d. the film density is independent of inclination – in reality, the film could become porous when inclined[7]. Within the model, evaporation on bar structures is firstly simulated, revealing no shadowing (**fig. 2a**). The conformality over the inclination and the taper angles are calculated and plotted in **fig. 2b.** Calculated data are in good agreement with experimental results. The demonstrative cross-section of the inclined evaporation on a bar structure with 90° side wall is shown in **fig. 2c.** Next, the model is developed for the shadow effects within circular or square holes (**fig. 2d,g**). For circular holes, the dependence of evaporation shadowing on the inclination angle as well as an exemplary distribution of deposition rate at 30° inclined evaporation over the rotation angles are illustrated in **fig. 2e**. The conformalities over the depths for different inclination angles are plotted in **fig. 2f**. For a square hole, the computed conformality distribution on one side wall is illustrated in **fig. 2h** for 60° inclined evaporation. The experimental result of the inclined evaporation (**fig. 2i)** shows the same triangle pattern as the modeling result.

Our model allows prediction of the step coverage on the side wall during inclined electron beam evaporation in order to select the inclination for the evaporation on three-dimensional nanostructures. With the help of this model, we can also forecast the layer conformality for various nanostructures of different sizes evaporated at the same time and, hence to create a design manual.

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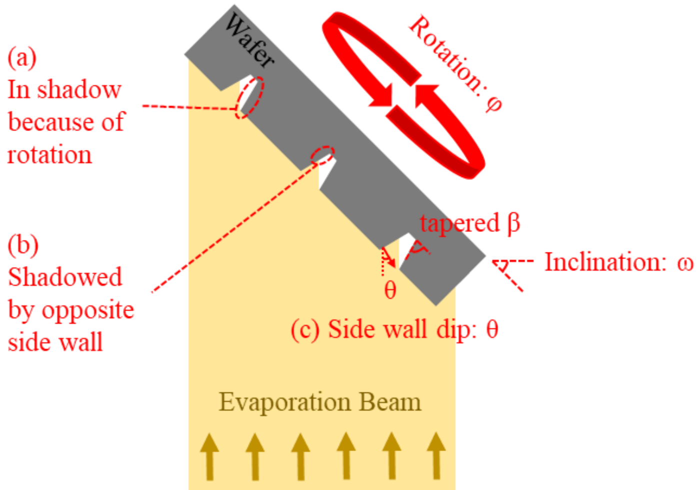

Figure 1: Schematic diagram of inclined electron beam evaporation

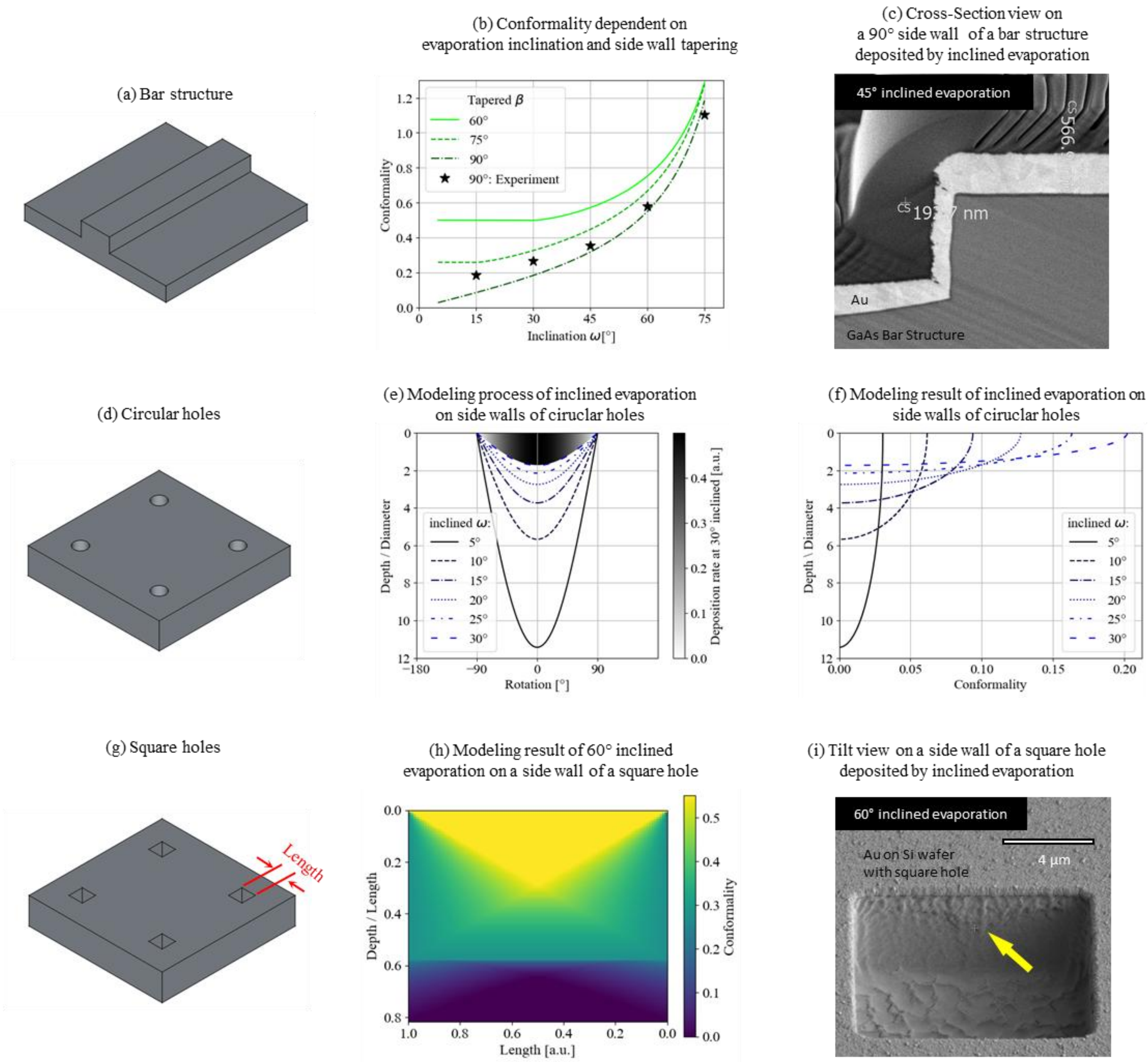

Figure 2: Physical model and experimental results of inclined evaporation on side walls