Locally Measuring the Adhesion of InP Membranes Directly Bonded on Silicon

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Direct bonding of III-V semiconductors on silicon has recently become a promising technology for the fabrication of hybrid photonic integrated circuits (PICs). In such hybrid PICs, active optical functions (amplification, emission) are ensured by the direct-gap III-V semiconductor and passive functions (guiding, switching) by the Si guiding layer. One particularly attractive feature of hybrid III-V/Si platforms is the possibility to densely integrate a variety of advanced optical functions in the guiding layer using sub-100 nm patterns in the silicon. Nano-patterning the silicon surface may, however, weaken the adhesion of the III-V semiconductor to silicon, potentially making the hybrid bonded stack subject to debonding in subsequent processing steps, such as cleaving. In this context, quantitatively assessing the adhesion of the III-V to Si in a patterned area and comparing it against the adhesion in a nearby unpatterned area can provide one with feedback useful for improving the patterning, post-patterning surface preparation, or bonding processes. Ultimately, such measurements can allow one to propose optimal designs for advanced embedded optical functions in hybrid III-V/Si PICs. Instrumented nanoindentation, Atomic Force Microscopy and Scanning Transmission Electron Microscopy have been combined ex situ to study the adhesion of thin InP membranes to bulk (100) silicon substrates but also to sub-100nm patterned (100) silicon substrates. Three distinct regimes are identified in the deformation of the InP/Si stacks during these experiments: the first is plastic flow of InP at low loads; the second is elastic debonding of the InP membrane, far from the indented zone at medium loads; lastly, the local amorphisation of the underlying Si substrate at high loads. The regime of intermediate loads is shown to be particularly useful in the evaluation of the surface bonding energy of InP to Si [1,2,3].

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My current research interests are focused on the growth and the structural study of nanostructures of III-V semiconductors such as quantum dots, nanowires, multi-quantum wells and strained-layer superlattices. I am currently working on their chemical and structural characterization until the atomic scale, using Transmission Electron Microscopy and aberration corrected Scanning Transmission Electron Microscopy. Recent results have been obtained on the structural characterization and mechanisms growth of catalysed III-V nanowires, and the determination of the morphology and the chemical composition of single InAsP Quantum Dot inserted in a nanowire. Other recent results of structural characterization have been obtained on the chemical composition and the strain field mapping of CdSe/CdZnS core/shells nanoplatelets.
I am also involved in the study of the in-situ growth of III-V semiconductor nanowires in a transmission electron microscope (Equipex TEMPOS) and I am responsible for the NANOTEM transmission electron microscopy platform (Titan Themis microscope and FIB dual beam Scios) linked to the Equipex TEMPOS project.