Ultrafast optically induced reflectivity switching at a gallium-silica interface

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It was reported recently that the reflectivity of a gallium-silica interface held close to, but below, the gallium melting point of 29.8°C can be changed significantly (>40%) by light over a very broad spectral range 400 – 1600 nm [1]. The effect has been attributed to a surface-assisted phase transition from the stable α-gallium phase to a phase of metallic nature. In this paper we present the results on the ultrafast switching dynamics of a gallium-silica interface.

The gallium films were deposited using pulsed laser deposition with a mode-locked Q-switched Nd:YAG laser producing 60 ps pulses of ~20 μJ with a rate of ~$5\cdot10^5$ pulses per second [2]. The laser beam was focussed on a high purity gallium target providing up to $5\cdot10^{11}$ W/cm^2 at the target surface. The silica substrates were placed on a cold finger cooled with liquid nitrogen in order to maintain the substrate temperature below −100°C. Our experience suggests that such a cooling is essential to form an alpha-gallium crystalline phase on the metal-substrate interface. The deposited film thickness was in the range of 1-2 microns.

The reflectivity measurements of the gallium-silica interface were performed using a pump-probe technique. The light source employed was a regeneratively amplified Ti-sapphire laser system providing up to 1 mJ, 150-fs pulses at 800 nm at 30 Hz repetition rate. The intensity of the reflected probe beam was monitored as the function of the presence or absence of the pump beam, the pump intensity and the delay between the pump and the probe pulse. In all cases the intensity of the probe beam was kept much lower than that of the pump beam.

The reflectivity change has an apparent threshold at ~0.5 mJ/cm^2. The saturation occured at the energy densities 10-15 mJ/cm^2. The reflectivity change occurred on the ps time-scale. The rise-time had a two-component structure. The total change in reflectivity was from ~60% to ~85% (Fig.1), with the initial 'fast' time constant of 2 ps (reflectivity rise from 60% to 70-75%), and a 'long' time constant of a few hundred ps (reflectivity rise from 70-75% to 80-85%). There was no significant difference in the initial 2-ps time rise when the temperature of the gallium mirror varied in the range from 5°C to 26°C. No switching was observed at the temperatures above the Ga melting temperature.

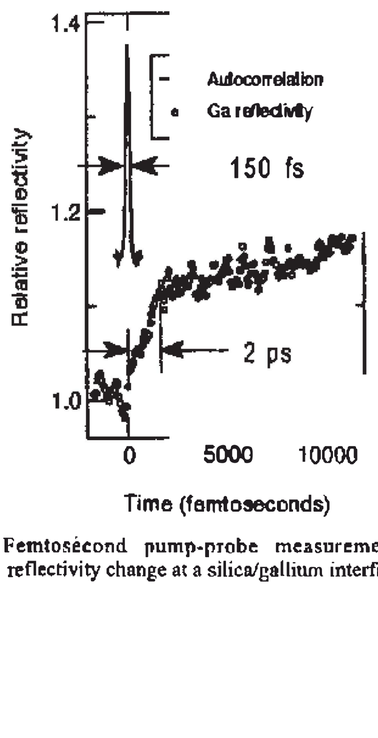

Fig 1 Femtosecond pump-probe measurements of the reflectivity change at a silica/gallium interface

The recovery kinetics was measured by replacing the pulsed probe beam with a CW He-Ne laser. The reflectivity decay had a rather complex behaviour depending on the mirror temperature and the pump fluence. The time constants were found to vary from tens of nanoseconds to hundreds of microseconds depending on the incident pump power and on the proximity of the phase transition point.

The presented switching characteristics demonstrate that the gallium mirror could find application as a broadband ultrafast optical switch.

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2. E. G Gamaly, A V Rode, B Luther-Davies, *J Appl Phys*, 85(8), 4213 (1999); A. V Rode, B Luther-Davies, and E G Gamaly, *J Appl Phys*, 85(8), 4222 (1999)