Cubic nonlinear optical phenomena in copper oxides thin films

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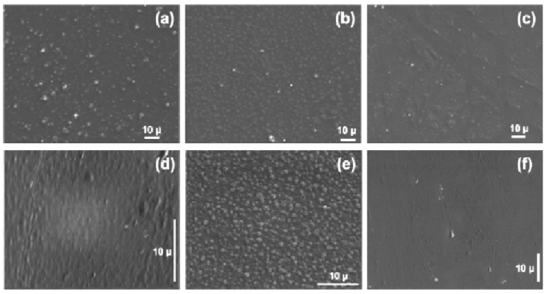

Fig.1. SEM images of nano-scale copper oxide films deposited by RPLD on SiO_2 substrates: at $P(O_2)$ = 1.0Pa, T_S = 293K (a), $P(O_2)$ = 3.0Pa, T_S = 293K (b), $P(O_2)$ = 5.0Pa, T_S = 293K (c) and $P(O_2)$ = 1.0Pa, T_S = 800K (d), $P(O_2)$ = 3.0Pa, T_S = 800K (e), $P(O_2)$ = 5.0Pa, T_S = 800K (f)

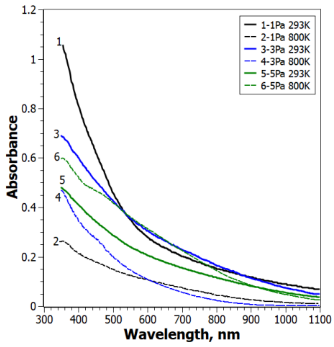

Fig.2. The linear optical absorption properties of nano-scale copper oxide films deposited, by RPLD on SiO_2 substrates: at $P(O_2)$ = 1.0Pa, T_S = 293K (1) and T_S = 800K (2); $P(O_2)$ = 3.0Pa, T_S = 293K (3) and T_S = 800K (4); $P(O_2)$ = 5.0Pa, T_S = 293K (5) and T_S = 800K (6)

Publications of different authors to have been carried out last years demonstrated that low-dimensional structures of transition metal oxides in the form of thin films and nanoparticles such as V_2O_3, Cr_2O_3, NiO_3, Fe_2O_3, PdO and so on are advanced non-linear optical materials owing to high values of their high third-order optical susceptibility ($\chi^{(3)}$) and fast responses time. Attractive attention of investigators was focused on the same structures, i.e. Cu_2O, CuO.

The results of the studies indicate that the nonlinearity parameters of various copper oxide nanostructures naturally depend on the characteristics of laser radiation (wavelength λ, pulse duration τ_p), on the type of structure, since depending on these factors the contribution of some or other mechanisms of nonlinearity changes. For thin-film structures, their cubic nonlinear optical characteristics depend on their sputtering technology, since their structure, phase composition, presence of certain impurities and the like may change. Therefore, the search for sputtering conditions providing improvement of optical nonlinearity parameters remains actual.

Here, we report about investigations of thin copper oxide (Cu_2O) films, utilizing Z-scan technique with nanosecond laser excitation (9 ns and 15 ns at the wavelengths of λ=532 nm and λ=1064 nm, accordingly)

λ=1064 nm

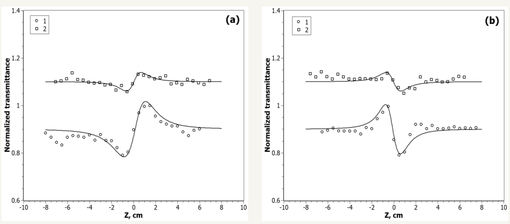

Fig.3. Closed aperture Z-scan results at λ = 1064 nm: (a) is for the sample at T_S= 293K, 1.0Pa (1) and 3.0Pa (2); (b) is for the sample at T_S= 293K, 5.0Pa (1) and T_S= 800K, 1.0 Pa (2). Marks represent experimental data and solid lines are numerical fits to the data using the theory.

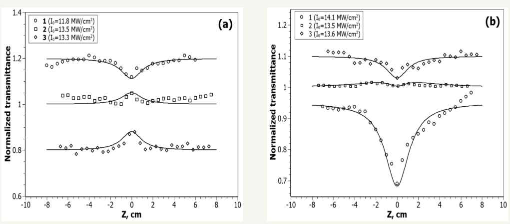

Fig.4. Open aperture Z-scan results at λ = 1064 nm (a) is for the sample T_S= 293K and 1.0Pa (1), 3.0 Pa (2), 5.0 Pa (3) (b) is for the sample at T_S= 800K and 1.0Pa (1), 3.0Pa (2), 5.0Pa (3). Marks represent experimental data and solid lines are numerical fits to the data using the theory.

Sample	I_0, [MW/cm²]	n_2, [cm²/W]	β, [cm/W]	$Re\chi^{(3)}$, [esu]	$Im\chi^{(3)}$, [esu]
293K, 1Pa	11.8	13.5×10^{-7}	1.5×10^{-3}	1.66×10^{-5}	2.07×10^{-6}
293K, 3Pa	13.5	0.63×10^{-7}	-1×10^{-3}	0.78×10^{-5}	-1.38×10^{-6}
293K, 5Pa	13.3	-2.07×10^{-7}	-1.8×10^{-3}	-2.54×10^{-5}	-2.49×10^{-6}
800K, 1Pa	14.1	-0.899×10^{-7}	9×10^{-3}	-1.103×10^{-5}	12.4×10^{-6}
800K, 3Pa	13.5	-	0.5×10^{-3}	-	0.69×10^{-6}
800K, 5Pa	13.6	-	1.7×10^{-3}	-	2.35×10^{-6}

λ=532 nm

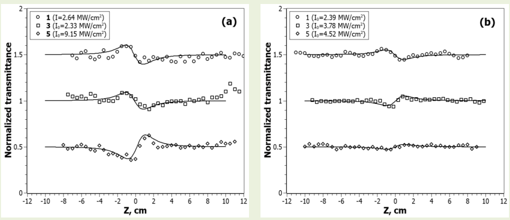

Fig.5. Closed aperture z-scan results at λ = 532 nm for the sample at T_S= 293K, 3.0Pa. Marks represent experimental data and solid lines are numerical fits to the data using the theory.

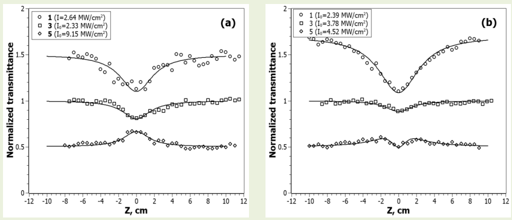

Fig.6. Open aperture Z-scan results at λ = 532 nm (a) is for the sample at T_S= 293K and 1.0Pa (1), 3.0 Pa (2), 5.0 Pa (3) (b) is for the sample at Ts = 800K and 1.0Pa (1), 3.0Pa (2), 5.0Pa (3). Marks represent experimental data and solid lines are numerical fits to the data using the theory.

Sample	I_0, [MW/cm²]	ΔT	n_2, [cm²/W]	β, [cm/W]	$Re\chi^{(3)}$, [esu]	$Im\chi^{(3)}$, [esu]	I_s, W/cm²
293K, 1Pa	2.64	-0.183	-3.22×10^{-7}	5.5×10^{-2}	-4.1×10^{-5}	3.95×10^{-5}	-
293K, 3Pa	2.33	-0.174	-5.16×10^{-7}	3.4×10^{-2}	-6.58×10^{-5}	2.44×10^{-5}	-
293K, 5Pa	4.32	0.074	1.25×10^{-7}	-	1.59×10^{-5}	-	1.45×10^{7}
800K, 1Pa	2.39	-0.108	-3.34×10^{-7}	25×10^{-2}	-4.26×10^{-5}	1.65×10^{-4}	-
800K, 3Pa	3.78	0.11	1.86×10^{-7}	1.05×10^{-2}	2.37×10^{-5}	7.55×10^{-6}	-
800K, 5Pa	4.52	0.056	1.01×10^{-7}	5.4×10^{-2}	1.29×10^{-5}	3.88×10^{-5}	5.6×10^{6}

Conclusions

Received maximum high values of nonlinear refractive coefficient $n_2=13.5\times10^{-7} cm^2/W$ for λ=1064 nm and $n_2=-6.5\times10^{-7} cm^2/W$ for λ=532nm might be useful for the advanced optimization of photoelectrical equipment. Nonlinear optical absorption to have been investigated, demonstrated SA or RSA advanced mechanism depending from sample that shows of perceptiveness of such films application for nonlinear photon purpose such as wide-range optical trigger which is being used as optical limiter for optical detector security.