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OPTICAL PROPERTIES OF SILICON AND TIN NANOSHEETS

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INTRODUCTION

Silicene and Stanene belong to a large group of two-dimensional materials better known as Xenes. They are artificial graphene-like monoelemental buckled lattices made of elements other than carbon. This class of materials shows a wide electronic diversity: within it, semimetals, semiconductors and topological insulators can easily be found. This makes them particularly attractive for several new technology applications, such as spintronics, nanoelectronics and photonics [1]. In order to have a direct access to their optical properties, we proposed sapphire as an optically transparent substrate capable of stabilizing the two-dimensional structure of epitaxial silicon [2] and tin [3] nanosheets, without destroying their electronic states. The absolute optical transmittance was measured on different samples, in the photon frequency range from Infrared to Ultraviolet. Using the RefFIT [4] data analysis software, microscopic optical functions were extracted. The absorption spectra - as a function of thickness for silicon and as a function of temperature for tin - are presented and discussed.

SAMPLE GROWTH AND SPECTROSCOPIC CHARACTERIZATION

Epitaxial growth in UHV conditions

Substrate preparation
$Al_2O_3(0001)$

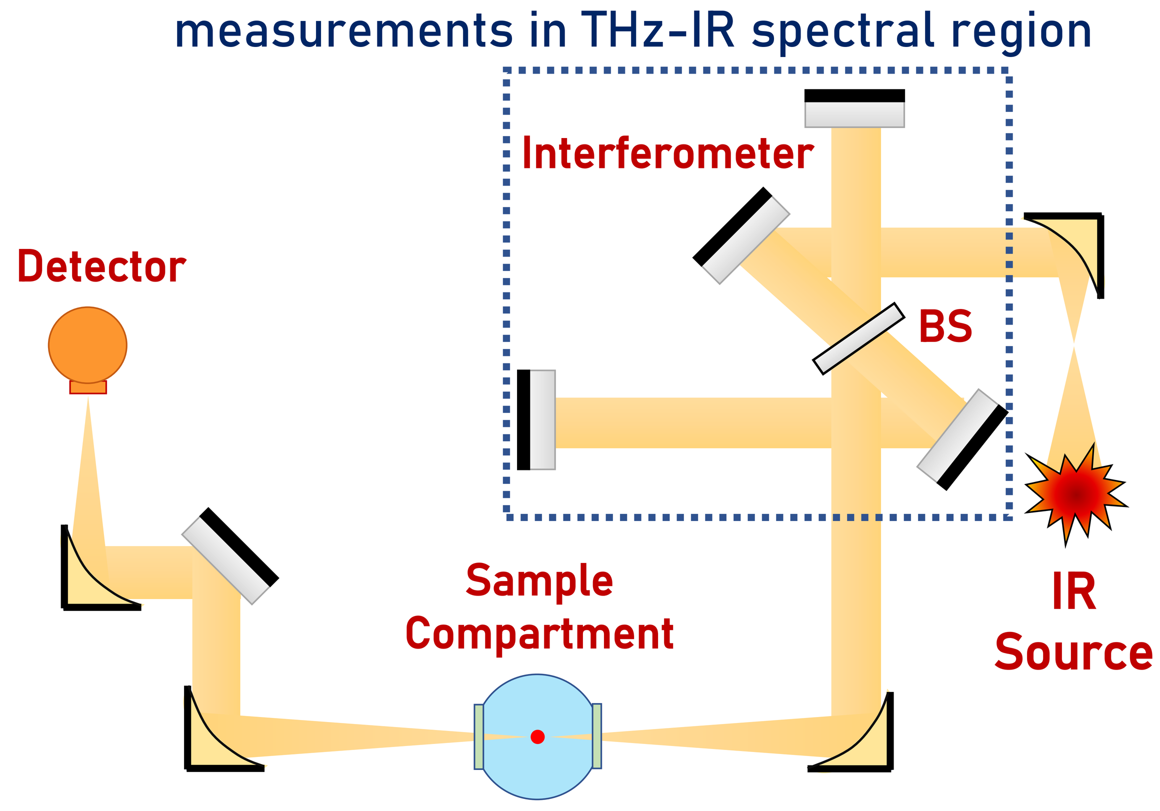
- Degassing at ~ 250 °C for several hours

Epitaxial deposition
Silicon or Tin

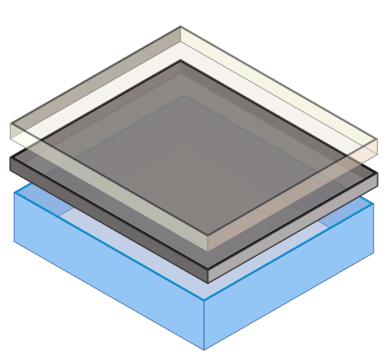
Encapsulation
$\sim 5nm$ Amorphous Al_2O_3

- Reactive co-deposition of Al+O_2

Optical scheme for transmittance measurements in THz-IR spectral region



Stacking of samples



Transmittance

$$T(\omega) = \frac{I_T(\omega)}{I_0(\omega)}$$

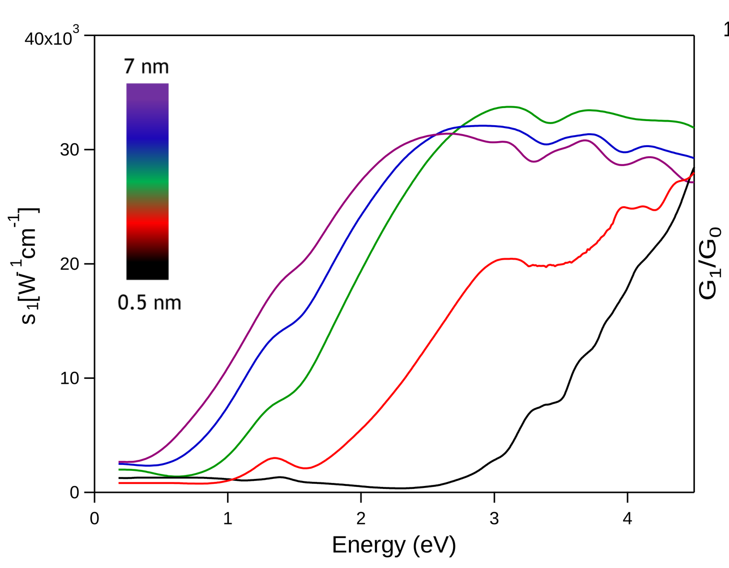
Optical conductivity
Refractive index

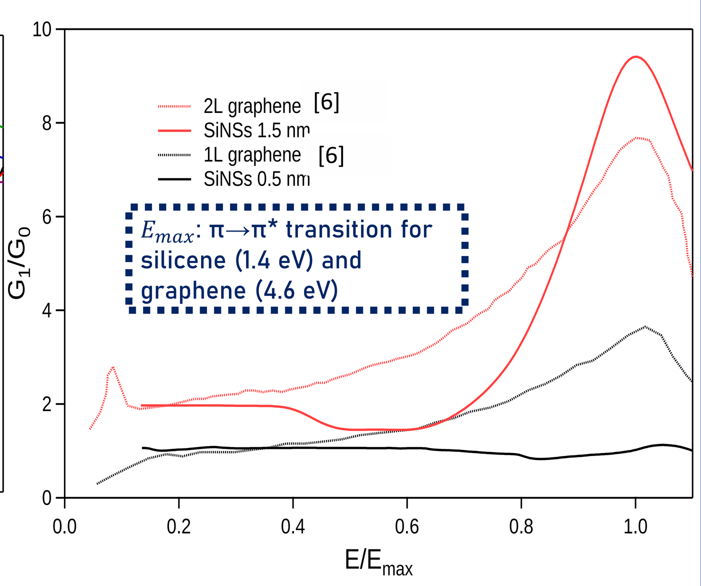
$$\tilde{\sigma}(\omega) = \sigma_1(\omega) + i\sigma_2(\omega)$$

$$\tilde{n}(\omega) = n(\omega) + i\kappa(\omega)$$

- The spectral range from THz to UV has been scrutinized combining FT-IR spectroscopy and NIR-Vis-UV dispersive spectrometry
- The absolute optical transmittance was measured and analyzed using the software RefFIT
- A multilayer Drude-Lorentz model was developed, consisting of two layers: one for the Al_2O_3 substrate and the other for the thin film
- Microscopic optical properties were determined through a K-K constrained fit of the experimental measurements

OPTICAL CONDUCTIVITY AND ABSORPTION SPECTRA





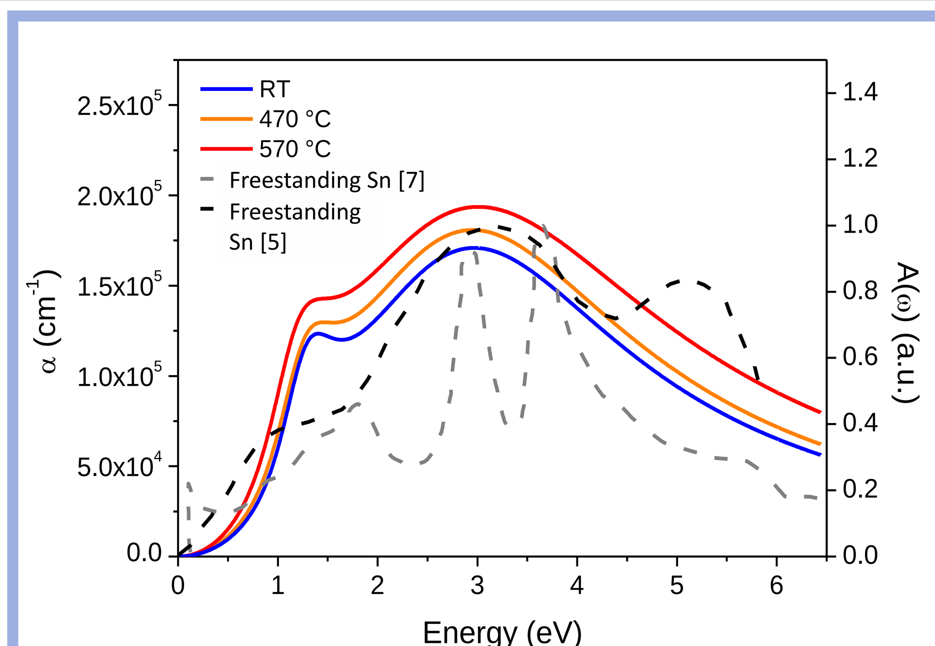
- At the 2D limit freestanding-like silicene behavior is observed: two resonances close to π→π* (1.6 eV) and σ→σ* (4 eV) transitions [5]
- The silicon nanosheets optical conductivity shows a low-energy electrodynamics

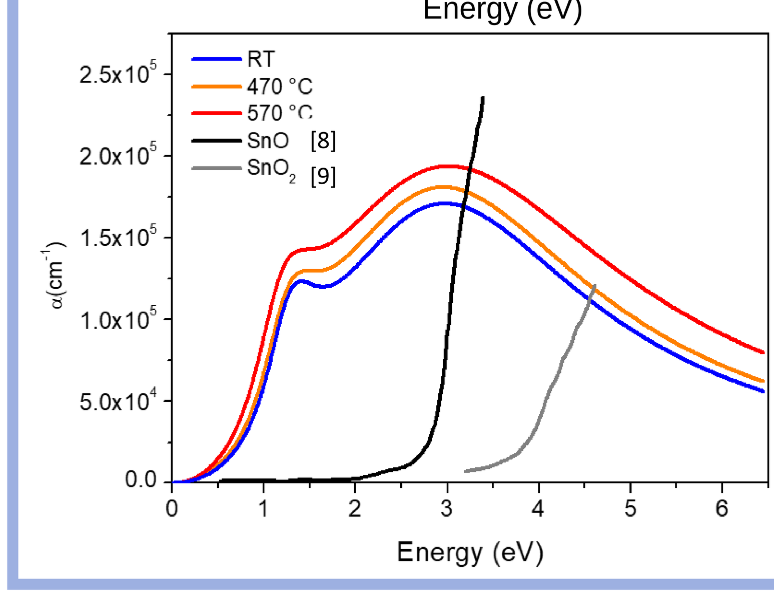
- The behavior of universal conductance, as function of layer thickness is consistent with a Dirac-like electronic dispersion

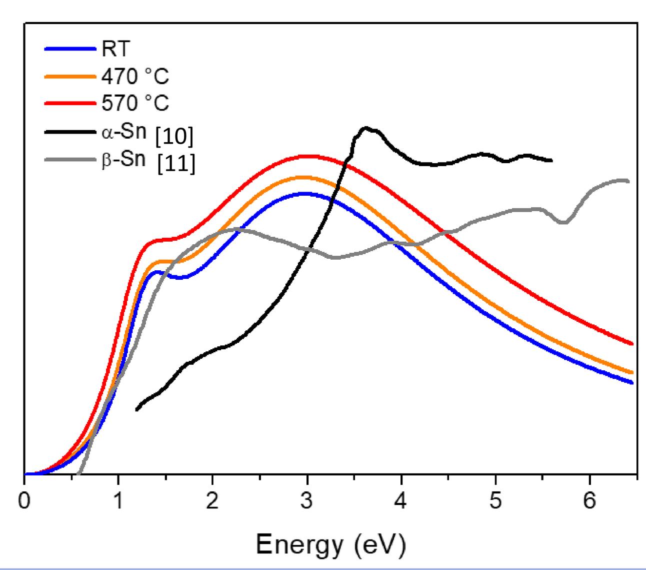
Universal Conductance

$$G_1(\omega) = \sigma_1(\omega)d$$

$$G_0(\omega) \sim 6.08 \times 10^{-5}\Omega^{-1}$$







- The optical behavior of the tin films at the 2D limit is very similar to each other, independently of growth temperature
- The trend is similar to those predicted by theory
- Expected electronic transitions for free-standing stanene:
  - π→π* at ~2 eV
  - σ→σ* at 3.1 and 4.0 eV

Absorption coefficient and Absorbance

$$\alpha(\omega) = \frac{2\kappa(\omega)\omega}{c}$$

$$A(\omega) = \alpha(\omega)d$$

- The absorption of tin films strongly differs from those of common tin oxide and from those conventional elemental tin phases

CONCLUSIONS

- The use of an optically transparent substrate allowed us to investigate the optical properties of silicon and tin at the 2D limit
- The behavior observed in the IR part of the optical conductivity spectra of 2D silicon films suggest the presence of Dirac fermions
- The optical conductivity of silicon nanosheets, at the 2D limit, show interband transition features, like ideal silicene
- The optical behavior of tin films at the 2D limit strongly differs from those of tin oxide and from those of elemental tin phases
- The absorption spectra show characteristic signatures, similar to those expected in the absorption spectrum of the freestanding stanene

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