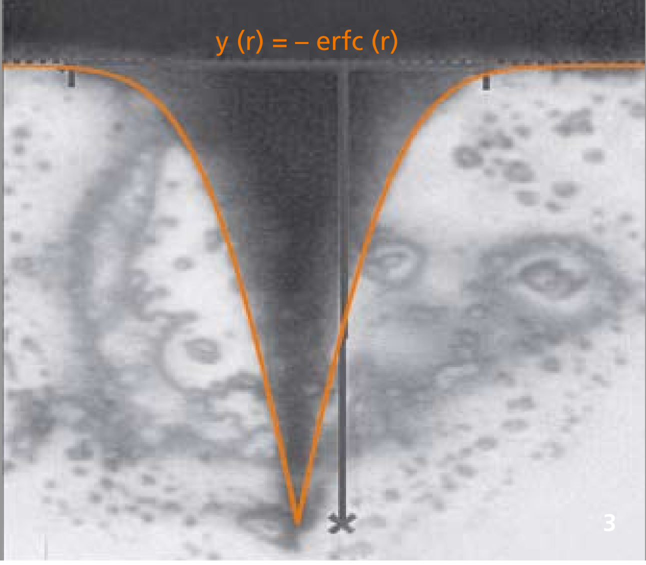

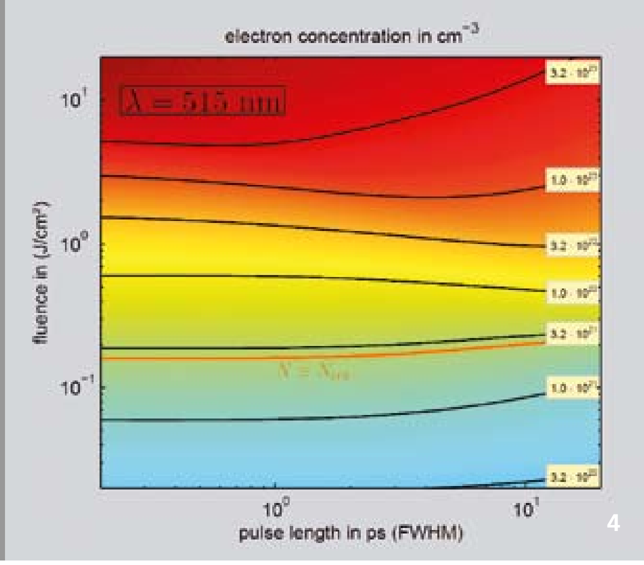

SIMULATION OF SILICON ABLATION

Task

The semi-conductor industry has been using ultra-short laser pulses to separate chips from silicon wafers in many ways. This process allows for high integration density, features high cutting speeds at large curvature and, in particular, can process very thin wafers. Among others, the successful LED production can open up great market potential thanks to this process. To expand the potential of this cutting technology, however, the mechanisms of ablation and the formation of damages along the cut joint have to be examined.

Method

The modelling and simulation aims to depict the ablation of silicon wafers, resolved spatially, for the case of ultra-short, high-intensity laser pulses. This depiction combines a macroscopic model, which depicts the form of a cut joint, and a microscopic model, which captures the dynamics of electron systems, the thermodynamics in solid bodies and the ablation itself.

Result

As a result, the asymptotic form of the cut (e.g. the maximum cut depth attainable) depends upon the beam profile of the laser and the ablation threshold of the wafer material. The cross-section in Figure 3 shows that the model's prediction, which can even be approached analytically in this case, reproduces the experimentally determined result well.

In order to predict the local ablation behavior as a function of the laser parameters (fluence, pulse shape, wavelength), the model has been implemented in a simulation; Partial processes – non-linear absorption, radiation propagation and excitation of electrons – are contained in this model. The creation of »process maps« of the relevant microscopic parameters (Figure 4) allows optimization, also in parameter ranges that are not yet accessible experimentally.

Applications

The models and approaches developed here can be transferred to other substrates relevant to the industry. Such substrates are, e.g., sapphire (also LED production), and glass (display manufacture, photovoltaics) for which pulsed laser ablation is also characterized by an »ablation threshold«.

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3 Experimental cross-section and simulation of asymptotic cut form.

4 Process map: electron density over fluence and pulse length.