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Feasibility study of micromachining of silicon wafer with excimer laser using COMSOL multiphysics

Gaganpreet Singh*, Shashank Sharma, Kartar Singh and J. Ramkumar

Department of Mechanical Engineering,
Indian Institute of Technology Kanpur, Kanpur -208016), India
*Email: gaganprt@iitk.ac.in

Silicon has always been in the interest of researchers due to its various application in different fields such as medical devices, electronics instruments, solar cells and microfluidicsetc. But micromachining of silicon wafer still remains a technological challenges because of its brittle nature. The conventional method of micromachining of silicon includes mechanical processes, reactive ion etching and wet chemical etching using acids. All the conventional method like wet chemical ethching have several drawbacks, as mechanical machining suffers with problems like dependence on crystallographic orientation and have the disadvantage of using hazardous chemical etchants.

The laser micromachining is a very promising technique for machining silicon. In this technique the surface of a material is irradiated with a high intensity laser beam which increases the temperature of the material beyond its melting point and sometimes beyond its boiling point which helps to remove the material. There have been numerous studies on computational modelling of laser machining processes like simulation of Silicon annealing using nanosecond laser by COMSOL Multiphysics [1] but not much literature is available for the computational simulation showing effect of multiple pulses on the melting depth of the substrate.

In the present study, we use COMSOL Multiphysics to understand the effect of number of pulses on the melting of silicon at constant energy.A 2D transient heat conduction model was created in COMSOL Multiphysics to show the temperature change in material.The model used for this simulation is 'Heat transfer with Phase Change' under 'Heat Transfer in Solid' title. Volumetric heat source is applied to domain 2 as shown in figure 1.Heat transfer through convection is applied as boundary condition on boundary (a) to (d).Properties of KrF Excimer laser i.e., a square spot laser of 20 ns (FWHM) and 248 nm wavelength were considered for this study.

First of all, effect of single pulse was studied, then a pulse train of two, three, four and five pulses are made using analytical function in COMSOL Multiphysics and their results were studied. We observed that with increase in number of pulses there was increase in melted depth of silicon (as shown in figure 2 a and b) which may be attribute to increase in temperature of silicon after successive pulse as shown in Figure 2(c) . These results are in well agreement with different experimental studies like excimer laser micromachine for electro-thermal-complaint micro devices [2].

Though we did not find any ablation on silicon which might be due to the high relaxation time or due to lesser number of pulses, as we considered for our study.

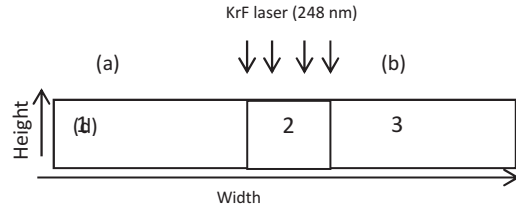

Figure 1: Sketch of part of bulk sample for modeling

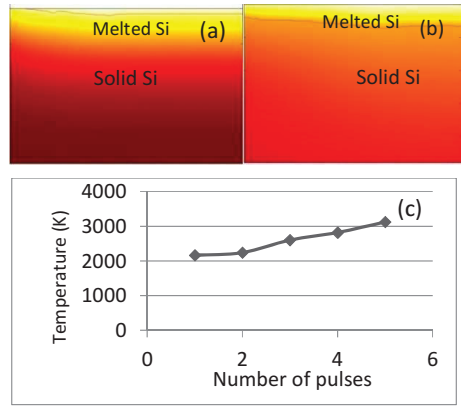

Figure 2: (a) and (b) shows the melted zone after 1 and 5 pulses (c) Increase in temperature with number of pulses

In conclusion, the paper purposes a model to study the feasibility of silicon machining using excimer laser. The results obtained are in good agreement with the experimental study concluded in past. Model can be further improved by taking into account the change in absorption coefficient with temperature.

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