Title
CALCULATED AND OBSERVED EFFECT OF SPHERICAL TUNGSTEN DISPERSIONS OF YOUNG’S MODULUS OF A GLASS

Permalink
https://escholarship.org/uc/item/27w9g4xv

Authors
Hasselman, D.P.H.
Fulrath, R.M.

Publication Date
1965-05-13
CALCULATED AND OBSERVED EFFECT OF SPHERICAL TUNGSTEN DISPERSIONS OF YOUNG'S MODULUS OF A GLASS

TWO-WEEK LOAN COPY
This is a Library Circulating Copy which may be borrowed for two weeks. For a personal retention copy, call Tech. Info. Division, Ext. 5545

Berkeley, California
DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.
CALCULATED AND OBSERVED EFFECT OF SPHERICAL TUNGSTEN DISPERSIONS OF YOUNG'S MODULUS OF A GLASS

D. P. H. Hasselman and R. M. Fulrath

May 13, 1965
CALCULATED AND OBSERVED EFFECT OF SPHERICAL TUNGSTEN DISPERSIONS ON YOUNG'S MODULUS OF A GLASS

D. P. H. Hasselman and R. M. Fulrath

Inorganic Materials Research Division, Lawrence Radiation Laboratory, and Department of Mineral Technology, College of Engineering, University of California, Berkeley, California

May 13, 1965

This note compares published theoretical expressions\(^1\)\(^-\)\(^4\) for the elastic moduli of two-phase systems with experimental results obtained for a sodium borosilicate glass containing dispersions of spherical tungsten particles. The glass used was of the same composition as the D-glass (16% Na\(_2\)O, 14% B\(_2\)O\(_3\), 70% SiO\(_2\)) used in previous investigations.\(^5\)\(^,\)\(^6\) The techniques of specimen preparation and measurement of Young's modulus were identical to those employed for the D-glass containing angular dispersions of alumina.\(^6\) Tungsten particle size was approximately 30µ. Figure 1 shows the microstructure of a glass-tungsten composite containing 40 volume percent tungsten. Table I gives the experimental and theoretical results, which are also illustrated in Fig. 2. For the theoretical calculation, glass property values were taken as Young's modulus = 805 kilobars\(^6\) and Poisson's ratio = 0.197.\(^5\) Tungsten elastic properties were taken as Young's modulus = 3550 kilobars\(^7\) and shear modulus = 1481 kilobars.\(^7\) Young's modulus for the predictions of Kerner,\(^1\) Hashin and Shtrikman,\(^3\) and Hashin\(^2\) were calculated from the

---

This work was done under the auspices of the U. S. Atomic Energy Commission.

The writers are, respectively, graduate student research assistant, Inorganic Materials Research Division, Lawrence Radiation Laboratory, and associate professor of ceramic engineering, Department of Mineral Technology, University of California, Berkeley, California.
corresponding equations for the bulk and shear modulus. Kerner's predictions coincided with Hashin's approximate equation for spherical phase geometry and Hashin and Shtrikman's lower bound for arbitrary phase geometry. Experimental results fall between Hashin's upper bound for spherical phase geometry and Hashin and Shtrikman's lower bound for arbitrary phase geometry, in agreement with theory. It is of interest to note here that similar results were obtained for the same glass containing angular dispersions of sapphire. It, therefore, appears that for this type of two-phase system, composed of a matrix containing random dispersions with Young's modulus higher than the matrix, dispersion shape, at least macroscopically, plays little or no role.
REFERENCES AND FOOTNOTES


* Attempts to investigate the effect of spherical particles of alumina on the elastic properties of the glass were unsuccessful, due to the formation of some porosity in the alumina during spheroidization introducing uncertainties in the elastic properties of the alumina.

Table I. Calculated and observed effect of spherical tungsten dispersion on Young's modulus of a sodium borosilicate glass ($E_0 = 805$ kilobars)

<table>
<thead>
<tr>
<th>Volume percent tungsten</th>
<th>Spherical phase geometry</th>
<th>Arbitrary phase geometry</th>
<th>Paul</th>
<th>Cubical inclusion</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upper bound</td>
<td>Lower bound</td>
<td>Approximate §</td>
<td>Upper bound</td>
<td>Lower bound</td>
</tr>
<tr>
<td>10</td>
<td>918</td>
<td>907</td>
<td>914</td>
<td>982</td>
<td>914</td>
</tr>
<tr>
<td>20</td>
<td>1053</td>
<td>1015</td>
<td>1039</td>
<td>1172</td>
<td>1039</td>
</tr>
<tr>
<td>30</td>
<td>1206</td>
<td>1137</td>
<td>1182</td>
<td>1359</td>
<td>1182</td>
</tr>
<tr>
<td>40</td>
<td>1386</td>
<td>1289</td>
<td>1349</td>
<td>1598</td>
<td>1349</td>
</tr>
<tr>
<td>50</td>
<td>1592</td>
<td>1479</td>
<td>1548</td>
<td>1850</td>
<td>1548</td>
</tr>
</tbody>
</table>

* Reference 3
+ Reference 4
† Reference 2
§ Identical to Reference 1
** Standard deviation
FIGURE LEGENDS

Fig. 1  Microstructure of a sodium borosilicate glass containing 40 volume percent tungsten.

Fig. 2  Experimental and theoretical results for Young's modulus of a sodium borosilicate glass matrix as a function of volume content of spherical tungsten particles.
Fig. 1
Fig. 2
This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.