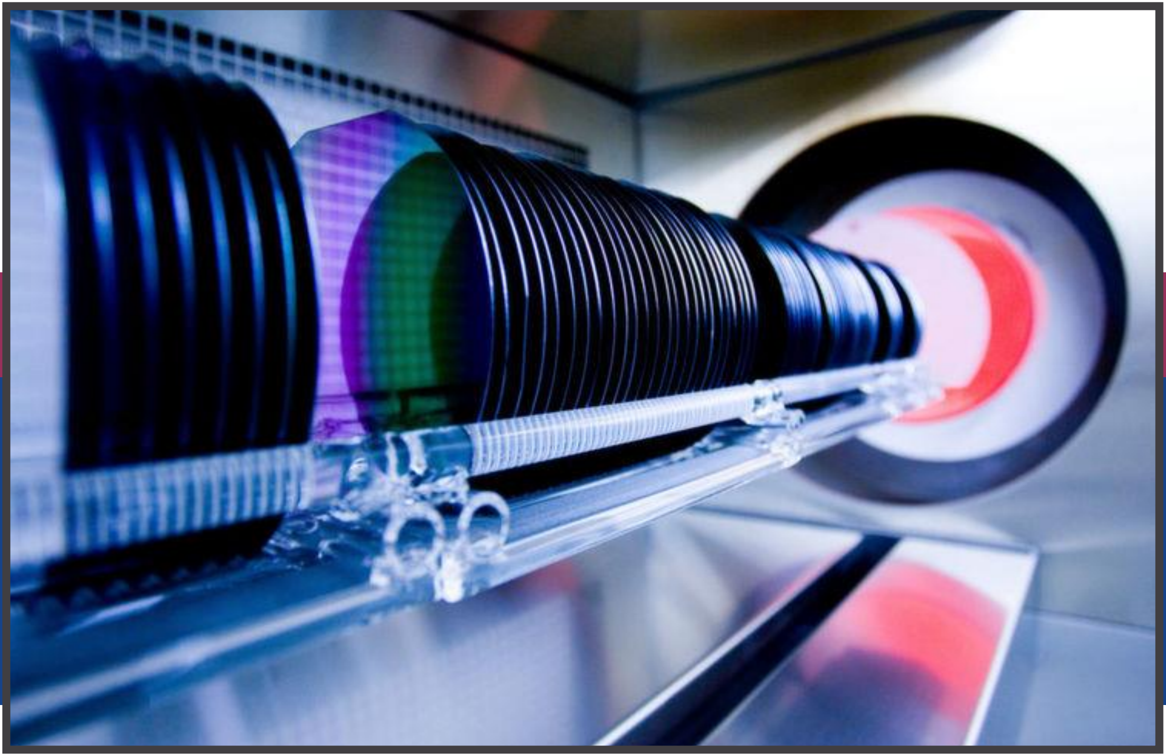

Forschungsinstitut für Mikrosensorik GmbH

Competence in Silicon

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21.06.21

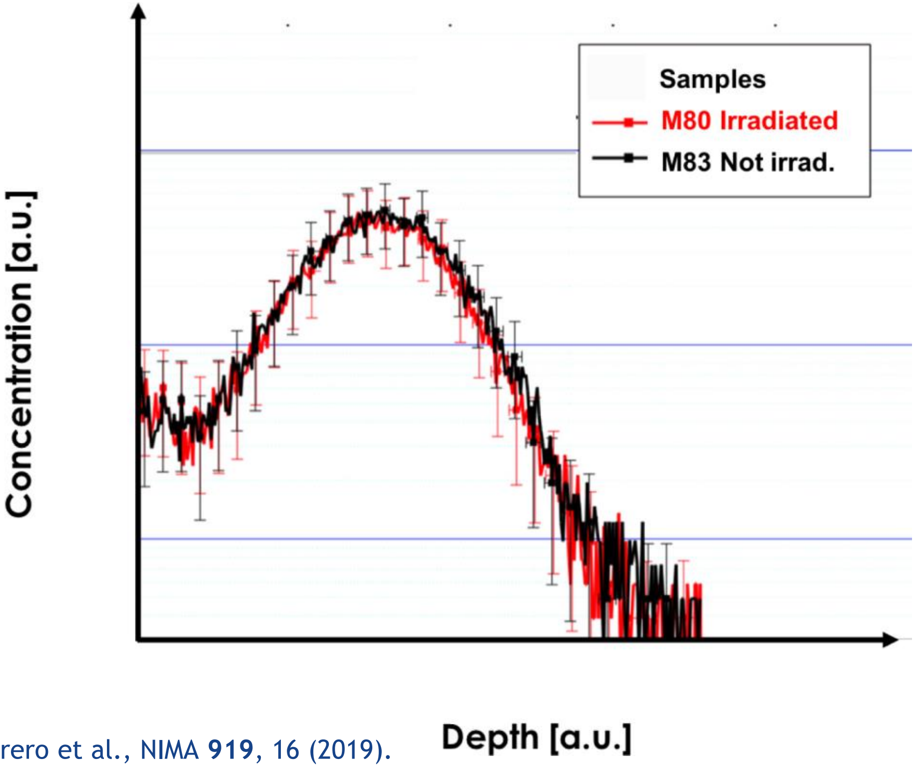
Investigation of acceptor removal by 4-point probe and LTPL measurements

Overview

- Motivation
- Experiment
- Implantation and annealing parameters
- 4-point probe (4pp) and low temperature photoluminescence spectroscopy (LTPL) results
- Summary

Motivation

- LGADs suffer from acceptor (boron) “removal” after irradiation
- Indeed not removed, but deactivated due to a defect reaction
- Removal effect can be reduced by carbon co-implantation
- What happens with different acceptors (e.g. gallium and indium) after irradiation?
- Are other co-implanted species beneficial?



M. Ferrero et al., NIMA **919**, 16 (2019).

Experiment

- 25 high resistivity FZ silicon wafers
- Implantation of different dopants and annealing
- Measurement of sheet resistance by 4-point-probe and measurement of LTPL spectra
- Irradiation with electrons and protons
- Measurement of sheet resistance by 4-point-probe and measurement of LTPL spectra

Implantation and annealing

- 3 acceptors boron, indium and gallium
- Co-implanted species are carbon, nitrogen, oxygen and fluor
- Annealing by rapid thermal processing (RTP) furnace

Implantation and annealing

- Parameters

Ion	Dose cm-2	Energy keV	Temperature C	Time s
B	4.9e12	102	1000	10
Ga	4.6e12	138	1000	10
In	3.1e13	152	1000	10

- Low dose

Ion	Implant dose cm-2	Implant energy keV	Temperature C	Time s
C	2.3E13	110	1000	10
N	4.6E12	110	1000	10
O	4.8E12	110	1000	10
F	4.8E12	110	1000	10

- High dose

Ion	Implant dose cm-2	Implant energy keV	Temperature C	Time s
C	2.4E14	110	1000	10
N	4.6E13	110	1000	10
O	4.9E13	110	1000	10
F	4.9E13	110	1000	10

Implantation and annealing

- Wafer plan

wafernumber	B	Ga	In	C	N	O	F
1							
2	X						
3	X			low dose			
4	X				low dose		
5	X					low dose	
6	X						low dose
7		X					
8		X		low dose			
9		X			low dose		
10		X				low dose	
11		X					low dose
12			X				
13			X	low dose			
14			X		low dose		
15			X			low dose	
16			X				low dose
17	X			high dose			
18	X				high dose		
19	X					high dose	
20	X						high dose
21			X	high dose			
22			X		high dose		
23			X			high dose	
24			X				high dose
25	only anneal				only anneal		

Irradiation

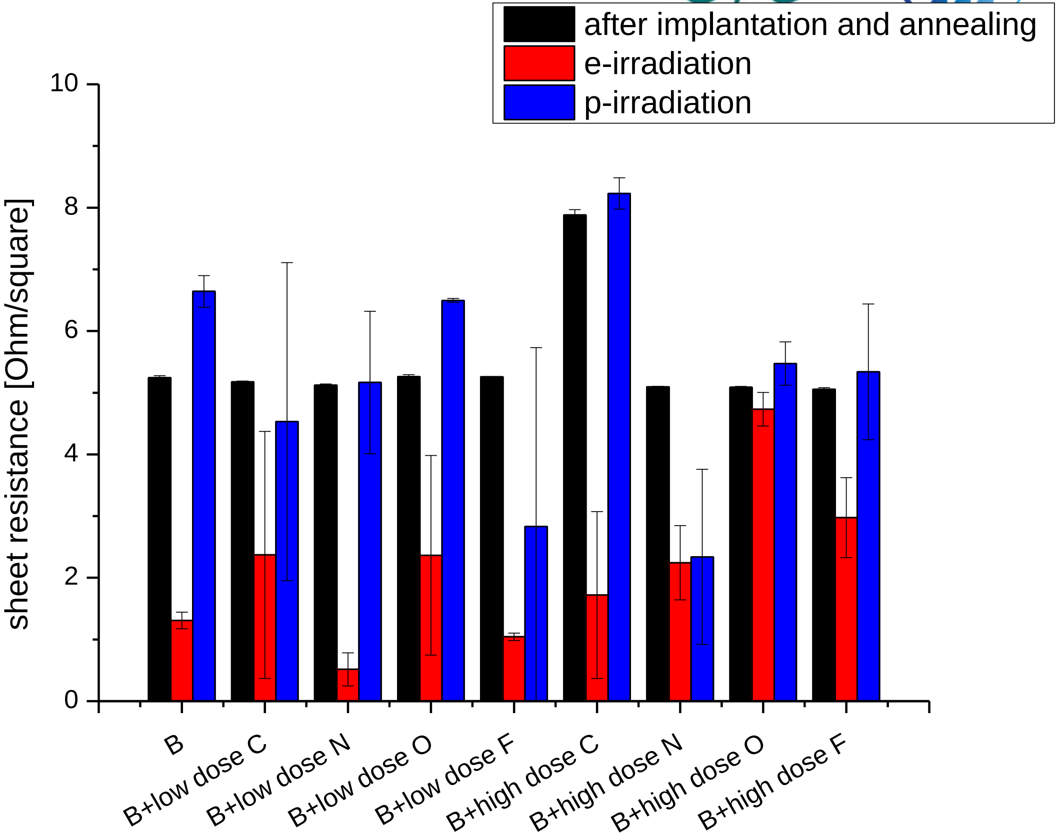
- Irradiation by 1MeV electrons and 23MeV protons
- Protons: 1x10^15 n_eq/cm^2
- Electrons: ~2e15 cm^-2

4pp results, boron

- Error bars show standard deviation of five measurements on one sample
- Co-implantation with carbon (high dose) reduces active boron

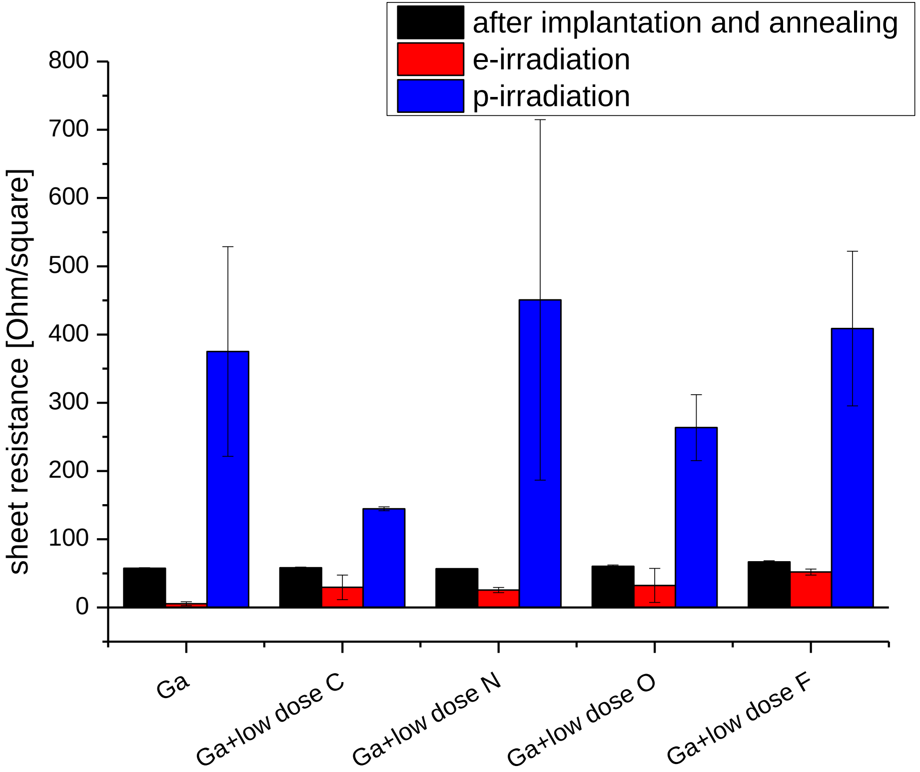
- Strong scattering after irradiation
- Maybe due to surface charging effects?

- Electron irradiation decreases, proton irradiation increases sheet resistance



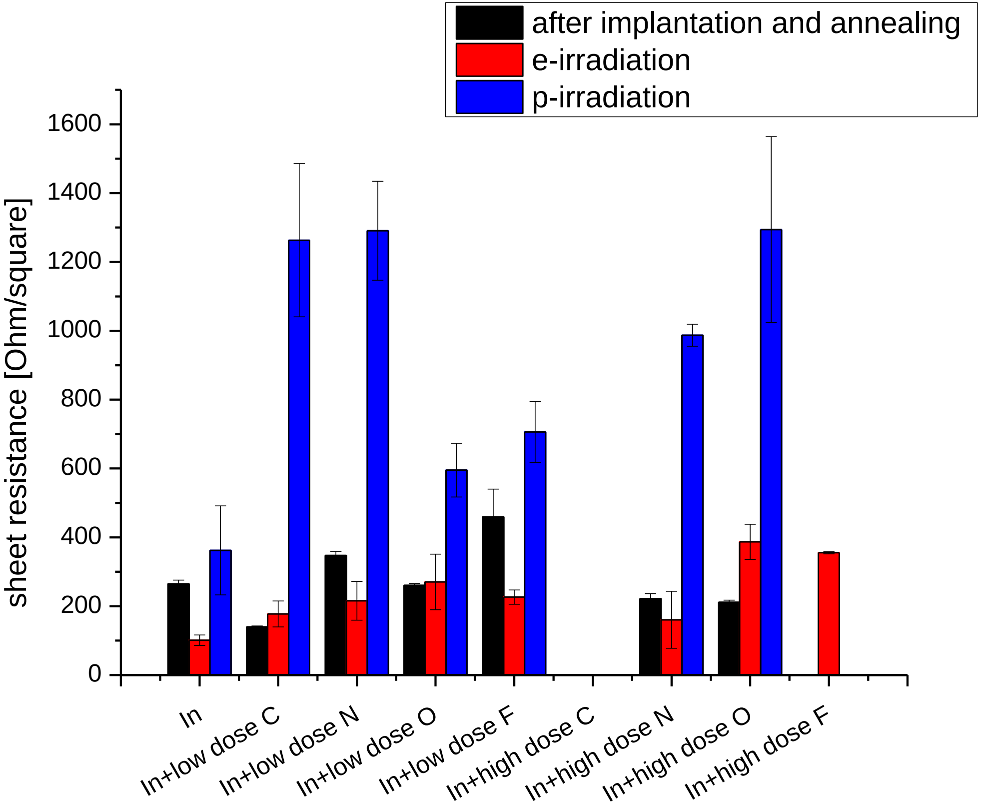
4pp results, gallium

- No impact of co-implantation species after implantation and annealing
- Electron irradiation decreases, proton irradiation increases sheet resistance
- Co-implantation with carbon and oxygen reduces sheet resistance in case of proton irradiation



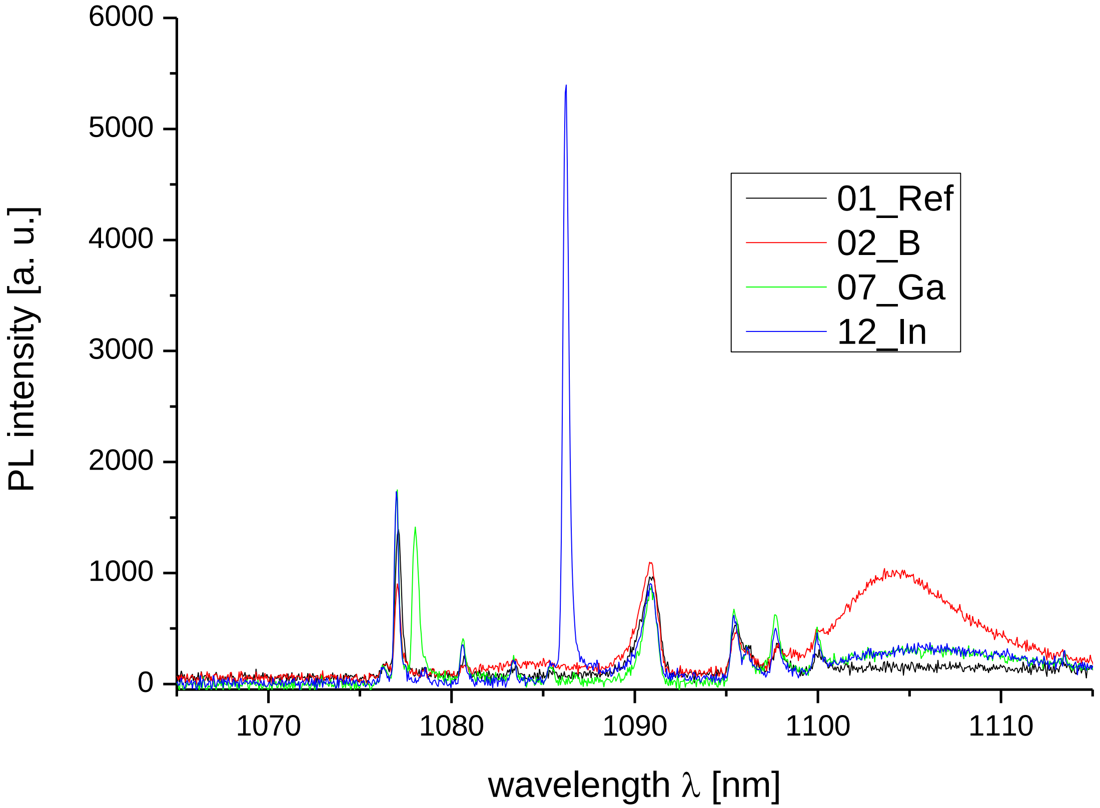
4pp results, indium

- Activation of indium affected by co-implanted species
- After electron an proton irradiation all co-implanted species increase the sheet resistance



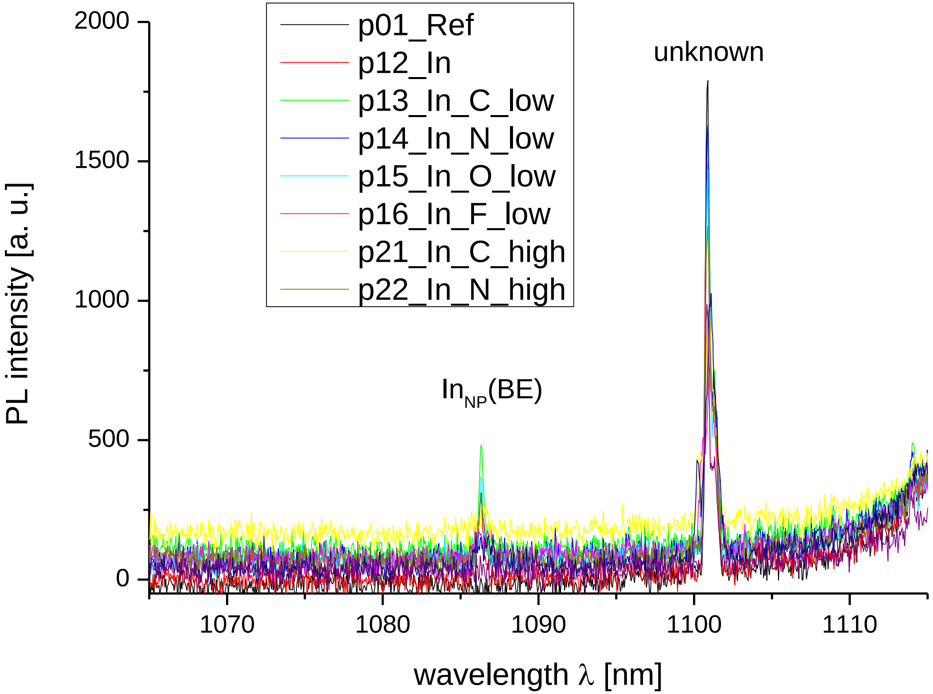
LTPL results, acceptors before irradiation

- Boron, gallium and indium related peaks clearly visible



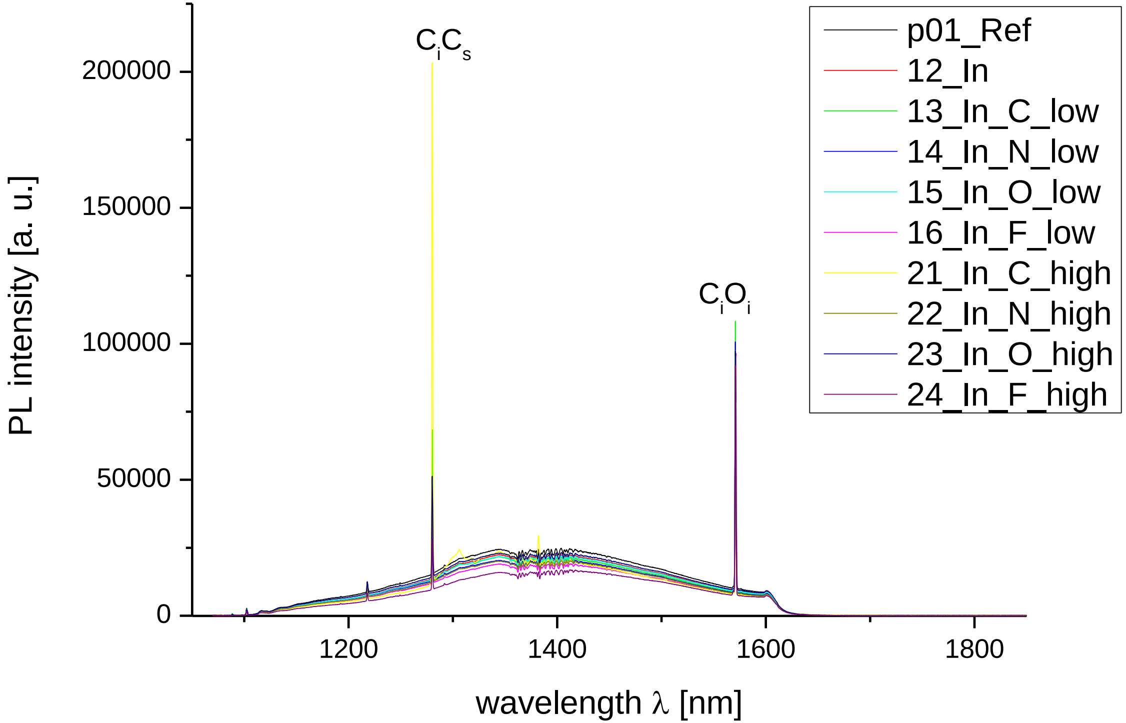
LTPL results, indium after irradiation

- Only for indium doped sample small indium related peak visible
- All other Peaks related to boron or gallium not visible



LTPL results, indium after irradiation

- Peaks related to carbon and oxygen become visible (G- and C-line)
- G-line (C_iC_s) maximized in carbon co-implanted samples
- C-line (C_iO_i) maximized in oxygen co-implanted samples



Summary

- FZ-silicon samples implanted with boron, gallium and indium
- Co-implanted with carbon, oxygen, nitrogen and fluor, Samples annealed in RTP furnace
- Measurement of sheet resistance before and after irradiation
- Irradiation with electrons and protons
- Strong scattering in sheet resistance after irradiation
- Electron irradiation decreases, proton irradiation increases sheet resistance
- For boron: co-implantation with carbon (high dose) reduces active boron
- For gallium: co-implantation with carbon and oxygen reduces sheet resistance in case of proton irradiation
- For indium: after electron an proton irradiation all co-implanted species increase the sheet resistance

Summary

- Low temperature photoluminescence spectroscopy (LTPL) applied
- Before irradiation peaks of acceptors visible
- After irradiation only a small indium related peak remains
- C_iC_s and C_iO_i visible in LTPL spectra

New SIMS at CiS

- Cameca IMS 7f Auto
- Installed recently and working

Thank you for your kind attention!

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