Epitaxial growth of pulsed laser deposited Ge-Sb-Te thin films on (111) oriented substrates

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Introduction
Phase change materials based on the material system Ge-Sb-Te (GST) have been widely used for optical storage for decades and is gaining more interest as a candidate for storage class memory. Recently, it was shown that memory devices with a ordered structure possess improved switching characteristics in terms of speed and stability\(^1\). Even more highly ordered Ge-Sb-Te-films in form of epitaxial layers have been achieved with MBE\(^2\), however, with severe limitations regarding deposition rate.

Here, Pulsed Laser Deposition (PLD) is used to deposit high quality epitaxial GST films from a compound target at high deposition rates (1-100 nm/min)\(^3\)-\(^4\) and the resulting films were investigated mainly by XRD and TEM.

### Pulsed laser deposition

**Experimental parameters**
- K-eximer laser (248 nm)
- \(P_{\text{ex}}\): 1-100 Hz
- \(P_{\text{ex}}\) = 200 Hz pulse length
- Fluence: 0.9 J/cm\(^2\)
- Target: \(\text{Ge}_2\text{Sb}_2\text{Te}_5\)
- Ar-flow: 1 sccm (10\(^{-6}\) mbar)
- Target-substrate distance: \(\approx 7\) cm

**Materials**
- \(\text{BaF}_2\)(111) Si(111)

**Technology**
- Distinct differences in properties between crystalline and amorphous state (electrical and optical)
- The differences can be read out as digital data (0 and 1)
- Used in re-writable optical media/non-volatile electronic memories

### Results

- **Baf\(_2\)(111)**
  - Smooth topography, occasional crystallites
  - Composition close to target material
  - No significant composition change below 250°C
  - Diffraction pattern mostly consistent with Ge-Sb-Te
  - Epitaxial growth already at 85°C
  - Two equal rotational domains until 210°C
  - Thereafter one domain dominates
  - Epitaxial relationship:
    - \(\text{Ge}_2\text{Sb}_2\text{Te}_5\) at low T (black annotation)
    - \(\text{Ge}_2\text{Sb}_2\text{Te}_5\) at high T (blue annotation)
  - Only (000) reflections present
  - Two components present in the rocking curve
  - Broad base partially originate from the substrate
  - At high T: FWHM < 0.06°

- **Si(111)**
  - Smooth topography, occasional crystallites
  - Loss of Ge and Te at high T (T>200°C)
  - Partial epitaxial growth < 220°C
  - Thereafter one domain dominates
  - Epitaxial relationship:
    - \(\text{Ge}_2\text{Sb}_2\text{Te}_5\) at low T
    - \(\text{Ge}_2\text{Sb}_2\text{Te}_5\) at high T
  - Only (000) reflections present
  - Two components present in the rocking curve
  - Broad base vanishes with increasing T
  - At high T: FWHM < 0.06°

### Conclusions

PLD has been demonstrated as an effective deposition method for high quality epitaxial Ge-Sb-Te thin films. The films were mainly analyzed with XRD and TEM and they are characterized by a hexagonal structure with a pronounced vacancy layer ordering. A clear improvement of the crystal quality is achieved by increasing the substrate temperature, but at high temperatures also simultaneous desorption of Ge and Te occurs.