Growth-Induced Temperature Changes During Transition Metal Nitride Epitaxy on Transparent SiC Substrates

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Accurate non-contact substrate temperature monitoring and control during MBE growth has been a topic of continued interest for more than 25 years [1-3]. While accurate temperature control is well understood for homoepitaxial growth, large substrate temperature changes that are not accurately sensed by the substrate heater thermocouple can be induced by high carrier densities [4-5], reduction of the effective bandgap of the substrate/epitaxial layer stack [1-2], and changes in the surface reflectivity (e.g. induced by the accumulation of gallium droplets in GaN MBE) [6] during growth. In general, any change of the thermal cavity that partially encloses the substrate can also be expected to lead to a change in substrate temperature.

An experimental case that exemplifies the one of most extreme examples of growth-induced temperature changes is the MBE growth of metallic films on transparent semi-insulating SiC. Integration of epitaxial metal layers are technologically important as they will enable substantial performance benefits, design flexibility, and novel device structures such as metal-base transistors [7] and integrated epitaxial superconductor/semiconductor heterostructures [8]. Metals are highly reflective, have very high carrier densities, and have very small or zero band gaps compared to the ~ 3 eV gap of SiC. All of these factors mean that even very thin epitaxial metal layers can be expected to lead to large substrate temperature changes during growth.

In this presentation, we will discuss the use of in-situ SiC band-edge thermometry and pyrometry to quantify and control the substrate temperature excursion during the MBE growth of transition metals and transition metal nitrides on transparent 3” diameter 4H- and 6H-SiC substrates.

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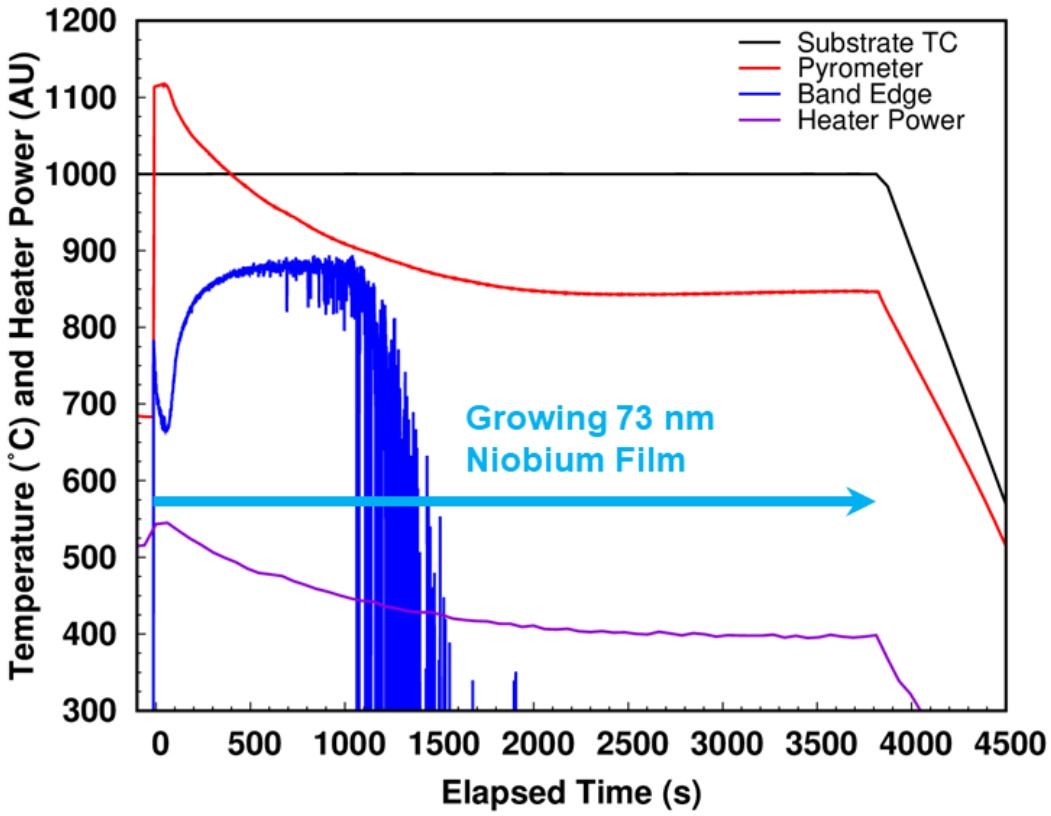
Supplementary Page:



Measured temperature and power excursions for 73 nm niobium (Nb) film grown on transparent SI 4H-SiC substrate with fixed heater thermocouple (TC) temperature illustrating:

- Band edge substrate temperature falls from 784 °C to 665 °C upon opening the substrate shutter while the substrate TC temperature is fixed.
- Band edge substrate temperature rises to 880 °C and stabilizes in the first ~ 9 nm of Nb growth.
- Band edge substrate temperature becomes unreliable after ~ 20 nm of Nb growth.
- Pyrometer temperature becomes reliable and substrate heater power stops changing after ~ 40 nm of Nb growth.
- The asymptotic band edge (880 °C) and pyrometer temperatures (846 °C) differ by 34 °C. The cause of this discrepancy is under investigation.
- At the end of the growth of the 73 nm Nb film, the thermocouple temperature, heater power, and pyrometer temperature all track as expected.