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"Sensitized" Stress Build-up in Doped Sodium Borate Glasses by Ultraviolet Irradiation

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Stress build-up by ultraviolet irradiation was observed in some borate and borosilicate glasses. The stress is caused by volume contraction (density increase) of glasses in the irradiated surface layers. Doping of some kinds of metal oxides into the glasses increased the value of the stress.[1]

Effects of doping of various metal oxides in a sodium borate glass were examined. Compositions of prepared test glasses were x(metal oxide)·$2ONa_2O$·$(80-x)B_2O_3$ in mol% and melted from reagent grade chemicals (Na_2CO_3, HBO_3 etc.) in a platinum crucible in an electric furnace with silicon carbide heating elements (Table I). Tetragonal columns with polished surfaces were made from these glasses and they were subjected to ultraviolet irradiation for 100 hr. The light source was 400 W silica glass mercury discharge lamps (outer diameter: 17 mm, length: 150 mm) and the distance between the outer surface of the lamp and irradiated surfaces of the glasses was 8 mm. During irradiation, the glasses were cooled by flow of dry air. After irradiation, stress at irradiated surfaces were measured photoelastically. Results are given in Table I. Stresses lower than about 20 kg/cm² were not detected owing to residual thermal stresses in the glass samples and they are indicated as "very low or zero" in the table.

Table I. Composition of the test glasses

Glass. No.	Doped oxides	x	Stress Kg/cm²	Raw materials of doped oxides
11	Na_2O	3	64	undoped
29	CuO	0.1	210	CuO
32	GeO_2	3	177	GeO_2
58-1	CeO_2	0.1	230	CeO_2
58-2	〃	3	35	〃
82-1	PbO	0.1	210	Pb_3O_4
82-2	〃	0.5	45	〃
82-3	〃	3	*	〃
92-1	UO_2	0.1	160	$Na_2U_2O_7$
92-2	〃	3	*	〃

*: "very low or zero"

It is concluded that: a) Some kinds of oxides increase and some others decrease the stress by doping compared to that of undoped glass No. 11, b) Some kinds of oxides increase the stress when doped in small amounts, but at the same time, they prevent the stress build-up when doped in relatively large amounts and c) Increase or decrease of the stress are caused by rather small amounts of oxides doped in the glass.

From these experimental results it is supposed that: a) Transfer of energy which is given by photons of ultraviolet ray may take place between doped ions and the main constituent ions (Na^+, B^{3+}, O^{2-}), b) Doped ions may have some role on excitation and deexcitation of the main constituent ions or on the ejection of electrons or the formation of holes in glass by photoelectric effect and c) Doped ions may act as internal filter, concentrator of energy absorbed, excitation centers or energy sinks, respectively and in the respective concentration ranges. It is also expected that the stress build-up in glass is structure sensitive although it might be not so distinct as in the cases of some properties of semiconductors and phosphorus which have regular crystal lattice structures. Melting conditions, structural defects or prior irradiation by ionizing radiation might have some effects on stress build-up.

Reference

1) T. Kishii and K. Ōoka: Yōgyō Kyōkai Shi (J. Ceram. Assoc. Japan) **72** (1964) 193; **73** (1965) 108, 147, 168; [in Japanese]; **74** (1966) 226, 363 [in English]; Preprint of the Annual Meeting of The Intern. Congress on Glass (1966) p. 259.