Experimental and numerical study of ultrafast dynamics of femtosecond laser-induced periodic surface structures on metals

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femtosecond laser-induced periodic surface structures (LIPSSs) are an effective technique for controlling the optical properties of metals in the UV, vis, and NIR spectral regions. We perform experimental study of the formation of LIPSSs on metals, Cu, Ag, and Al (Fig.1). Under identical experimental conditions, LIPSSs show distinctly different level of morphological clearness on the three different metals. We performed a detail study of LIPSSs on Cu for different number of laser pulses (Figs.2) and for different laser fluence (Figs.3). The theoretical study for LIPSSs on Cu has been done (Figs.4,5).

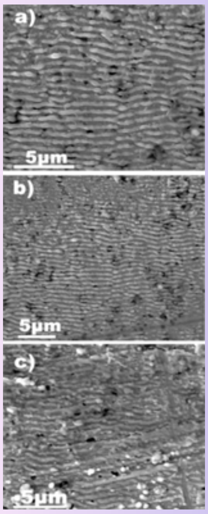

FIG. 1: Surface ripples induced by a train of 60fs laser pulse at 0.8mJ/pulse for (a)Cu, (b)Ag, and (c)Al.

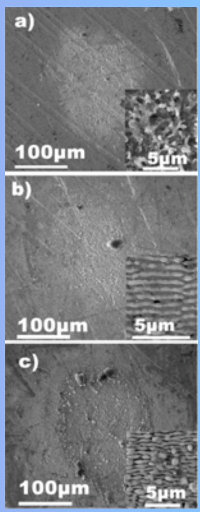

FIG. 2: Surface ripples induced by a train of 60fs laser pulse at 0.8mJ/pulse for Cu with (a)4 pulses, (b)125 pulses, (c)500 pulses. The inset in each figure shows a detailed partial view at the same relative location of the irradiated spot site.

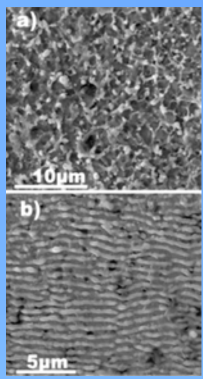

FIG. 3: Surface ripples induced by a train of 60fs laser pulse for Cu with with (a)0.46mJ/pulse, and (b)0.8mJ/pulse

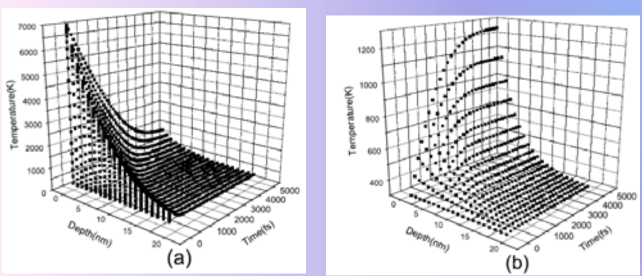

FIG. 4: (a) Electron temperature distribution and (b) lattice temperature distribution at different times and position predicted by the two-temperature model for the copper target irradiated by a 60fs, 800nm pulse at 0.46mJ/pulse.

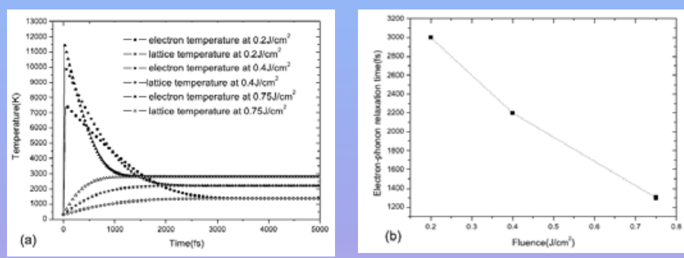

FIG. 5: (a) The time-dependence temperature of the electron and the lattice of the surface at different laser fluence and (b) the corresponding fluence dependence of electron-phonon relaxation time for the copper target.

Experimental results show that LIPSSs on Cu are most pronounced among the three metals under the same experimental parameters. We can also find that when laser fluence is 0.8mJ/pulse and the pulse number is 125 pulses, LIPSSs on Cu are most obvious. Theoretical results present that the electron-phonon relaxation time becomes long for low laser fluence. The difference of LIPSSs on metals is attributed to the different degree of spatial nonuniform lattice heat distribution. The higher fluence laser, the shorter the electron-phonon relaxation time is, and the higher the different degree of spatial nonuniform lattice heat distribution is.

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References:

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