Title: **Low-Temperature Integration of SiGe-on-Si using Aluminum-Induced Crystallization for Advanced Optical and Electronic Sensors**

Presenter name: **Lucia Crocetto**
Company name / Institute: TU Delft

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The integration of SiGe on Si is a key step toward next-generation optical and electronic devices, enabling applications such as virtual substrates for high-mobility transistors [1], buffer layers for Ge epitaxy [2], and absorber layers for broadband optical sensors [3]. Conventional methods such as molecular beam epitaxy [2] or chemical vapor deposition [1,3] require high temperatures, high vacuum conditions, and often toxic gases, increasing fabrication costs and preventing post-processing or back-end-of-line (BEOL) CMOS integration.
We propose aluminum-induced crystallization (AIC) as a promising low-cost, low-temperature (≤ 350 ˚C) approach, avoiding toxic precursors and fully compatible with post-processing and BEOL integration. However, a systematic understanding of how process parameters affect the resulting SiGe properties is still lacking. To address this knowledge gap, we comprehensively investigated the effects of annealing time, metal composition, and initial thickness on the AIC-grown layers. In addition to the standard Al (99.999% purity) target, we used an Al-Si (1 wt% Si) target to evaluate the impact of 1% silicon on the AIC process. We monitored SiGe growth by scanning electron microscopy (SEM) and used a neural network to identify nucleation sites and track their evolution. Adding 1% silicon accelerates the AIC process to the detriment of crystal quality. Electron back-scatter diffraction (EBSD) shows decreasing SiGe grain size and (100)-oriented fraction with increasing thickness, with the Al-Si (1 wt% Si) target exhibiting the strongest thickness dependence. Longer annealing time improves both crystal size and orientation. Secondary-ion mass spectroscopy reveals that the Al-Si (1 wt% Si) target results in an increased Si content (2%) and a lower Al concentration in the SiGe layer.
These results provide new insights into the correlations between process parameters and SiGe properties. Depending on the target application, different trade-offs between thickness, metal composition, and annealing time can be exploited. This work paves the way for integrating high-quality SiGe layers into advanced optical and electronic sensors, offering practical guidelines to tailor AIC for diverse device applications.

References

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