Literature Review Key – *Science* article (Yablonovitch)

1. Yablonovitch states that, as a result of nonpolarity, electron-lattice interactions in semiconductors such as Si are very weak. **Why is this advantageous?**

Electron-lattice interactions reduce carrier mobility, resulting in decreased conductivity. Very weak interactions (or small numbers of interactions) in semiconductors allow for higher mobility and higher conductivity.

2. What is a Fermi level?

There are several different (but related) definitions here. The Fermi level in a solid is the highest occupied energy level (typically specified for T = 0 Kelvin). It is also defined as a measure of chemical potential.

Yablonovitch discusses Fermi levels for both the valence and conduction bands in a semiconductor. Here, Fv and Fc are the highest occupied orbitals in each band. They are also chemical potentials for the two bands, and Yablonovitch uses that idea when discussing the flow or diffusion of charge carriers. (For example: In an LED, electrons flow from an area of high chemical potential – or "concentration" – in the CB of the n-type material to an area of low potential in the VB of the p-type material.)

3. How are the two quasi-Fermi levels related to the operation of a semiconductor solar cell? A semiconductor laser?

The energy difference between Fc(n-type) and Fv(p-type) defines the band gap of the semiconductor device.

In a solar cell (an unbiased p-n junction), this is the minimum energy required for absorption of a photon from the sun. That absorption creates mobile electrons in the CB of the n-type material (and mobile holes in the VB of the p-type material), which can be harnessed as an electrical current.

In a laser (a forward-biased p-n junction), the applied voltage causes electron-hole recombination as these carriers move across the junction. When recombination occurs, an electron drops from the CB of the n-type material to the VB of the p-type material and a photon with E=Fc-Fv is given off. (Photons stimulate emission of additional photons, causing amplification and lasing.)

4. Why is it crucial to minimize defects in semiconductors (both on the surface and in the bulk)? Give examples of different types of defects.

Defects act as permanent sites for non-radiative electron-hole recombination (by introducing discrete energy levels in the band gap). This destruction of mobile charge carriers results in decreased conductivity and compromises the function of semiconductor devices (e.g., reducing radiative recombination and light generation in LEDs and lasers, etc.). We discussed several different types of defects in class – vacancies, interstitials, dislocations, etc.

5. What is special about the Si—SiO_2 interface?

It has a very low defect concentration (the best known at the time of publication): 99.9999% defect free (1 defective bond in 1 million).

6. What is the difference between direct and indirect band-gap semiconductors?

Direct: Lowest lying absorption levels interact with visible light. Indirect: these absorptions are forbidden.

7. **How does a light-emitting diode (LED) work? Specifically, what event causes light emission?**

   See your lecture notes. An LED is a forward-biased p-n junction. The applied voltage causes electrons and holes to flow across the interface and recombine. When this occurs, the electron drops from the CB of the n-type material to the VB of the p-type material and the energy difference [E(band gap) = Fc-Fv] is given off as a photon.

8. **What "remarkable accident" related to GaAs and AlAs does Yablonovitch cite and why is it important?**

   These two III-V compound semiconductors have near-perfect matching between their lattice structures – <0.1% mismatch in unit-cell dimensions. As a result, a sandwich structure composed of these materials is almost indistinguishable structurally from pure GaAs or pure AlAs, and there are very few defects at the interface(s) (interfacial bonds 99.999% saturated).