Phase Transitions Induced by Femtosecond Laser Pulse Irradiation of Indium Phosphide

J. Bonse*, S. M. Wiggins, and J. Solis

*Instituto de Optica, C.S.I.C.
Serrano 121, E-28006, Madrid, Spain
e-mail: jbonse@io.cfm.csic.es*

With the ever increasing speed of electronic devices and the ever decreasing duration of commercially available lasers, there is a strong demand for the development of new optoelectronic materials. One of the most promising materials for future applications in high-speed optoelectronic components is the III-V compound semiconductor indium phosphide (InP).

In this contribution, the irradiation of single-crystalline indium phosphide with 150 fs laser pulses at a wavelength of 800 nm and with different laser fluences up to the ablation threshold has been investigated. For both single and multiple laser pulse irradiation, the induced structural transformation dynamics has been studied by means of time-resolved reflectivity measurements with two different experimental set-ups employed to cover complementary timescales up to 500 ns after the laser excitation.

A non-collinear femtosecond pump-probe set-up, where the temporal resolution is given by the pulse duration itself, has allowed the initial stages of the phase transitions to be investigated on the fs and ps timescales. Additionally, in-situ real-time reflectivity (RTR) measurements by means of a ps-resolution streak camera and a ns-resolution photodiode set-up [1] have been used to study the subsequent resolidification processes on the ns timescale.

The results obtained show that for fluences above the threshold of 0.16 J/cm^2 , *thermal melting* of the material occurs on the timescale of 1-2 ps, while ablation at higher fluences ($>0.23 \text{ J/cm}^2$) is preceded by an ultrafast phase transition (*non-thermal melting* [2,3]) occurring within ~ 400 fs after the arrival of the pulse to the surface. The evolution of the reflectivity on a longer timescale allows determination of the reflectivity of the liquid phase and shows resolidification times typically around 10-30 ns after which an amorphous layer several tens of nm thick is formed on the surface. This over-layer significantly alters the optical surface properties which finally leads to a reduced ablation threshold for subsequent laser pulses.

Optical simulations of the surface reflectivity evolution have allowed us to investigate in detail the resolidification scenario which is responsible for the amorphisation process in the small fluence range between the melting and ablation thresholds.

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