

THE STUDY OF ENERGY BANDGAP AND REFRACTIVE INDEX OF  $\text{Si}_{1-x-y}\text{Ge}_x\text{C}_y$  ALLOYS

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ABSTRACT

The addition of C into substitutional sites in  $\text{Si}_{1-x}\text{Ge}_x$  alloys allows one to tailor the strain in the alloys and changes its band structure. This may overcome the critical thickness limitation imposed on  $\text{Si}_{1-x}\text{Ge}_x$  films grown epitaxially on Si [1]. We notice that there are only a few optical studies on strained  $\text{Si}_{1-x-y}\text{Ge}_x\text{C}_y$  films that examine the band structure of the material. There is no report on the change of the refractive index  $n$  due to the increase of C concentration. Experiments on the individual elements Si, Ge and C reveal an inverse relationship between  $n$  and the indirect bandgap energy  $E_g$ . Therefore, when designing our SiGeC/Si waveguides, we used the guideline  $n(\text{SiGeC}) > n(\text{Si})$  for compositions that have  $E_g(\text{SiGeC}) < E_g(\text{Si})$ . Thus the task of finding  $n$  was replaced by the task of determining  $E_g$  [2]. To calculate the energy bandgap for SiGe alloys we adopted Weber and Alonso [3] expression by adding the exciton binding energy  $E_b(x)$  to the experimentally derived exciton energy gap [4]. The change of energy bandgap of relaxed SiGeC was predicted when the alloys lattice has mismatches of +5%, 0%, -5% with respect to Si [2]. From these studies we carried out three empirical relations for compressive strain, perfect compensation (zero strain) and tensile strain. With the aid of computer programming we can determine the accurate composition of Ge and C content in SiGeC alloy that produce the desired  $n$ . This program facilitates the calculation of SiGeC energy bandgaps and can be used by everyone for the design of waveguide devices. Our results are in agreement with experimental values quoted in literatures.

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REFERENCES

- [1] Grimmeiss HG, Olajos J. Phys. Scr. T69, PP.52 (1997).
- [2] R. A. Soref, J. Vac. Sci. Technol. A14(3), PP. 913(1996).
- [3] J. Weber and M. I. Alonso, Phys. Rev. B40, PP. 5683(1989).
- [4] D. J. Robbins, L. T. Canham, S. J. Barnett, A. D. Pitt, and P. Calcott, J. Appl. Phys. 71(3), PP. 1407(1992).
- [5] R. A. Soref, J. Appl. Phys. 70, PP. 2470 (1991).
- [6] M. A. Herman, Crys. Res. Technol. 34, PP. 583 (1999).
- [7] S. C. Jain, Germanium-Silicon strained layers and heterostructures (Academic press, Boston 1994).
- [8] R. People, IEEE J. Quant. Electron. 22, PP. 1696 (1986).
- [9] M. E. Levinshtein, S. L. Romyantsev, Ms. Shur. Properties of advanced semiconductor materials. (A Wiley- Interscience publication 2001 ).
- [10] Rudiger Lange, S. S. Iyer, A. P. Powell, K. Eberl, J. Appl. Phys. 80 (8), PP. 4578 (1996).
- [11] E. Kasper and H. Jorke, J. Vac. Sci. Technol. A 10, PP. 11927 (1992).
- [12] Osten, H. J., Dietrich, B. , Rucker, H. , Methfesse, M. J. Cryst. Growth, 150. PP. 931 (1995).
- [13] H. J. Osten, E. Bugiel, and P. Zahmseil, Appl. Phys. Lett. 64, PP. 3440 (1994).

- [14] P. Herve and L. K. J. Vandamme, *Infrared Phys. Technol.* V.35, No. 4, PP.609 (1994).
- [15] T. S. Moss, (*Photoconductivity in the elements*),(Academic Press 1952).
- [16] N. M. Ravindra and V. K. Srivstava, *Infrared Phys.* 19, PP. 603 (1979).
- [17] N. M. Ravindra, Sushil, and V. K. Srivastava, *Phys. Stat. Sol. (b)* 93, K 155 (1979).
- [18] T. S. Moss, *Physica Status Solidi (b)*, 131, PP. 415 (1985).
- [19] R. R. Reddy and S. Anjaneyulu, *Phys. Stat. Sol. (b)* 174, K 91 (1992).
- [20] R. A. Soref, R. D. Lareau. *IEEE. Electronics Lett.* Vol. 26, 20, PP. 1633 (1990).
- [21] Persall, T. P. , *CRC Critical review in solid state and materials science*, 15, PP551 (1989).
- [22] J. Weber and M. I. Alonso, *Phys. Rev. B*.Vol. 40, PP.5683 (1989).
- [23] D. J. Robbins, L. T. Canham, S. J. Barnett, A. D. Pitt, P. Calcott, *J. Appl. Phys.* Vol. 71, PP. 1407 (1992).
- [24] R. Braunstein, A. R. Moor, and F. Herman. *Phys. Rev.* 109, PP. 695 (1958).
- [25] R. People, *IEEE. J. of Quant. Electron.* Vol. 22, PP. 1696 (1986).
- [26] Van de Walle, R. M. Martin, *Phys. Rev. B.* Vol. 34, PP. 5621 (1986).
- [27] H. Jorg Osten, *J. of Appl. Phys.* Vol. 84, No. 5, PP. 2716 (1998).
- [28] R. A. Soref, *J. Vac. Sci. Technol. A* 14 (3), PP. 913 (1996).
- [29] R. A. Soref, Z. Atzman, F. Shaapur, Mc D. Robinson, and R. Westhoff, *Optics Letters*, Vol. 21, No. 5, PP.345 (1996).