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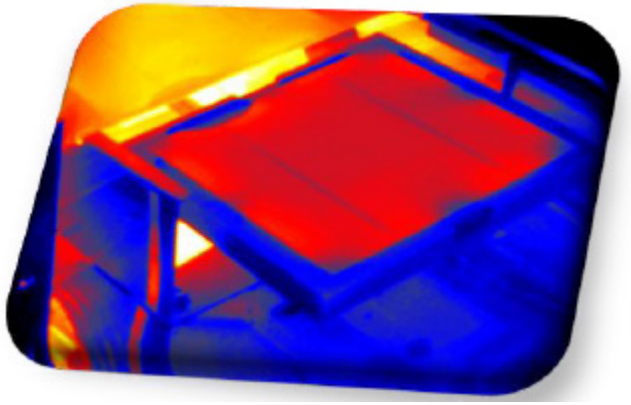
sense and simplicity

Improved method of contact formation using RTP: Rf firing

RF team

Philips Applied Technologies

April 12, 2010



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What is Philips Applied technologies

A leading technology center
Founded in 1968

Worldwide representation

North America:	San José (USA), Andover (USA)
Europe:	Eindhoven (NL), Redhill (UK)
Asia:	Bangalore (India), Singapore

University degree / Ph.D.s
± 390

Other type of education
± 140

Bachelors & Engineers
± 315

A multinational highly qualified workforce of about 845 people (+ 150 temporary employees)

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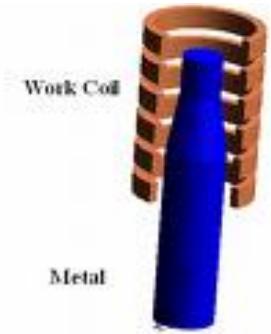
What is RF heating

- Inductive heating
  - Work coil
  - Metal part
- Applications from home to industrial:
  - heating, brazing, soldering, hardening, melting etc.



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Trends in metallization for higher efficiency solar cells

- Use of higher ohmic emitters lead to more efficient solar cells
  - IR firing is much more difficult for these emitters
    - high contact resistance, low shunt resistance leading to lower efficiencies
  - Costly alternative approaches have to be used ⇨
    - Selective emitters (masking, etching, two drive in steps, etc)
    - Selective opening of anti reflex coating (ARC)
- Plating also leads to more efficient cells ⇨
  - Seed layer still has to be fired through the ARC
    - Same issues with high ohmic emitters, small process window for existing IR process

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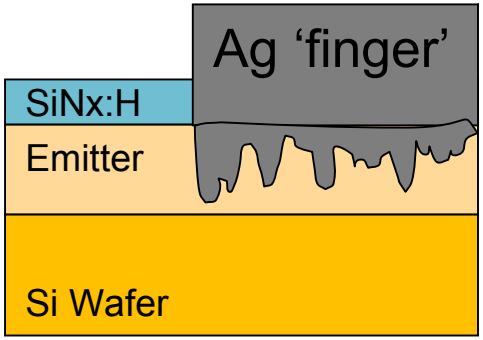
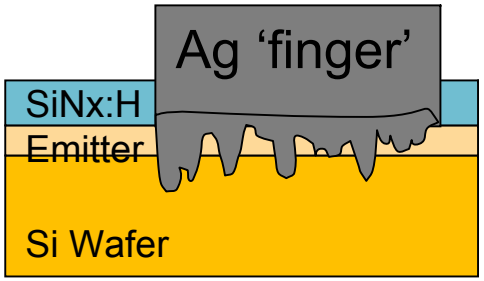
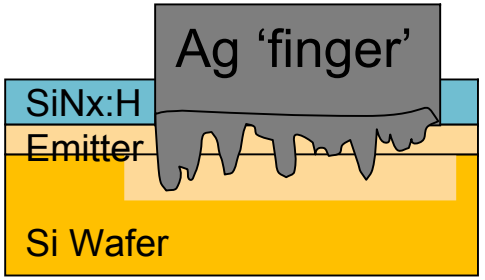
Difficult firing for higher ohmic emitters



Current low Ohmic:
Bad blue response,
High surface recombination velocity



Current high Ohmic:
Shunts or high contact resistance



Selective emitter:
Extra process steps

Current process: IR, limited process control over Ag-Si temperature and time leads to shunting with shallower emitters

Costly extra steps need to be taken to circumvent this, using f.i. selective emitter formation or local opening of SiNx followed by plating

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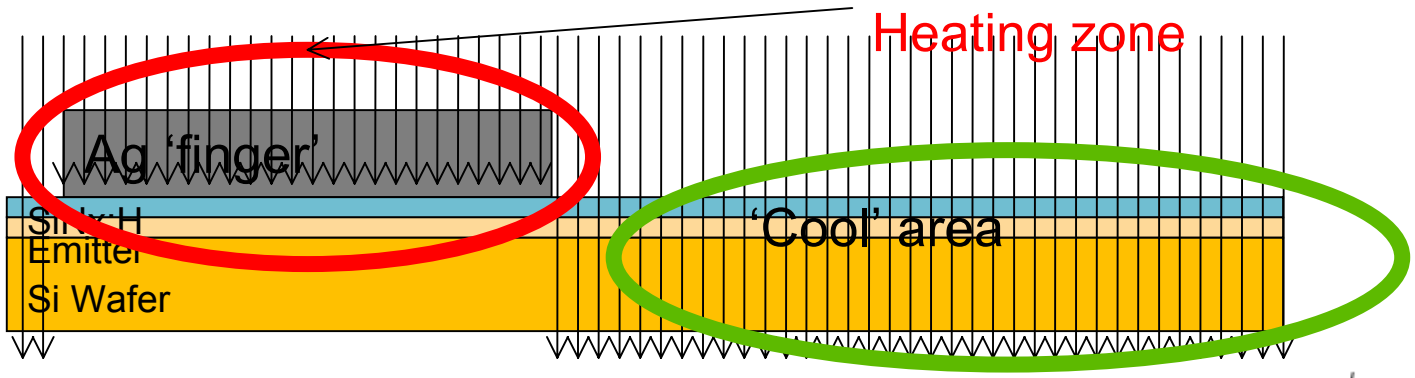
RF firing process control principle (1)

- Only heating where necessary, RF passes through Si, couples in Ag
- Independent on properties substrate, only on conductivity Ag
- Tight control of power and time possible



- For Ag : d=12 µm
- For Al : d=18 µm
- For Si : d=12 m (rt)

$$\delta = 503\sqrt{(\rho/f^{*}\mu_r)}$$

δ = penetration depth (m);

ρ = electric conductivity (Ohm m);

f = RF frequency (Hz); and

μ_r = relative magnetic permeability.

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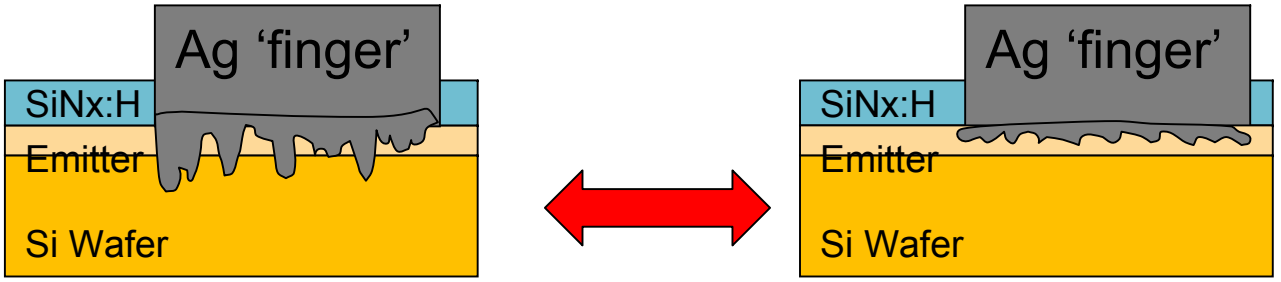
RF firing process control principle (2)



IR firing RF firing

- Rapid heating and cooling may ensure homogeneous emitter penetration
  - Si act as heat sink
- Precise control over power and speed may permit depth of penetration to be well controlled
  - When RF power is switched off, cooling to <600 C is 'immediate'

- This combination may enable direct contacting of shallow high ohmic emitters using for instance high reactivity pastes

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RF firing: potential solution for high ohmic emitters

- More control over firing is possible using RF technology
  - Using High ohmic emitters without extra process steps resulting in increased efficiency
  - Good control over seed layer fire through
  - Potential for more robust processing
  - Limited ajustment of existing lines necessary

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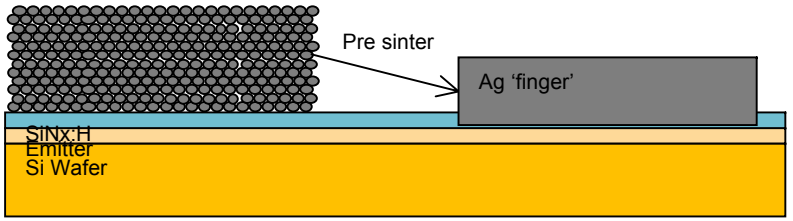
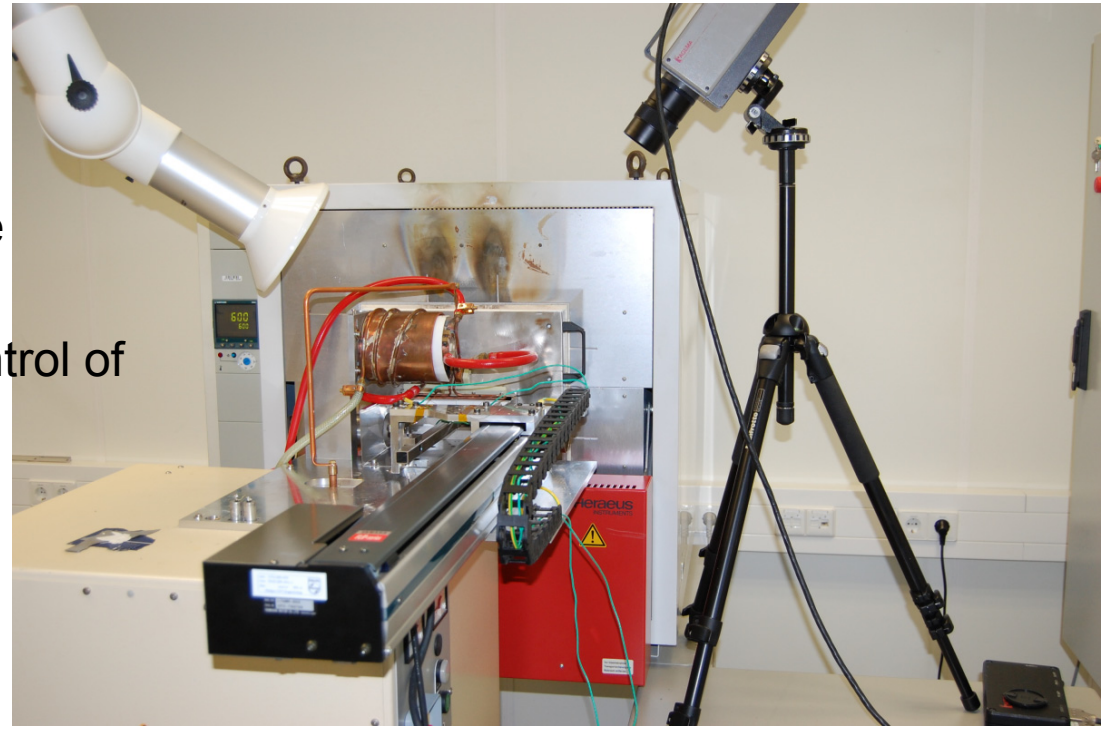
RF experiments, sample & measurement setup.

- Use pre sintering in tube oven to create conductive silver finger
  - Different settings



- RF lab setup
  - Oven for pre heating
  - IR camera for temperature imaging
  - Motion stage for exact control of RF time



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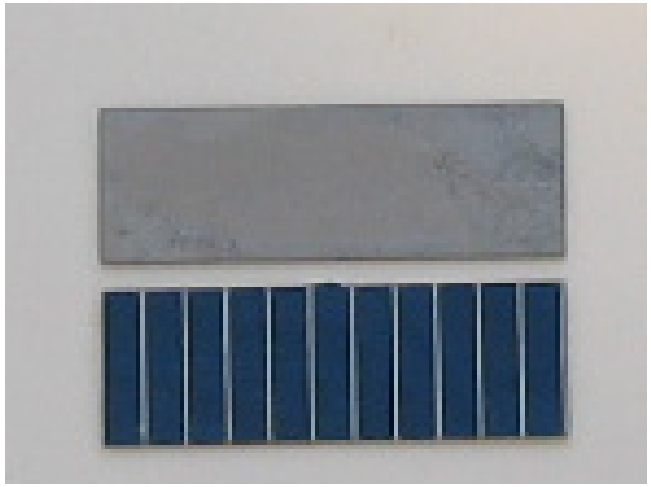
Samples used

- P-type mc-Si substrate
- 50-60 Ohm emitter
- Front SiNx layer (50-80 nm)
- Standard front side silver paste (PV145), H-pattern with 2.7 mm pitch
- Line width ~130 micron
- No coverage of backside (no Al, no SiNx)



- TLM sized, 10x30 mm (laser scribed)

- ‘reference’: wafer fired using ‘standard’ IR firing process

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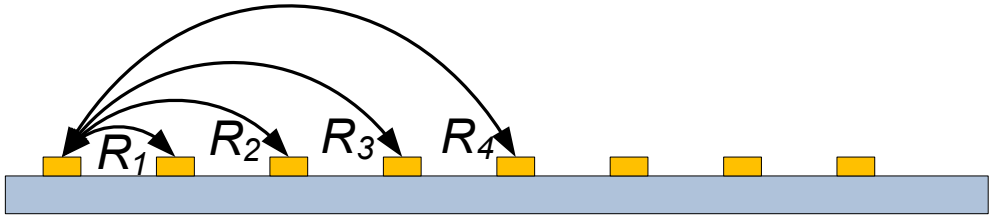
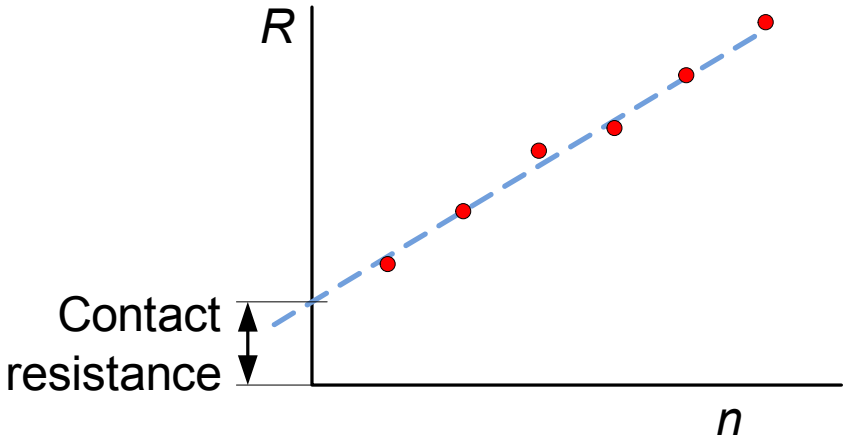
Measurement of contact resistance



- Measurement yields resistance values R_n
- R_n is the combined result of contact resistance and sheet resistance
- Assumption: contact resistance is constant, sheet resistance increases linearly



Contact resistance = resistance R_0 (extrapolation)

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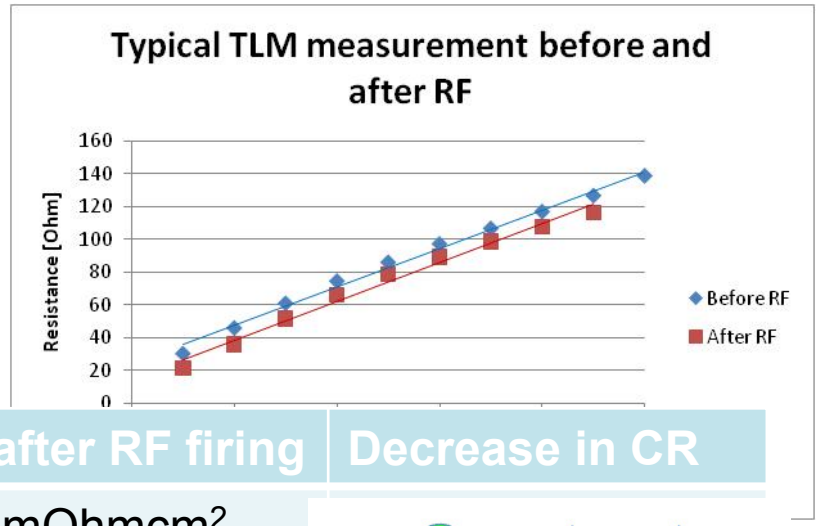
Results RF experiments



Pre sinter setting	CR before RF	CR after RF firing	Decrease in CR
1	312 mOhmcm^2	162 mOhmcm^2	Contact resistance halved for each pre sinter setting
	286 mOhmcm^2	134 mOhmcm^2	
2	158 mOhmcm^2	95 mOhmcm^2	
	178 mOhmcm^2	90 mOhmcm^2	
3	144 mOhmcm^2	52 mOhmcm^2	
	85 mOhmcm^2	39 mOhmcm^2	
Reference		57 mOhmcm^2	

No shunts visible using lock in thermography

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Further observations

- Aluminium backside does not change process window
  - Difference in electrical properties is large enough
- Si surface remains below 450 °C
- Heatup and cool down from < 250 °C within 1 second possible using this lab setup

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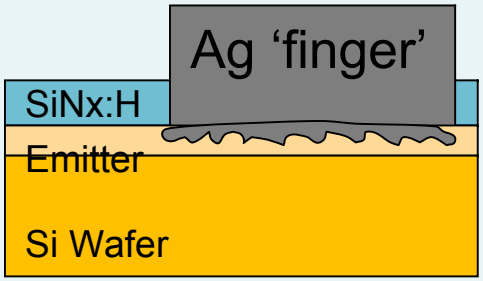
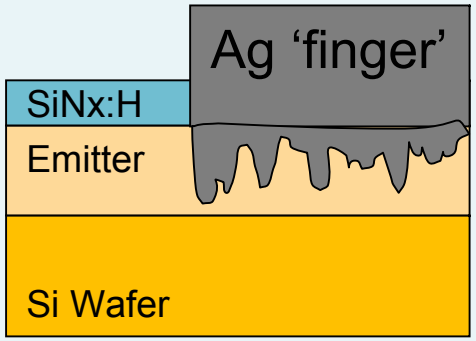
Summary RF firing vs IR firing

	RF firing	IR firing
		
Emitter	High Ohmic	Low Ohmic
Si thickness	Not dependent	Dependent
Optical properties	Not dependent	Dependent
Ag conductivity	Dependent	Not dependent
Pre sintering	Necessary	Necessary
Metal geometry	Restricted	No restrictions
Potential to improve eff. with minimal impact/cost	High	Low

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Conclusions

- Selective heating of Ag to >750 °C within 1 second is possible using RF
- TLM samples show significant electrical effect of RF without inducing shunts
  - Promising for higher ohmic emitters
- Cool Si also opens options for using heat sensitive ARC's

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Questions?

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