MICROWAVE SOLID-STATE DEVICES

ECE 524E – MICROWAVE ENGINEERING

Thursday, March 5, 2020

WHERE ARE WE IN THE SYLLABUS?

Course Content:

Introduction: Components of RF and microwave design, Behaviour of passive components, Propagation of guided waves. Micro-stripline circuits; Evaluation of attenuation constant for the rectangular waveguide. Waveguides and Components: Review of electromagnetic (EM) spectrum. Rectangular waveguides, Circular Waveguides, Microwave cavities. Microwave antennas: electromagnetic horns; reflector antennas; micro-strip antennas; phased arrays. Micro Strip Antenna. Directional couplers. Circulators, isolators. Wave guide couplings, bends and twists, Transitions, hybrid couplers, Matched load, Attenuators and phase shifters, E-plane, H-plane and Hybrid Tees, Hybrid ring. Waveguide discontinuities: Windows, Irises and Tuning screws, Detectors, wave meters. Strip Lines: Microstrip lines. Parallel strip lines. Coplanar strip lines. Shielded strip lines. Microwave Active circuits: Microwave transistors and tunnel diodes. Microwave FETs. Transferred electron devices: Avalanche transit time devices. Microwave linear beam tubes. Microwave crossed-field tubes. Microwave Communication Systems. Effect of Biological Exposure to microwave radiation. Microwave tubes: Klystron, Reflex Klystron, Magnetron, TWT, BWO: Their schematic, Principle of operation, performance characteristics and application. Microwave semiconductor devices: PIN diode, Tunnel diode, LSA diode, varactor diode, Gunn Devices, IMPATT and TRAPATT, their Principal of operation, characteristics and applications. Microwave Relays: Line-of-site path characteristics, FM radio stations and repeaters, FM microwave systems, analogue FM/AM, analogue versus digital switching arrangements.

TYPES OF MICROWAVE TRANSISTORS

1. MESFETs (Metal-Semiconductor FETs)
2. HEMTs (High Electron Mobility Transistors)
3. MOSFETs
4. BJTs
5. HBTs (Heterojunction Bipolar Transistors)

APPLICATIONS OF MICROWAVE TRANSISTORS

Microwave transistors are used in

1. Low Noise Amplifiers (LNA)
2. Power Amplifiers,
3. Mixers,
4. Frequency converters and multipliers
5. Attenuators,
6. Phase shifters

They can be into 2 groups:

1. low-noise transistors and
2. power transistors

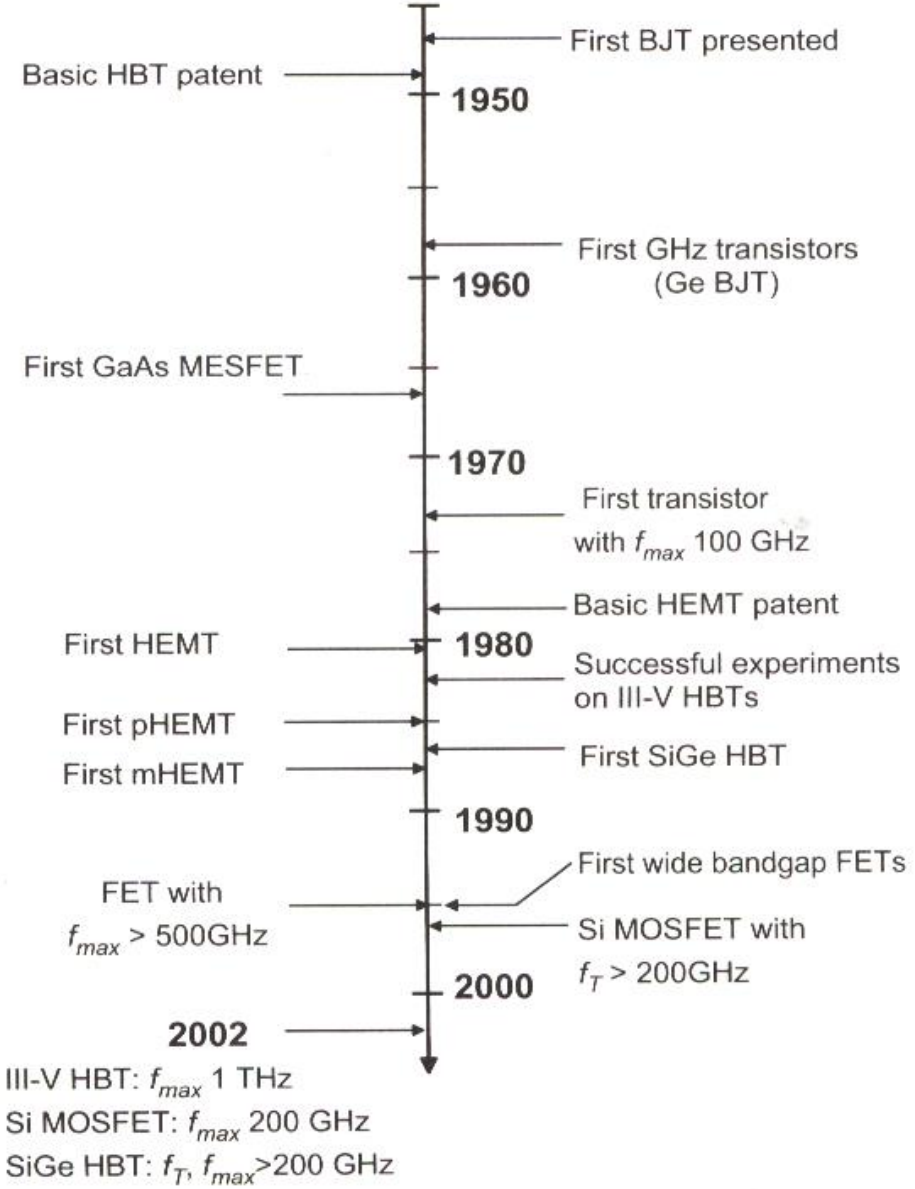


Figure 1.15. Major milestones of the development of microwave transistors.

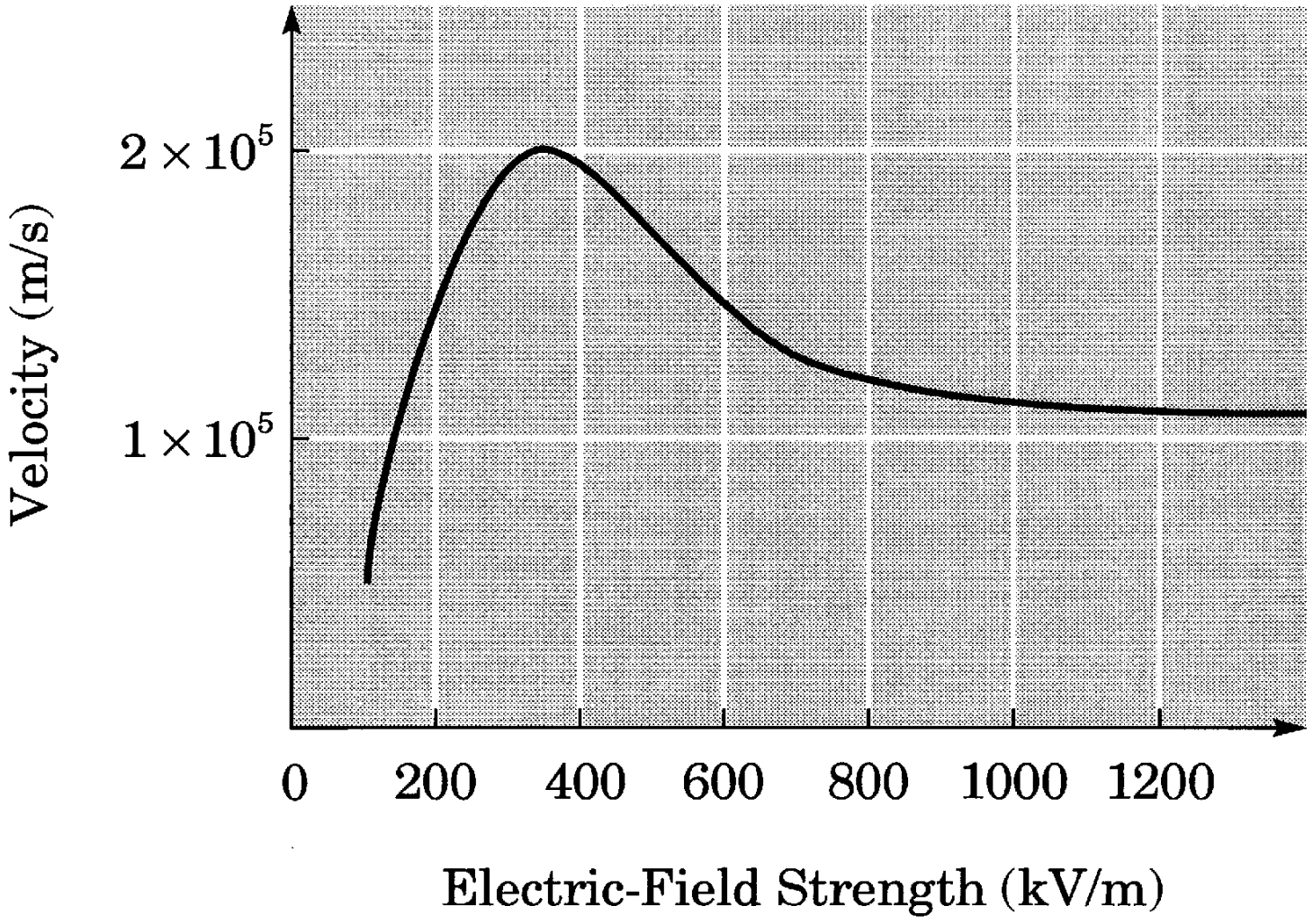
MICROWAVE TRANSISTORS (2)

- **Microwave transistors** are designed to minimize capacitances and transit time
- NPN bipolar and N channel FETs preferred because free electrons move faster than holes
- Gallium Arsenide has greater electron mobility than silicon

GUNN DEVICE (1)

- Slab of N-type GaAs (gallium arsenide).
- Sometimes called Gunn diode but has no junctions.
- Has a negative-resistance region where drift velocity decreases with increased voltage which causes a concentration of free electrons called a domain.

GUNN DEVICE (2)



Transparency 267 (Figure 19.33)

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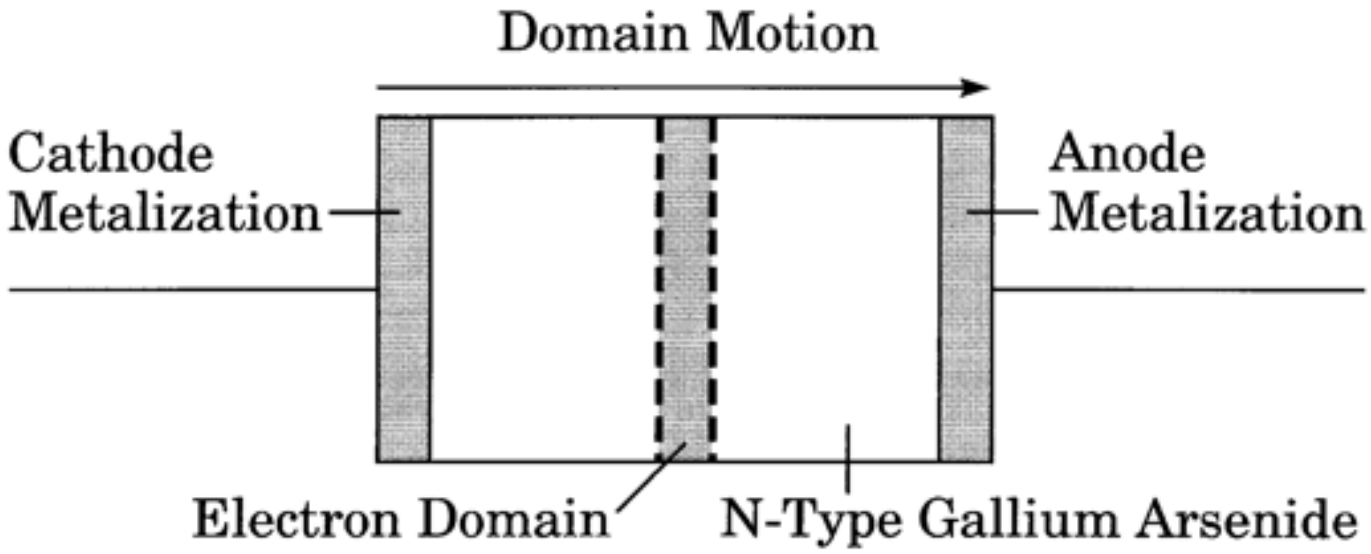
TRANSIT-TIME MODE

- Domains move through the GaAs till they reach the positive terminal
- When domain reaches positive terminal it disappears and a new domain forms
- Pulse of current flows when domain disappears
- Period of pulses = transit time in device

GUNN DEVICE (3)



GUNN OSCILLATOR FREQUENCY

- $T = \frac{d}{v}$

  T = period of oscillation

  d = thickness of device

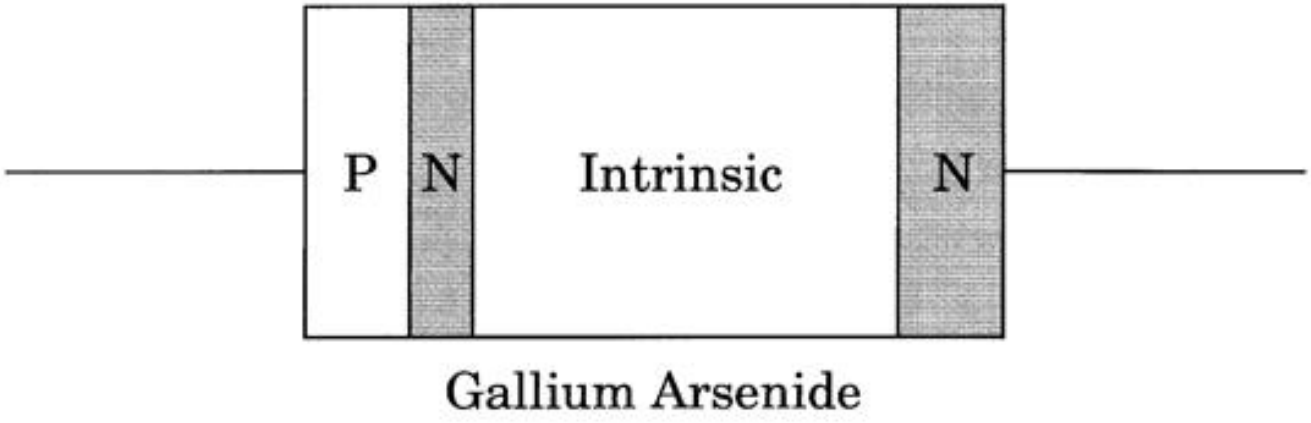
  v = drift velocity, about 1×10^5 m/s

- $f = 1/T$

IMPATT DIODE (1)

- IMPATT stands for Impact Avalanche And Transit Time
- Operates in reverse-breakdown (avalanche) region
- Applied voltage causes momentary breakdown once per cycle
- This starts a pulse of current moving through the device
- Frequency depends on device thickness

IMPATT DIODE (2)

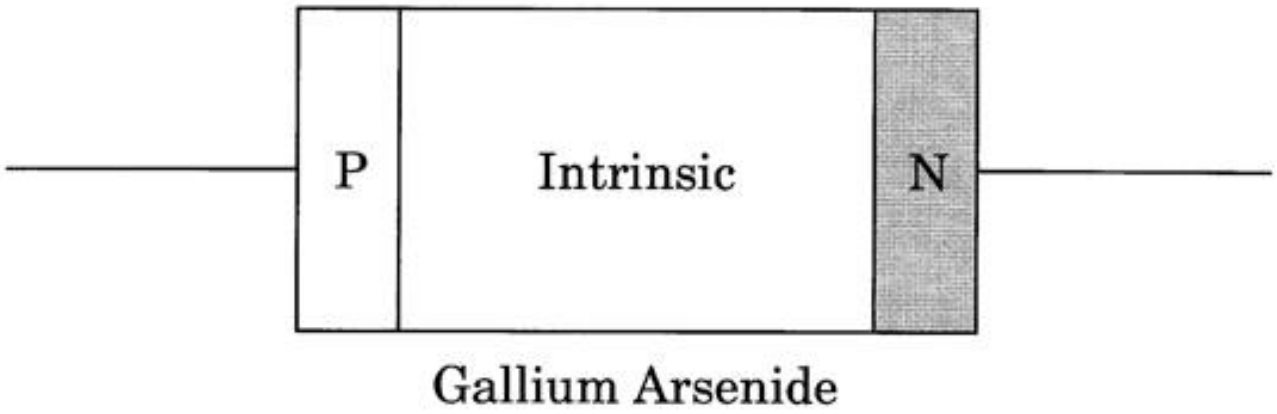


PIN DIODE (1)

- P-type --- Intrinsic --- N-type
- Used as switch and attenuator
- Reverse biased - off
- Forward biased - partly on to on depending on the bias

PIN DIODE (2)

1. A PIN diode has a wide, un-doped intrinsic semiconductor region between a p-type semiconductor and an n-type semiconductor region.
2. The p-type and n-type regions are typically heavily doped.
3. The PIN diode is widely used in attenuators, fast switches, photodetectors, and high voltage power electronics applications.



VARACTOR DIODE

- Varactor diode is used at lower frequencies as voltage-variable capacitor
- At microwaves, it is used as frequency multiplier
  - this takes advantage of the nonlinear V-I curve of diodes

YIG DEVICES

- YIG stands for Yttrium - Iron - Garnet
  - YIG is a ferrite
- YIG sphere in a dc magnetic field is used as resonant cavity
- Changing the magnetic field strength changes the resonant frequency