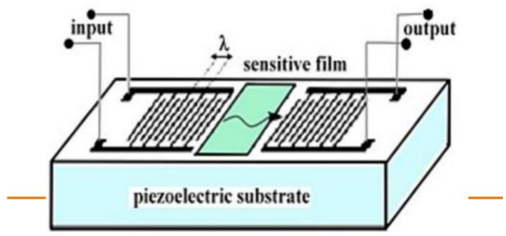
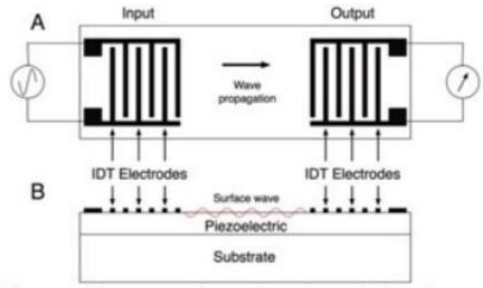
10 marks

1. Describe in detail about the surface acoustic waves (SAW) principle and working with detailed applications (any three applications)

   Surface acoustic wave technology consists of a piezoelectric substrate and interdigitated electrodes or transducers (IDTs). The IDTs are patterned on the surface of the piezo substrates by design. Together, they transform the applied electrical energy into mechanical energy and generate surface acoustic waves. The largest consumer for SAW devices is the telecommunications industry, where SAWs are used as bad pass filters in the radio frequency (RF) range in mobiles phones and base stations. Some of the emerging applications for acoustic wave devices include sensors for the automotive (e.g., torque and pressure sensors), medical (e.g., chemical sensors) and industrial markets (e.g., humidity, temperature and mass sensors). SAWs are also used for advanced touch screens. Surface Acoustic Wave devices (SAW) are acoustic devices commonly used for high frequency filtering applications such as in mobile telephony. Acoustic waves are generated by applying an alternating voltage across electrodes on the piezoelectric. As the piezoelectric starts to oscillate in it generates an acoustic wave, the resonant frequency being a function of the spacing between the electrodes and the acoustic wave velocity of the material. This wave is received at a second set of electrodes and converted back to an a.c. voltage. The resonant frequency of such devices can be increased by either reducing the electrode spacing in the IDT or using a material of higher sound wave velocity. Diamond has the highest acoustic wave velocity of any material and thus offers the highest possible resonant frequencies of any SAW device. Diamond is not a piezoelectric and thus has to be combined with a piezoelectric material such as AlN in order to fabricate a discrete device. The integration of AlN onto diamond films requires very smooth surfaces, typically below 2 nm over several micron.

2. Explain the working mechanism of magneto resistive sensors with neat diagram.

A magnetotransistor is a bipolar junction transistor (BJT) whose structure and operating conditions are optimized with respect to the magnetic sensitivity of its collector current.

The magnetic sensitivity of a magnetotransistor is usually defined

$$S_I = \left| \frac{1}{I_c} \frac{\Delta I_c}{B} \right|. \tag{7.15}$$

Here, I_c denotes the collector current, and ΔI_c is the change in the collector current due to a magnetic induction $\boldsymbol{B}$:

$$\Delta I_c = I_c(B) - I_c(0). \tag{7.16}$$

The sensitivities of magnetotransistors reported hitherto cover a surprisingly wide range: from 10^{-2} to over $10\,\mathrm{T}^{-1}$. This large spread of sensitivities indicates that the operation of various magnetotransistors is based on different effects. Indeed, the Hall effect may interfere with the action of a bipolar transistor in many ways and give rise to different end effects. The following three major end effects may be distinguished:

- The current deflection effect. This is essentially the same effect that we studied in large-contact Hall plates.
- The injection modulation. The Hall voltage generated in the base region of a magnetotransistor modulates the emitter-base voltage, and thus also the carrier injection.
- The magnetodiode effect. The emitter-base diode of a transistor may function as a magnetodiode. This leads to a magnetic sensitivity of collector current. In principle, these three effects coexist and cooperate in any magnetotransistor.

The magnetodiode effect comes about as a result of the cooperation of the Hall effect and a few other effects pertinent to a p–n junction diode. The basic effects are: the conductivity modulation due to a high injection level ; the current deflection ; and the magnetoconcentration effect

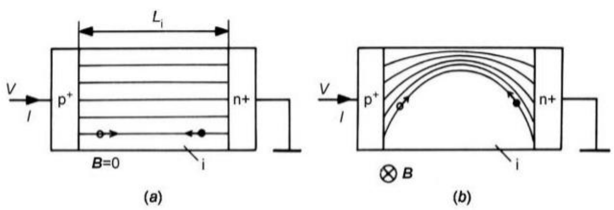


Figure 7.10. Current density lines in a magnetodiode with volume recombination. (a) No magnetic field; (b) a magnetic field perpendicular to the drawing plane is present. Then both electrons (•) and holes (○) are deflected towards the same boundary of the slab, and the current lines get longer.

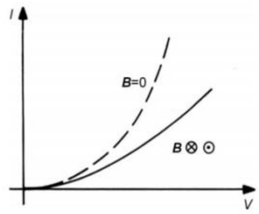


Figure 7.11. Current–voltage characteristics of a magnetodiode with volume recombination. At a constant bias voltage, a magnetic field causes a decrease in diode current, irrespective of the sign of the magnetic field.

The current in the magnetodiode decreases in the presence of a magnetic field. The lower the current, the lower the injection level and the higher the resistance of the i-region. Then the larger portion of the diode voltage drops across the i-region, the voltage across the injecting junctions decreases, and the diode current decreases. Thus at a high injection level, a magnetic field triggers a cumulative process of current reduction, which greatly boosts the magnetic sensitivity of the magnetodiode.

Magnetodiodes have been made of various semiconductors, including germanium, silicon and GaAs. Early devices were discrete