International Journal of Advanced Research in Physical Science (IJARPS)
Volume 5, Issue 12, 2018, PP 38-40
ISSN No. (Online) 2349-7882
www.arcjournals.org

Relation between the Young's Modulus in Hooke's Law and the Binding Energy of a Single Atom in Solid

Erokhin K.M[1], Kalachnikov E.S, Kalashnikov N.P[2]

[1]*The Moscow Polytechnic University, Russia*

[2]*The National Research Nuclear University MEPHI*

***Corresponding Author:** ***Erokhin K.M,** The Moscow Polytechnic University, Russia*

Abstract: *The connection between the Young's modulus in Hooke's law and the binding energy of an individual atom of matter is considered. The formula for calculating the Young's modulus is proposed.*

Keywords: *elastic deformation, Young's modulus, Hooke's law, binding energy of an atom, the atomic concentration.*

1. Introduction

In the papers series (Search for Simplicity) [1-2] V.F. Weissk of described the possibility of microscopic interpretation of some macroscopic characteristics of substances. We propose to consider the process of elastic deformation of substances and to relate the macroscopic Young's modulus with the binding energy of the single atom and the atom concentration per unit volume of a substance.

2. Problem Statement

The Hooke's law assumes that the elastic strain strength is proportional to the relative change in the length of the rod [3]:

$$\frac{F}{S} = \sigma = E\frac{\Delta x}{x}, \qquad (1)$$

where σ is the stress in the rod, E is the Young's modulus and $\Delta x/x$ is relative rod lengthening. The elastic deformation of the rod leads to an increase in the potential energy of a unit volume of rod [3,4]:

$$\Delta U/\Delta V = \frac{\sigma^2}{2E} = \frac{E}{2}\left(\frac{\Delta x}{x}\right)^2. \qquad (2)$$

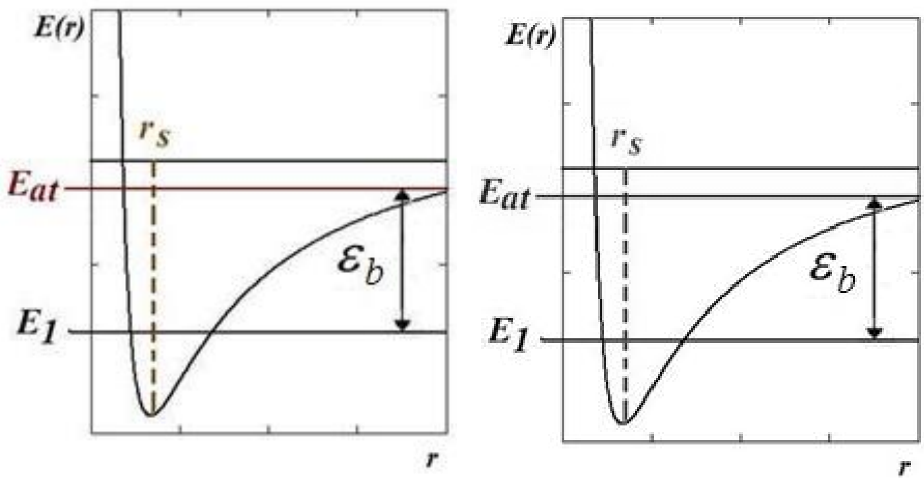


Fig1. *Qualitative dependence of the full energy of the conductivity electron from the cell center*

Let's suppose that we impart such potential energy to rod that each atom of substance acquires the energy equal to the binding energy of the atom ε_b (ε_b is the energy which is required for atom separation from solid [4]). If we are going to complete such an operation, then the whole substance would be divided into atoms, i.e. disintegrated. Let's suppose qualitatively that destruction occurs when the inter atomic distance is increased twice, i.e.: the rod length is doubled $\Delta x/x = 1$!

3. RELATIONSHIP OF THE YOUNG'S MODULUS WITH THE BINDING ENERGY OF THE ATOM IN THE LATTICE

Let us consider the behaviour of the two neighbouring atoms rod. A solid is characterized by the concentration of n ($10^{28} m^{-3}$). Under the relative deformation $\Delta x/x$ the potential energy of one atom $(\Delta U)_1$ is increased by the amount:

$$(\Delta U)_1 = \frac{E}{2}\left(\frac{\Delta x}{x}\right)^2 \frac{1}{n} \quad . \qquad (3)$$

On the other hand, an increase of the potential energy for "maximum" possible deformation $\Delta x/x = 1$ is equal to ε_b. Thus, we get an assessment for the Young's modulus:

$$E = 2n\varepsilon_b \qquad (4)$$

In table 1 the Young's modulus values are presented which was obtained from equation (4) and the experimental values from [5], as well as the binding energy ε_b [4] and atomic concentration of the substance n [4]:

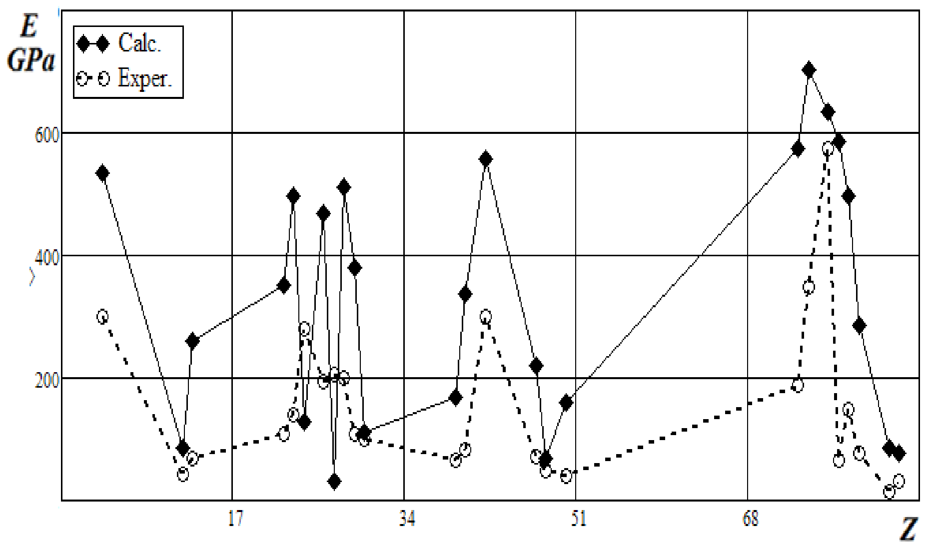
Table1.

№/№	Metal	$E_{calc} = 2n\varepsilon_b$ (GPa)	E_{exper} (GPa)	n $(10^{28} m^{-3})$	ε_b (eV)
1	Fe	138,6	195-205	8,50	4,29
2	Ni	154,0	200-220	9,14	4,435
3	Cr	129,8	280-315	8,33	4,10
4	Al	76,4	69-72	6,02	3,34
5	Cu	112,4	110-130	8,45	3,50
6	Pb	25,9	14-18	3,30	2,0
7	W	207,3	350-400	6,30	8,66
8	Ag	65,8	72-83,5	5,85	2,96

As can be seen from table 1, the most simple solids actually possess the Young's modulus order of hundreds GPa. In handbook [5] (p.48, Table. 3.2) the relative lengthening of samples after its failure is described, which the values for certain metals are in the range of 0.1 ÷0.75. Let's suppose that the "maximum" possible deformation was chosen $(\frac{\Delta x}{x})_{max}$ =0,5. Then, instead of (4) for Young's modulus can be written

$$E = \frac{2n\varepsilon_b}{(\frac{\Delta x}{x})^2_{max}} = 8n\varepsilon_b \qquad (1)$$

On fig. 2 the results of the Young's modulus calculation with the formula (5) are presented.



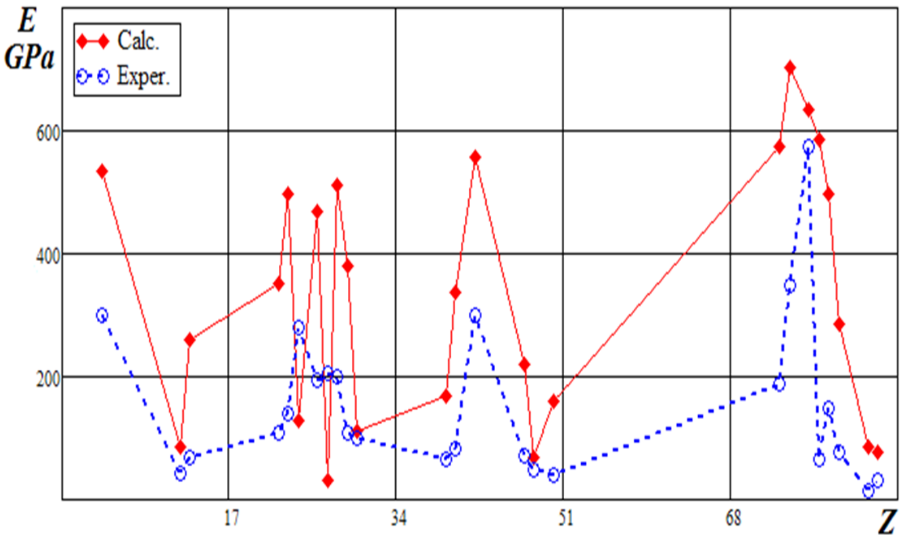


Fig2. *Experimental [5] and calculated values (5) of the Young's modulus*

ACKNOWLEDGEMENTS

One of the authors (N.P.K.) is grateful to the Competitiveness Program of the National Research Nuclear University “MEPhI” for supporting the study.

REFERENCES

[1] Weisskopf V.F., Bernstein H. (Search for Simplicity).American Journal of Physics. December 1985. v. 53, №12, p. 1140-1142.

[2] Weisskopf V. F. Modern Physics from an Elementary Point of View Lectures Given in the Summer Vacation Programme 1969, CERN Geneva, 1970.

[3] L.D. Landau, E.M. Lifshitz. Theory of Elasticity. v. VII. -M.: "Nauka". 1965.-203 p.

[4] Charles Kittel. Introduction to Solid State Physics. John Wiley and Sons, Inc. New York, London.

[5] Physical Quantities. Handbook. Ed. I.S.Grigoriev, U.Z. Mejlihova. -M.:Energoatomizdat. 1991.-1232 p.

Citation: *Erokhin K.M et al. "Relation between the Young's Modulus in Hooke's Law and the Binding Energy of a Single Atom in Solid", International Journal of Advanced Research in Physical Science (IJARPS), vol. 5, no. 12, pp. 38-40, 2018.*