GaAs Fabrication

Block Course HS17

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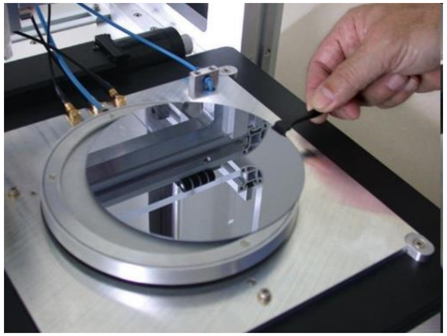
Motivation

- GaAs is a III-V semiconductor with properties superior to other semiconductors (e.g. Si)
  - direct band gap (laser, diode)
  - heterostructures with high mobility
  - fast switching -> high frequency applications

From Bulk… to Device

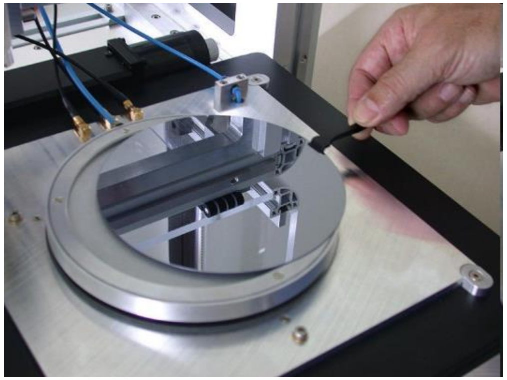
- from pure material to GaAs wafer
    - crystalline blocks (ingots, boules)…

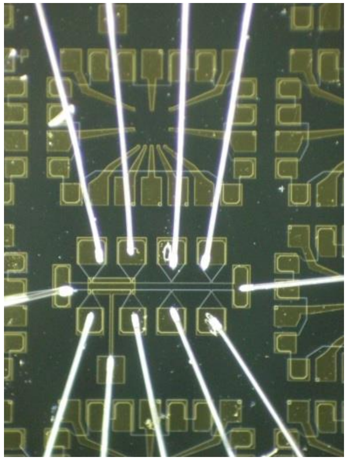
    - … are sawed into wafers



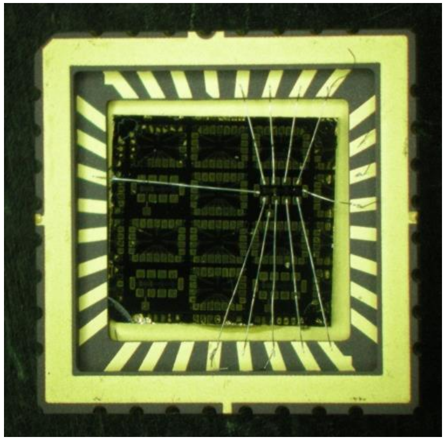
From Bulk to Device

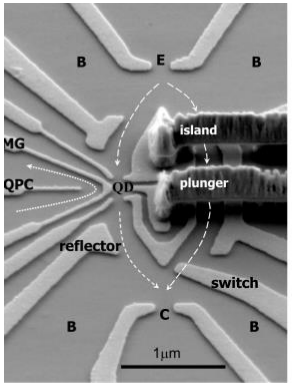
- starting point: wafer

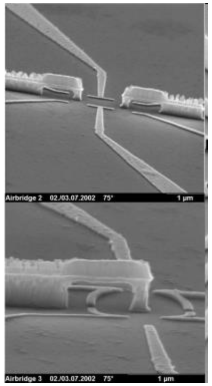




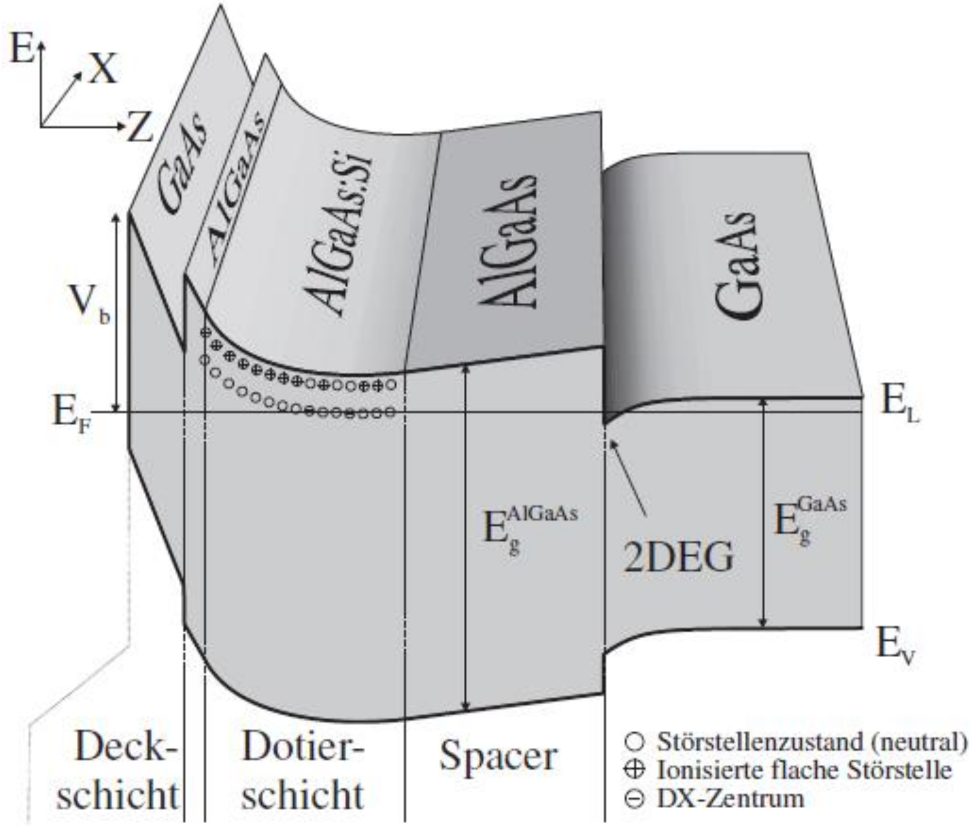
- goal: device







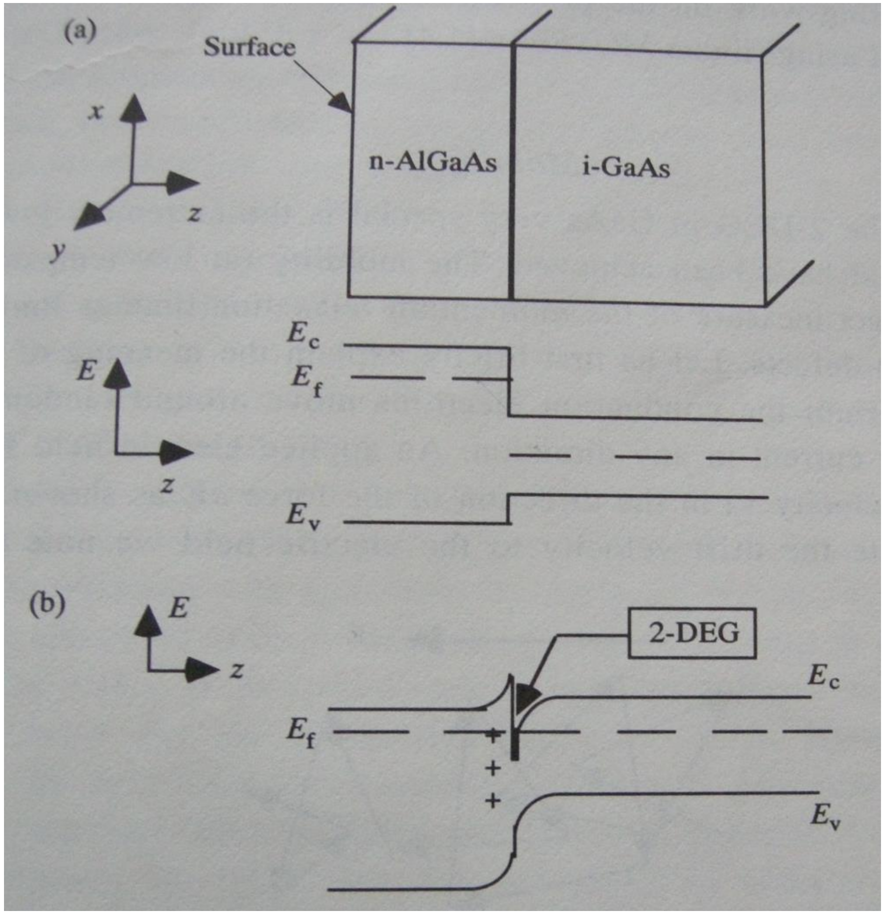
2-Dimensional Electron Gas



- electrons can move "freely" inside the 2DEG

  -> shape transport ways
- transport measurements
  -> need contacts

2-Dimensional Electron Gas



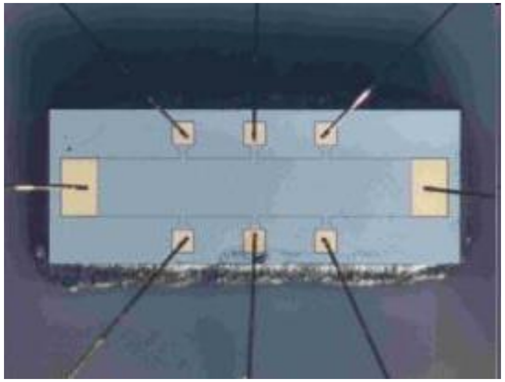
- Different Fermi levels in n-AlGaAs and GaAs
- After charge transfer, Fermi levels align
- 2DEG is generated at the interface

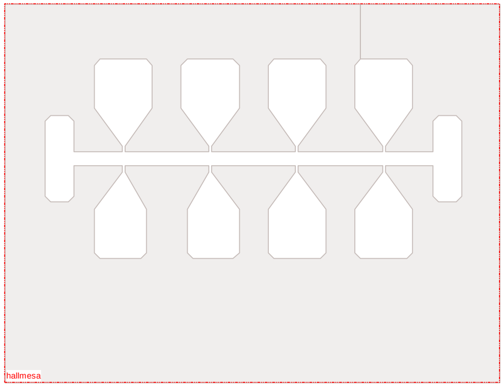
Shaping the 2DEG

- two ways:
  - **permanent:** the 2DEG is removed at unwanted places by etching → Mesa
  - **dynamic:** gates are placed on the surface. Negative voltages repel electrons and deplete the 2DEG. Positive voltages increase electron density.

Mesa Pattern: Principle

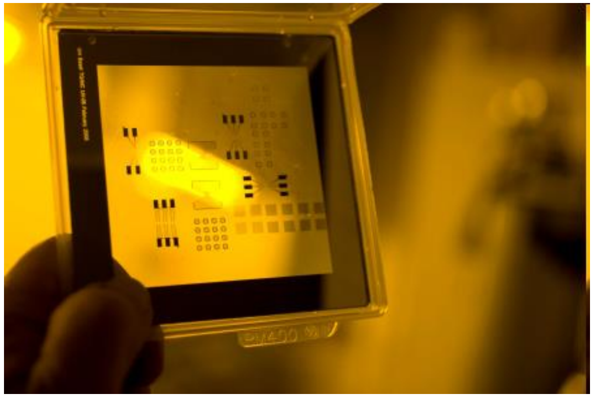
- unwanted 2DEG area is etched away with a wet-etch (H_2SO_4, H_2O_2, H_2O)
- 2DEG area is protected by a protective layer (UV-resist)

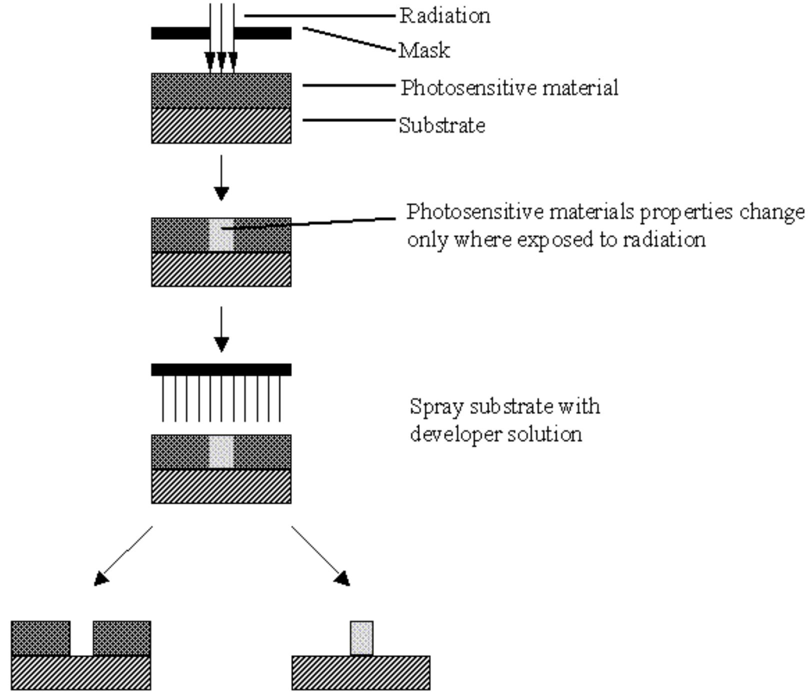




Mesa Pattern: UV-Lithography

- contact lithography





Radiation

Mask

Photosensitive material

Substrate

Photosensitive materials properties change only where exposed to radiation

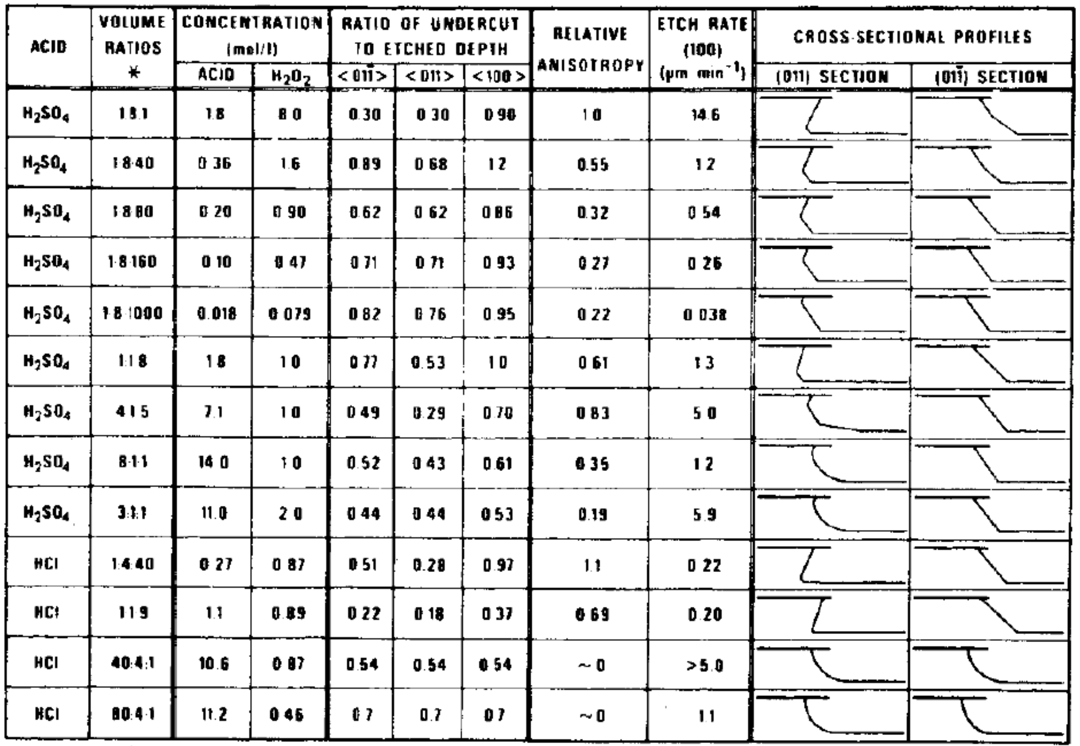
Spray substrate with developer solution

a) Positive resist, developer solution removes exposed material

b) Negative resist, developer solution removes unexposed material

Mesa Pattern: Wet Etch

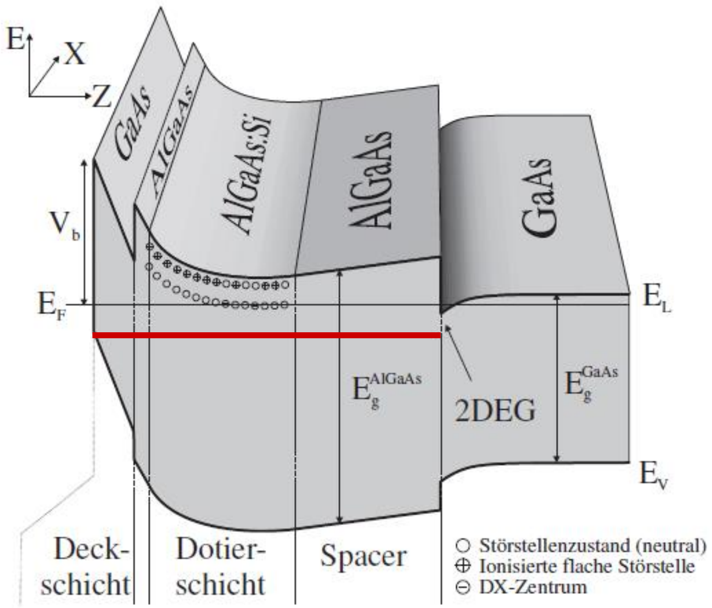
- H_2SO_4, H_2O_2, H_2O



ACID	VOLUME RATIOS *	CONCENTRATION (mol/l)		RATIO OF UNDERCUT TO ETCHED DEPTH			RELATIVE ANISOTROPY	ETCH RATE (100) (µm min^{-1})	CROSS-SECTIONAL PROFILES	
		ACID	H_2O_2	$\langle 0\bar{1}1\rangle$	$\langle 011\rangle$	$\langle 100\rangle$			(011) SECTION	$(01\bar{1})$ SECTION
H_2SO_4	1:8:1	1.8	8.0	0.30	0.30	0.90	1.0	14.6		
H_2SO_4	1:8:40	0.36	1.6	0.89	0.68	1.2	0.55	1.2		
H_2SO_4	1:8:80	0.20	0.90	0.62	0.62	0.86	0.32	0.54		
H_2SO_4	1:8:160	0.10	0.47	0.71	0.71	0.93	0.27	0.26		
H_2SO_4	1:8:1000	0.018	0.079	0.82	0.76	0.95	0.22	0.038		
H_2SO_4	1:1:8	1.8	1.0	0.77	0.53	1.0	0.61	1.3		
H_2SO_4	4:1:5	7.1	1.0	0.49	0.29	0.70	0.83	5.0		
H_2SO_4	8:1:1	14.0	1.0	0.52	0.43	0.61	0.35	1.2		
H_2SO_4	3:1:1	11.0	2.0	0.44	0.44	0.53	0.19	5.9		
HCl	1:4:40	0.27	0.87	0.51	0.28	0.97	1.1	0.22		
HCl	1:1:9	1.1	0.89	0.22	0.18	0.37	0.69	0.20		
HCl	40:4:1	10.6	0.87	0.54	0.54	0.54	~0	>5.0		
HCl	80:4:1	11.2	0.46	0.7	0.7	0.7	~0	1.1		

* ACID (CONCENTRATED): H_2O_2(30%): H_2O

Ohmic Contacts



- stable contact from surface to 2DEG
- should not affect measurement
- how to make a wire through brittle GaAs?

Ohmic Contacts

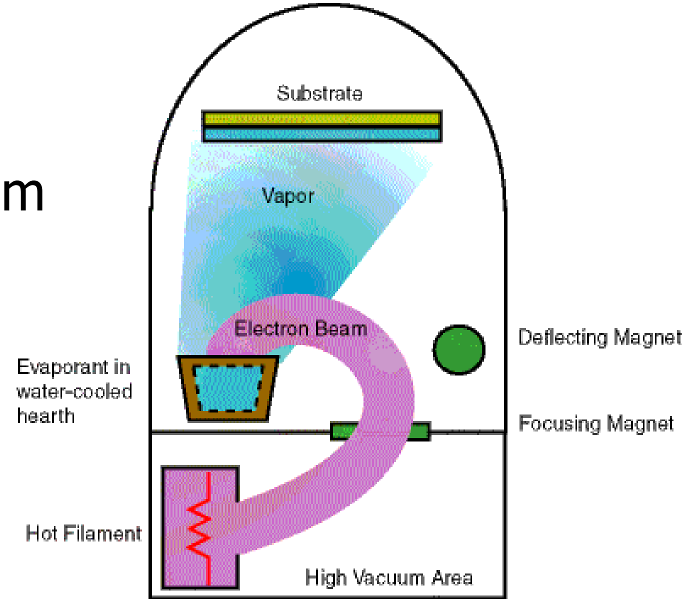
- typical material
  - Au/Ge/Ni
  - Au/Ge/Pt

- different definitions
  - perfect source and sink of both carrier types and having tendency to inject or collect either electrons or holes
  - a source of carriers with an internal resistance R_C which is totally negligible compared to semiconductor resistance
  - a source of carriers with non-negligible internal resistance R_C, but one which obeys Ohm’s law for current densities of interest

Ebeam or Thermal Evaporation

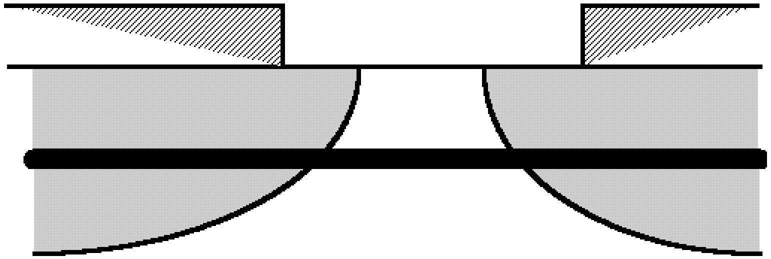
- Thermal evaporation: mostly used for Ohmics
  - Substrate is heated using high currents

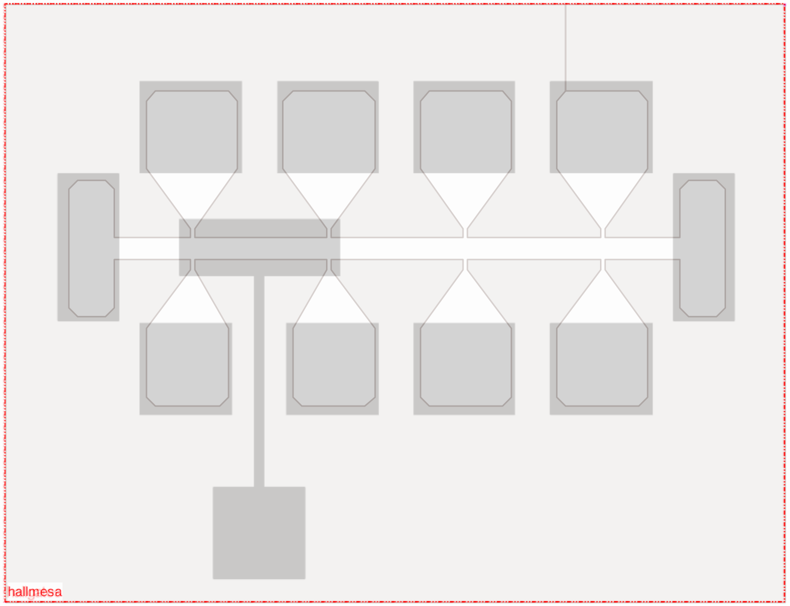
- E-beam evaporation
  - Substrate is heated using an electron beam

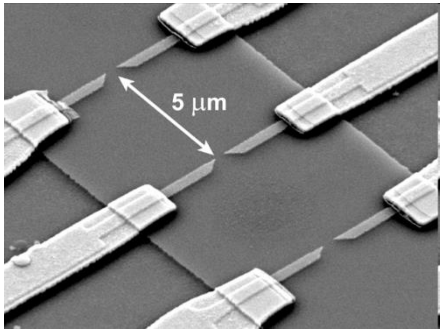


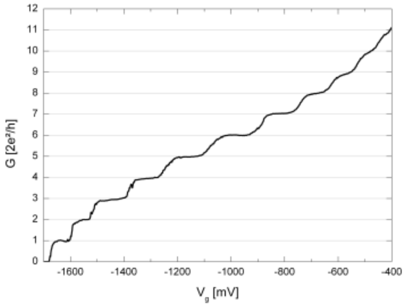
Shaping the 2DEG II: Gates

- gates can be added by UV or E-beam lithography

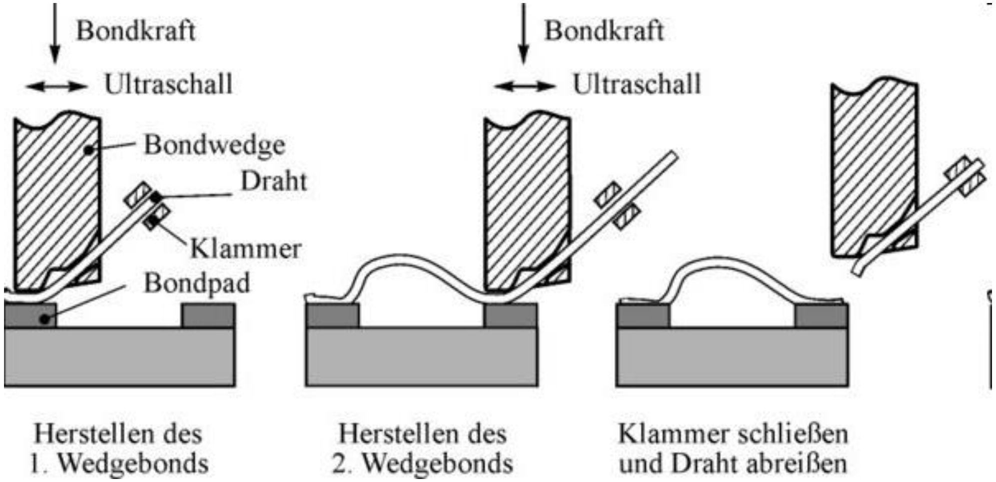


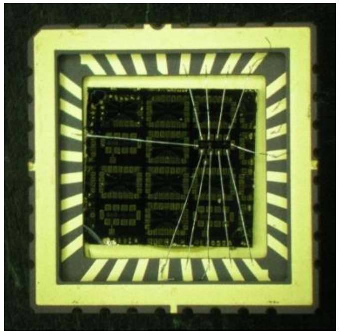






Wedge Bonding





Bericht & Termine

Abgabe als **pdf** – LaTeX erwünscht und stark empfohlen. Englisch wird ebenfalls empfohlen.

Terminvorschläge:

Abgabe erste Version: 23. Oktober 2017 (Montag) +2W
Definitive Abgabe / Endfassung: 6. November 2017 (Montag) +4W

Nach Abgabe einer ersten Version (fakultativ) erfolgt eine mündliche Zwischenbesprechung. Wird der Termin für die erste Version nicht eingehalten, erfolgt keine Vorbesprechung und es wird die Endfassung bewertet.

Die Note für den Blockkurs setzt sich zusammen aus der Endfassung und der Mitarbeit im praktischen Teil (siehe Bewertungsblatt).