WORLD SCIENCE PUBLISHING
LONDON LTD
LONDON
London International Monthly Conference on Multidisciplinary Research and Innovation

SURFACE ACTIVITY OF A THIOURETHANE-GROUP OLIGOMERIC MODIFIER (TGF-8) IN SODIUM LIQUID GLASS AND ITS IMPLICATION FOR WETTING OF PAPER SUBSTRATES

Murodov D.M.
Bukhara State Technical University, Bukhara, Uzbekistan
e-mail: doston_ximik@mail.ru

Abstract. The surface activity of the thiourethane-group oligomer TGF-8, synthesized from thiourea, glycerol and formaldehyde, was studied in undiluted sodium liquid glass (silicate modulus 2.8, $\rho = 1.38$ g/cm³) by the stalagmometric method at 20 °C. Increasing the TGF-8 content from 0 to 10 wt% lowered the surface tension from 67 to 48 mN/m (by 28.4 %). The Gibbs equation applied to the 2–8 wt% range gave an apparent surface excess $\Gamma \approx 4.0 \cdot 10^{-6}$ mol/m² and an area per adsorbed molecule $A \approx 0.41$ nm². Above 8 wt% the surface tension changed only within about 1 mN/m, which indicates apparent saturation of the liquid–air interface. At this content the surface tension of the adhesive approaches the surface free energy reported for recycled paperboard, which favours wetting of the substrate.

Keywords: liquid glass, sodium silicate, thiourethane, surface tension, Gibbs adsorption, wetting, paper adhesive.

Introduction

Sodium silicate (liquid glass) is an inexpensive, non-flammable and environmentally safe binder, but its use as an adhesive is limited by relatively low bond strength and sensitivity to moisture compared with organic adhesives [1]. Organic and hybrid modifiers are introduced to overcome these drawbacks [6]; however, most organic compounds are poorly compatible with the strongly alkaline silicate medium. For paper and cardboard bonding, the adhesive must first wet the substrate, and wetting is governed by the relation between the surface tension of the liquid adhesive and the surface free energy of the solid. The aim of this work was to evaluate the surface activity of the thiourethane-group oligomer TGF-8 in sodium liquid glass and to estimate its adsorption parameters at the liquid–air interface.

Materials and methods

Sodium liquid glass with a silicate modulus of 2.8 and a density of 1.38 g/cm³ was used without dilution. The oligomeric modifier TGF-8 was obtained by a two-stage isocyanate-free route: reaction of thiourea with glycerol (molar ratio 2:1, 110–120 °C), followed by polycondensation with formaldehyde in an alkaline medium [2]. TGF-8 was added in amounts of 2, 4, 6, 8 and 10 wt% relative to the mass of liquid glass, and the mixtures were stirred until homogeneous.

Surface tension was measured with a Traube stalagmometer by the drop-counting method at (20.0 ± 0.1) °C after 15–20 min of thermostatting. Distilled water was used as the reference liquid ($\sigma_0 = 72.74$ mN/m at 20 °C [3]). Surface tension was calculated from the relative formula $\sigma_x = \sigma_0 \cdot (n_0 \cdot \rho_x)/(n_x \cdot \rho_0)$, where n is the number of drops and ρ is the density determined pycnometrically. Each measurement was repeated three times. Because the drop-counting method is sensitive to the viscosity of the liquid [4], the values obtained for liquid glass are treated as relative.

The surface excess was calculated from the Gibbs equation $\Gamma = -(1/RT) \cdot (d\sigma/d \ln C)$, and the area per adsorbed molecule from $A = 1/(\Gamma \cdot N_A)$.

Results and discussion

The results are summarized in Table 1 and Fig. 1. Unmodified liquid glass had a surface tension of 67 mN/m. With increasing TGF-8 content the surface tension decreased monotonically and reached 49

© 2026 London International Monthly Conference on Multidisciplinary Research and Innovation. All Rights Reserved.

mN/m at 8 wt% and 48 mN/m at 10 wt%, i.e., a 28.4 % reduction. Thus TGF-8 behaves as a surface-active substance in the silicate medium and accumulates at the liquid–air interface.

Table 1. Effect of TGF-8 content on the surface tension of sodium liquid glass (M = 2.8; 20 °C)

C(TGF-8), wt%	**0**	**2**	**4**	**6**	**8**	**10**
σ, mN/m	67	63	59	54	49	48
Δσ, %	–	6.0	11.9	19.4	26.9	28.4

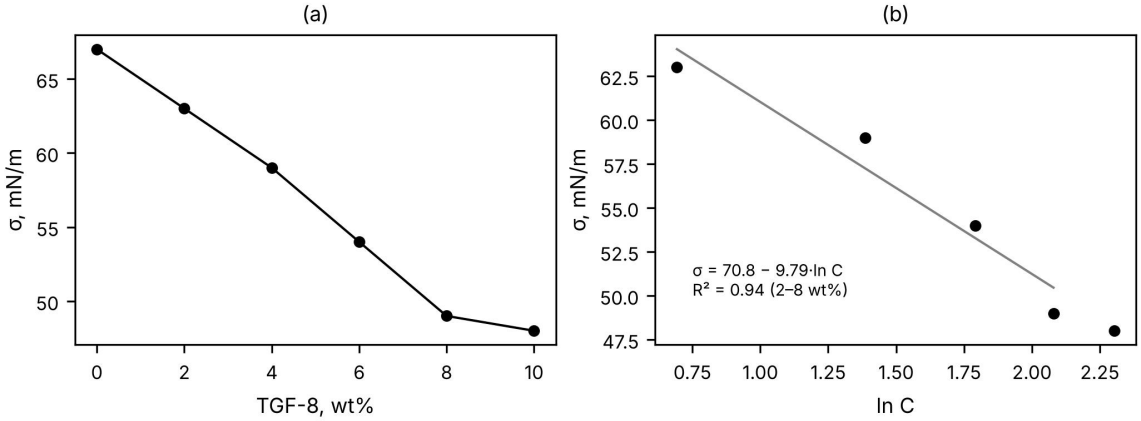


Fig. 1. Surface tension of liquid glass versus TGF-8 content (a) and versus ln C with the linear fit used in the Gibbs equation (b)

In the 2–8 wt% range the dependence σ = f(ln C) was approximated by a straight line with a slope of dσ/d ln C = −9.79 mN/m (R^2 = 0.94). The resulting apparent surface excess is $\Gamma \approx 4.0 \cdot 10^{-6}$ mol/m², and the area per adsorbed molecule is A ≈ 0.41 nm². Between 8 and 10 wt% the surface tension changed by only about 1 mN/m, which is comparable to the measurement uncertainty. We therefore interpret this region as apparent saturation of the interface rather than as a critical micelle concentration, since micelle formation was not examined.

These parameters should be interpreted with caution. The Gibbs equation was applied in its ideal form, with concentrations used in place of activities, to a concentrated alkaline electrolyte, and the σ–ln C dependence shows some curvature (R^2 = 0.94). If Γ is assigned to oligomer molecules with a number-average molar mass of about 2.9 kg/mol, it would correspond to about 11.6 mg/m², which is high for a monolayer. This suggests that the surface activity is governed mainly by lower-molecular-weight fractions of the modifier, so Γ and A are effective values.

From a practical standpoint, the decrease in surface tension is important for wetting cellulosic substrates. The surface free energy of recycled corrugating medium determined by the contact-angle (Owens–Wendt) method has been reported as approximately 48–51 mN/m [5]. Unmodified liquid glass (67 mN/m) therefore has a surface tension well above the substrate surface energy, whereas at 8–10 wt% TGF-8 (48–49 mN/m) the two values become comparable. This is a favourable condition for spreading of the adhesive and for its penetration into the fibre network. It agrees with the increase in peel strength of the modified adhesive observed by us at the same modifier content (from 2.28 to 3.22 kN/m at 8 wt%). This comparison is approximate, because the total surface free energy of a solid is not identical to its critical surface tension of wetting.

Conclusions

© 2026 London International Monthly Conference on Multidisciplinary Research and Innovation. All Rights Reserved.

1. The thiourethane-group oligomer TGF-8 is surface-active in sodium liquid glass: at 10 wt% it lowers the surface tension from 67 to 48 mN/m (by 28.4 %).

2. The Gibbs equation (2–8 wt%) gives an apparent surface excess $\Gamma \approx 4.0 \cdot 10^{-6}$ mol/m² and A ≈ 0.41 nm². Apparent saturation of the interface is reached at about 8 wt%.

3. At 8 wt% TGF-8 the surface tension of the adhesive approaches the surface free energy of paperboard. This creates favourable conditions for wetting and is consistent with the improved adhesion of the modified composition. Measurements of the dynamic surface tension and of contact angles on paper substrates are planned to refine these conclusions.

References

1. Faria D.L., Soriano J., da Silva L.C.P., Sanadi A.R., Tonoli G.H.D. Improved performance in multilayer paper composites through the incorporation of inorganic nanomaterials into sodium silicate adhesive // Materials. 2026. Vol. 19. Art. 1897. DOI: 10.3390/ma19091897.

2. Murodov D.M., Niyozov A.K., Akhmedov V.N. Synthesis and preliminary spectroscopic-thermal characterization of a novel thiourethane-group oligomeric modifier (TGF-8) based on thiourea and glycerol // Chemical Science International Journal. 2026. Vol. 35(5). P. 110–117.

3. IAPWS R1-76(2014). Revised Release on the Surface Tension of Ordinary Water Substance. International Association for the Properties of Water and Steam, 2014.

4. Harkins W.D., Brown F.E. The determination of surface tension (free surface energy), and the weight of falling drops // Journal of the American Chemical Society. 1919. Vol. 41. P. 499–524.

5. Keresztes J., Csóka L. Characterisation of the surface free energy of the recycled cellulose layer that comprises the middle component of corrugated paperboards // Coatings. 2023. Vol. 13(2). Art. 259. DOI: 10.3390/coatings13020259.

6. Razgovorov P., Loginova S., Politaeva N., Velmozhina K., Shinkevich P. Modification of liquid glasses is a key factor in the technology of obtaining hybrid compositions and coatings with anticorrosive properties // Coatings. 2023. Vol. 13. Art. 974. DOI: 10.3390/coatings13060974.

© 2026 London International Monthly Conference on Multidisciplinary Research and Innovation. All Rights Reserved.