Control of Impurity Diffusion in Semiconductors by Intensive IR Excitations

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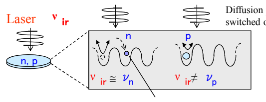
1. motivation

Idea of selective diffusion by excitation of impurity vibrations

laser frequency ν_{ir} Resonance vibration frequency ν_n, ν_p

excitation of the motion of a selective species only



Only the excited impurity migrates

2. purpose

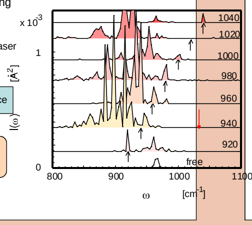
Selective impurity diffusion by IR excitation

Promotion of diffusion of a specific impurity by using resonance excitation at the impurity mode.

- Problem → no availability of suitable IR laser
- Computer simulation → Design of light source

First attempt of excitation of O by SPring-8

BL43IR



3. diffuison length

Diffusion of Oxygen

$$D = D_0 \exp(-Q/kT)$$

$$D\,[\mathrm{cm^2/s}] = 0.194 \exp(-2.54[\mathrm{eV}]/kT)$$

T. Y. Tan and U. Gösele, Appl. Phys. A37 1 (1985)

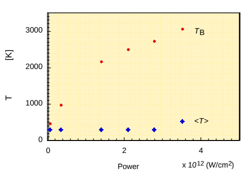
T [K]	[eV]	D [cm²/s]
1000	0.086	3.0×10^{-14}
1600	0.137	1.9×10^{-9}
2000	0.172	7.6×10^{-8}
2500	0.215	1.4×10^{-6}
3000	0.258	1.0×10^{-5}

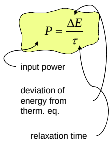
T [eV]	D [cm²/s]	τ [s]	L_D [μm]
0.137	3.0×10^{-14}	1	0.3
		10^{-1}	0.1
0.172	7.6×10^{-8}	1	2.7
		10^{-2}	0.27
0.215	1.4×10^{-6}	1	11.8
		10^{-3}	0.3

4. power balance

Power Dependence

B mode

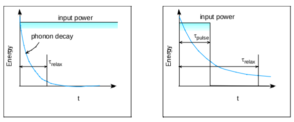




$\tau \sim 1$ ps

5. power consideration

Power consideration



$\tau_{phonon} < \tau_{pulse} < \tau_{decay}$

6. power required

Intensity of laser power

For an atom $P_{atom} = \frac{\Delta E}{\tau}$ deviation of atom energy from thermal equilibrium 0.22 eV; phonon relaxation time 10 ps

$P_{atom} = 1 \times 10^{-9}$ [W/atom]

impurity concentration $n_i = 1 \times 10^{18}$ [/cm³] $P_{abs} = n_i x P_{atom} = 1 \times 10^9$ [W/cm³]

absorption coefficient $\alpha = 1 \times 10^4$ [cm⁻¹] $I_{in} = P_{abs}/\alpha = 1 \times 10^5$ [W/cm²]

$P_{pulse} = 1 \times 10^5$ W/cm²

7. estimate

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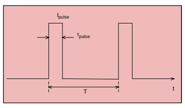

$P_{atom} = 2.6 \times 10^{-12}$ W/atom•pulse

<I> = 0.15 μW/cm⁻¹ at 1000 cm⁻¹

beam size 150 x 100 μm

< J > = 0.1 W/cm² for width 100 cm⁻¹

$J_{pulse} = \frac{15}{100} \frac{\tau_{int}}{\tau_{pulse}} \times \langle J \rangle = 256$ W/cm²•pulse

8. apparatus

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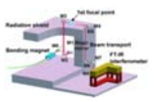
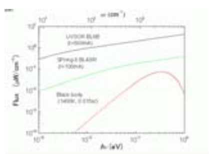
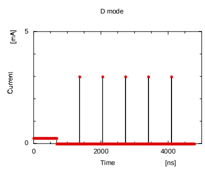




9. beam data

Beam data

D mode



$$t_{diffusion} = t_{irr} \times \frac{\tau_{pulse}}{\tau_{interval}}$$

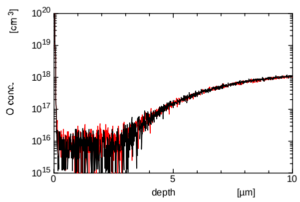
$$12(\mathrm{hrs}) \times \frac{40(\mathrm{ps})}{684.3(\mathrm{ns})}$$

$$= 2.5(\mathrm{sec})$$

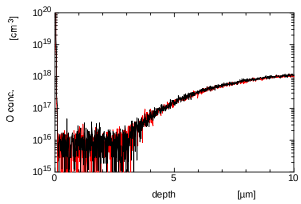
11. result

Detection of change in diffusion by SIMS depth profile

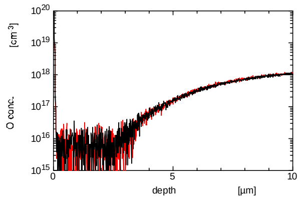
SIMS O profile



IR / no — without filter

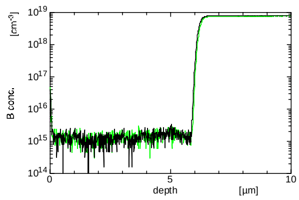


IR / no — LP1450

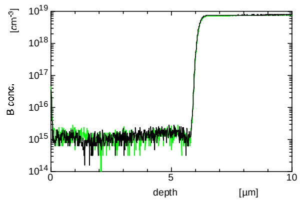


IR / no — BP2432-1333

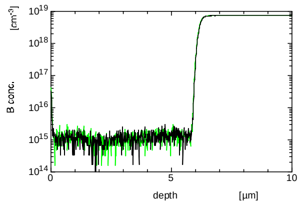
SIMS depth profile for B



IR / no — without filter



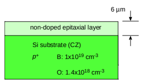
IR / no — LP1450

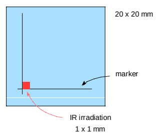


IR / no — BP2432-1333

10. sample

Samples





IR irradiation

12 hrs irradiation

impurity mode

O: 1100 cm⁻¹

B: 520 cm⁻¹

Filtering

	O	B
BP2432-1333	×	×
LP1450	○	○

12. Summary

Summary

1. First attempt of IR excitation of impurity diffusion has been failed.
2. The most significant error comes from the estimate of the input power at the sample.
3. The present experience of power estimation could bring about success in the next stage of experiment.