Physical section, Faculty of Science, Masaryk University, Brno

PHYSICAL PRACTICUM

Physical practicum 3

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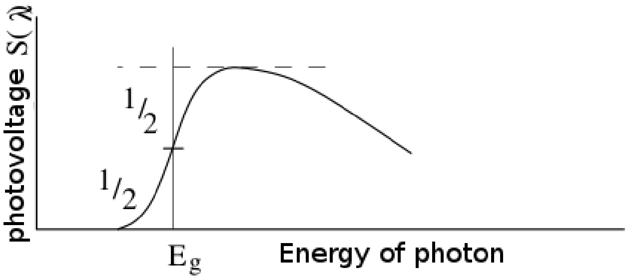
Field of Study: AF **Grade:** II **Semester:** IV **Tested:**

Task No. **5:** **Measurement of band gap**

1. Theory

In solid state physics, a band gap, also called an energy gap or bandgap, is an energy range in a solid where no electron states can exist. In graphs of the electronic band structure of solids, the band gap generally refers to the energy difference between the top of the valence band and the bottom of the conduction band in insulators and semiconductors. This is equivalent to the energy required to free an outer shell electron from its orbit about the nucleus to become a mobile charge carrier, able to move freely within the solid material. So the band gap is a major factor determining the electrical conductivity of a solid. Substances with large band gaps are generally insulators, those with smaller band gaps are semiconductors, while conductors either have very small band gaps or none, because the valence and conduction bands overlap.

In this practicum is measurement of two types of semiconductors: germanium an silicon. Band gaps of these semiconductors can be determined by dependence of photovoltage on energy:



where energy of photon can be calculated by equation $E = \frac{hc}{\lambda}$ and photovoltage per photon $S(\lambda)$ is equal to measured photovoltage $U(\lambda)$ devided by number of photons $N(\lambda)$:

$$S(\lambda) = \frac{U(\lambda)}{N(\lambda)},$$

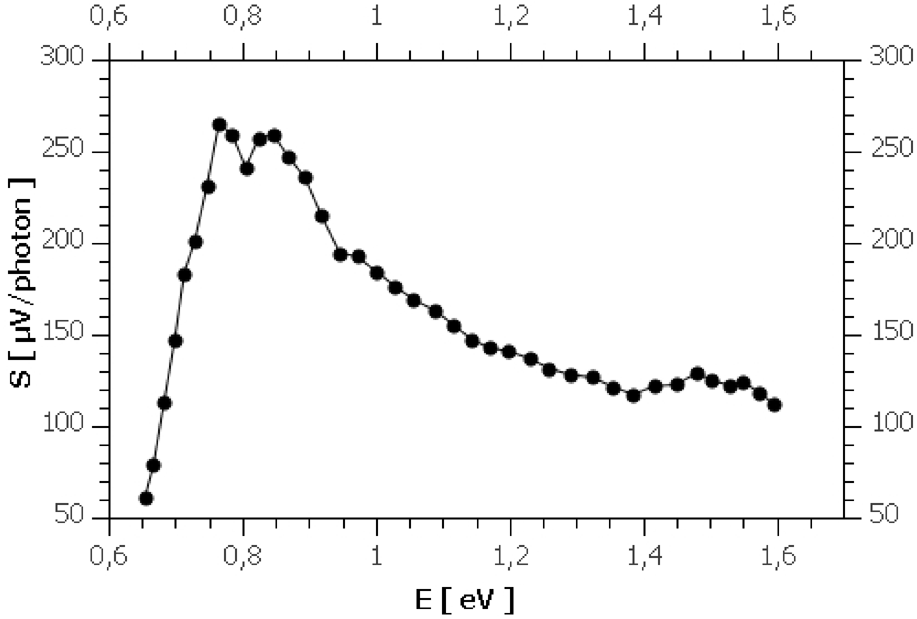
Specific wavelengths of photons are provided by monochromator and are measured by micrometric thread in depth of threading d but dependence $\lambda(d)$ is known. Values of dependence $N(\lambda)$ are known by another measurement too.

2. Measurement

Table 1: Known, measured and calculated values for germanium and silicon:

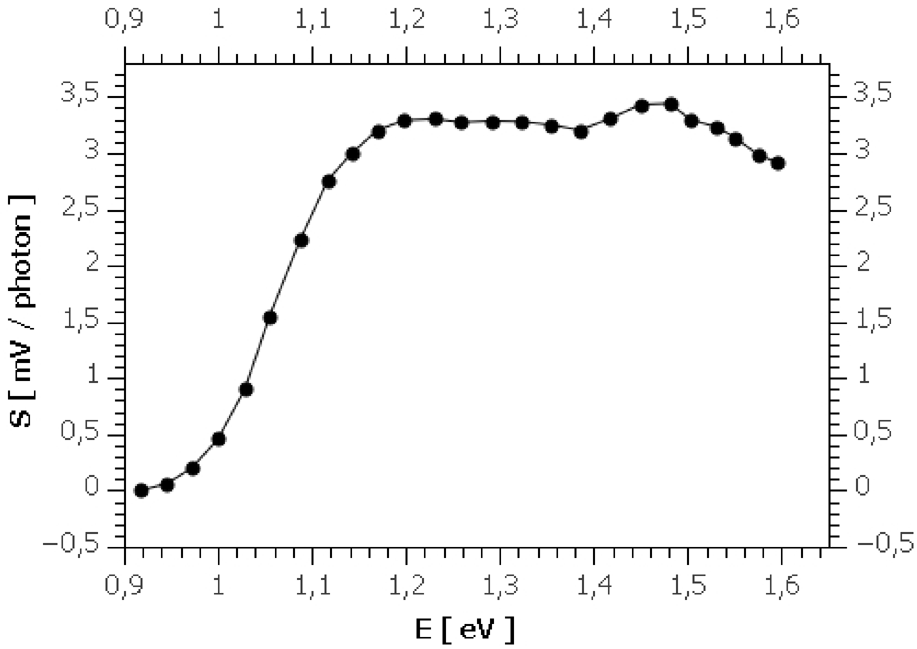
Known values				Germanium		Silicon	
d [mm]	λ[nm]	N [photons]	E [eV]	U [μV]	S [μV/photon]	U [mV]	S [mV/photon]
12,00	777	0,67	1,596	75	111,9	1,95	2,910
11,95	787	0,72	1,575	85	118,1	2,15	2,986
11,90	800	0,765	1,550	95	124,2	2,40	3,137
11,85	810	0,82	1,531	100	122,0	2,65	3,232
11,80	825	0,88	1,503	110	125,0	2,90	3,295
11,75	837	0,93	1,481	120	129,0	3,20	3,441
11,70	855	1,02	1,450	125	122,5	3,50	3,431
11,65	875	1,15	1,417	140	121,7	3,80	3,304
11,60	895	1,28	1,385	150	117,2	4,10	3,203
11,55	915	1,40	1,355	170	121,4	4,55	3,250
11,50	937	1,54	1,323	195	126,6	5,05	3,279
11,45	960	1,72	1,292	220	127,9	5,65	3,285
11,40	985	1,94	1,259	255	131,4	6,35	3,273
11,35	1007	2,12	1,231	290	136,8	7,00	3,302
11,30	1035	2,34	1,198	330	141,0	7,70	3,291
11,25	1060	2,56	1,170	365	142,6	8,20	3,203
11,20	1085	2,78	1,143	410	147,5	8,35	3,000
11,15	1110	2,90	1,117	450	155,2	8,00	2,759
11,10	1140	3,04	1,088	496	163,2	6,80	2,237
11,05	1175	3,16	1,055	535	169,3	4,90	1,551
11,00	1205	3,26	1,029	575	176,4	2,95	0,905
10,95	1240	3,28	1,000	605	184,5	1,50	0,457
10,90	1275	3,27	0,972	630	192,7	0,65	0,199
10,85	1310	3,24	0,946	630	194,4	0,20	0,062
10,80	1350	3,18	0,918	685	215,4	0,00	0,000
10,75	1387	3,12	0,894	735	235,6	-	-
10,70	1425	3,04	0,870	750	246,7	-	-
10,65	1465	2,97	0,846	770	259,3	-	-
10,60	1505	2,90	0,824	745	256,9	-	-
10,55	1540	2,82	0,805	680	241,1	-	-
10,50	1580	2,72	0,785	705	259,2	-	-
10,45	1620	2,64	0,765	700	265,2	-	-
10,40	1660	2,54	0,747	587	231,1	-	-
10,35	1700	2,46	0,729	495	201,2	-	-
10,30	1740	2,36	0,713	433	183,5	-	-
10,25	1775	2,28	0,699	336	147,4	-	-
10,20	1815	2,18	0,683	247	113,3	-	-
10,15	1860	2,06	0,667	162	78,64	-	-
10,10	1895	1,98	0,654	120	60,61	-	-

Figure 1: Dependence of photovoltage per photon S on radiant energy E for germanium



Band gap of germanium: $E_g = (0,691 \pm 0,010)$ eV $\qquad \delta_r = 1,5\%$

Figure 2: Dependence of photovoltage per photon S on radiant energy E for silicon



Band gap of silicon: $E_g = (1,060 \pm 0,010)$ eV $\qquad \delta_r = 0,9\%$

3. Conclusion

Result of this practicum are relatively accurate values of band gaps. Measured band gaps of germanium (0,691 eV) and silicon (1,060 eV) are approximately equal to tables values, which are 0,67 eV for germanium and 1,11 eV for silicon at temperature 302 K.