

INTERACTIONS OF GUM DEPRESSANTS WITH TALC: STUDY OF ADSORPTION BY SPECTROSCOPIC AND ALLIED TECHNIQUES

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Gums are often used as depressants for talceous gangue minerals in the flotation of nickel and platinum bearing ores. However, the mechanisms of gum adsorption on talc are not clearly established. In this paper, adsorption of guar gum at the talc-solution interface is investigated using spectroscopic and allied techniques. Guar gum adsorption on talc is not affected much by changes in solution conditions such as pH and ionic strength. Electrokinetic studies showed that guar gum decreased the negative zeta potential of talc but did not reverse the charge. Fluorescence spectroscopy studies conducted to investigate the role of hydrophobic bonding using pyrene and dansyl probes showed no evidence of the formation of hydrophobic domains at talc-aqueous interface. Urea, a hydrogen bond breaker, reduced the adsorption of guar on talc to the same extent as that for guar/alumina system, in which hydrogen bond plays an important role. All of the above results suggests that one of the main driving forces for guar adsorption on talc is hydrogen bonding rather than electrostatic or hydrophobic force.

INTRODUCTION

Talc is a layered hydrous magnesium silicate in which the layers are held together by van der waal's bonds. During grinding, two different surfaces are formed. Basal cleavage planes are formed by rupture of van der waal's bonds. Because the resulting planes contain no broken Si-O and Al-O bonds, the surface is neutral and hydrophobic. However, the edges of the mineral sheets contain broken Si-O and Al-O bonds and, consequently, charged species and exhibit hydrophilic properties.

Guar gum is a natural nonionic polysaccharide with the average molecular weight of 100,000 to 2000,000. The repeating unit of guar gum is shown in Fig. 1. Each unit contains nine OH groups. These OH groups are available for hydrogen bonding of the guar gum molecule to mineral surfaces [1].

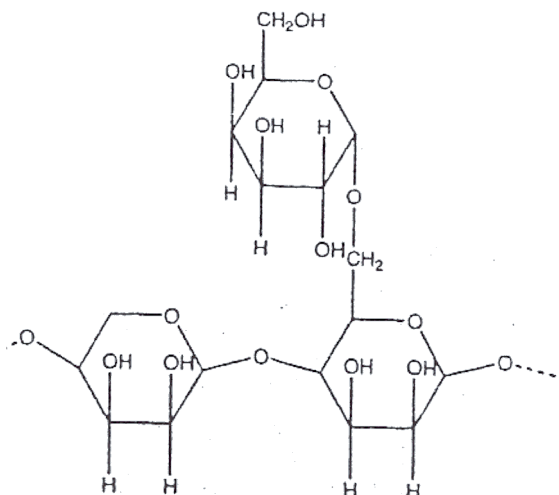


Fig. 1 The monomeric structure of guar gum

In the flotation of platinum bearing ores, guar gum is often used as a depressant for the talceous gangue minerals. In spite of a large number of studies conducted easier, the mechanism of adsorption of guar gum on talc has not yet been well understood. Mackenzie [2], Pugh [3], Healy [4] and Rath [5-6] proposed that the mechanisms that govern the adsorption of polymers on mineral surfaces include hydrophobic interaction, hydrogen bonding, chemical and electrostatic interactions. However the reason for the selectivity of the adsorption of depressants on minerals could not be accounted for. Steenberg et al. [7-8] and Ralston et al. [9] proposed that the adsorption of guar gum on talc occurs mainly at the talc basal planes via hydrophobic force. In contrast, Rath et al. [10] proposed that the adsorption of guar occurs through hydrogen bonding on the talc edges.

The objective of the present study was to explore further the mechanistic aspects of the interactions between guar gum and talc using spectroscopic, electrostatic and adsorption measurements.

MATERIALS AND EXPERIMENTS

Materials

Talc was obtained from Cytec Industries. Its particle size distribution was 150-300 microns. The N₂ BET surface area for talc was measured using a Coulter Omnisorb 100. The specific surface area obtained was 2.61 m²/g after further grinding. Unmodified guar gum and dansyl-labelled guar gum were obtained from Cytec Industries.

All guar gum stock solutions were prepared by the following method. 0.045 g guar gum powder was quickly added into 45ml of vigorously stirred water. The solution was stirred further for 30 minutes and refrigerated overnight to ensure complete hydration or dissolution of guar gum and then filtered through filter paper (Whatman #4) to remove any undissolved impurities.

Experiments

Adsorption Measurements

The suspensions of talc, with ionic strength adjusted to the desired level using KCl at 10% solid loading were ultrasonicated for 30 minutes and then stirred with a magnetic stirrer for 2 hours after the pH was adjusted to the desired value using HCl and KOH. Guar gum stock solution was then added to the talc suspension and left to condition overnight at constant pH. The suspensions were then centrifuged. The supernatants were pipetted out for determination of guar concentration by TOC (Total Organic Carbon Analyzer). The adsorption density of guar gum on talc was calculated using initial and residual guar gum concentrations.

Colorimetric Method

The colorimetric method was used in experiments wherein other organic additives, such as urea, were used. The procedure described by Dubois et al [11] was followed. 80% phenol and 5 ml 98% sulfuric acid were added to 2ml supernatant obtained after centrifugation. After 4 hours of color development under warm conditions UV absorbance was measured at a wavelength of 487.5nm. By the difference of absorbance, the adsorption density of guar on talc (or alumina) was calculated.

Electrokinetic Measurements

Appropriate amount of 10^{-3} M KNO_3 solution was added to each vial, followed by small amounts of talc and ultrasonicated for 30 minutes, magnetically stirred for 2 hours and the pH adjusted to the desired value using HCl and KOH. Finally, the guar gum stock solution was added and left to condition overnight keeping pH constant. The zeta potential was then measured using a Zeta meter.

Fluorescence Studies

The suspensions of talc at 10% solid loading were ultrasonicated for 30 minutes and mixed for 2 hours with a magnetic stirrer. Guar gum stock solution with saturated pyrene in it or dansyl-labeled guar gum was then added to the talc suspension. The vials containing the suspensions were quickly wrapped with aluminum foil to avoid light and left to condition overnight. Finally, the hydrophobicity of the supernatant and the solid were analyzed via a LS-1 fluorescence spectrophotometer (Photon Technology International) separately.

RESULTS AND DISCUSSION

Adsorption Studies

The influence of pH

Fig. 2 shows the isotherms for the adsorption of guar gum on talc in 0.1 M KCl at pH 4 and pH 9. It can be seen from the data that the adsorption density does not vary measurably between pH 4 and 9. If electrostatic interaction plays an important role in the adsorption process, the adsorption density of guar gum on talc should have been affected significantly since the surface charge of talc should change with change in pH from 4 to 9. Such is not the case here, and so it can be concluded that electrostatic interaction is not the dominant force for the adsorption of guar gum on talc.

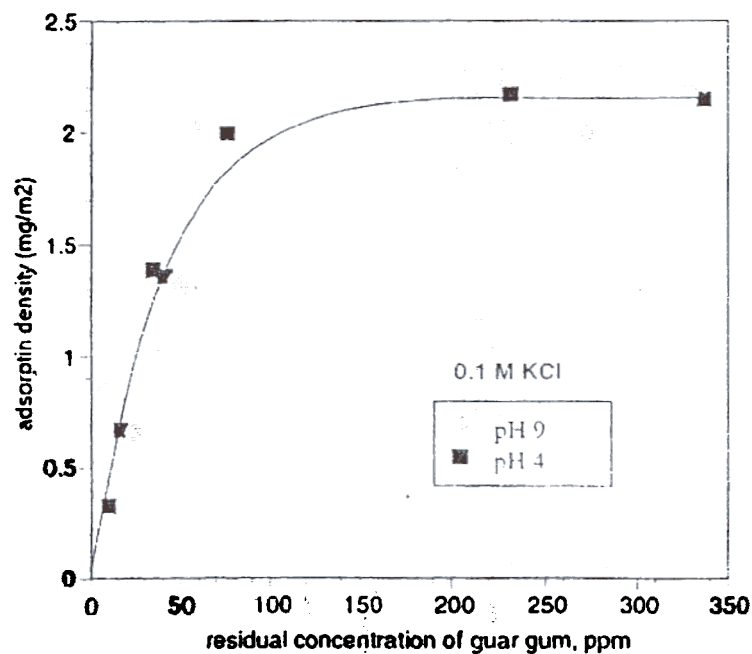


Fig. 2 Adsorption isotherm of guar gum on talc at different pH

The influence of ionic strength

Adsorption isotherms of guar gum on talc as a function of ionic strength at pH 9 are shown in Fig. 3. From this data, it is clear that the influence of ionic strength is negligible. It is well known that if hydrophobic force makes a significant contribution to adsorption of polymer on mineral, the adsorption density will be increased in the presence of KCl due to "salting-out" effect. Also if the ionic strength increases gradually from 0.1M to 1M, the adsorption density will be decreased. This is not in agreement with the experimental results. It would appear that the hydrophobic force is not the main driving force for the adsorption of guar gum on talc.

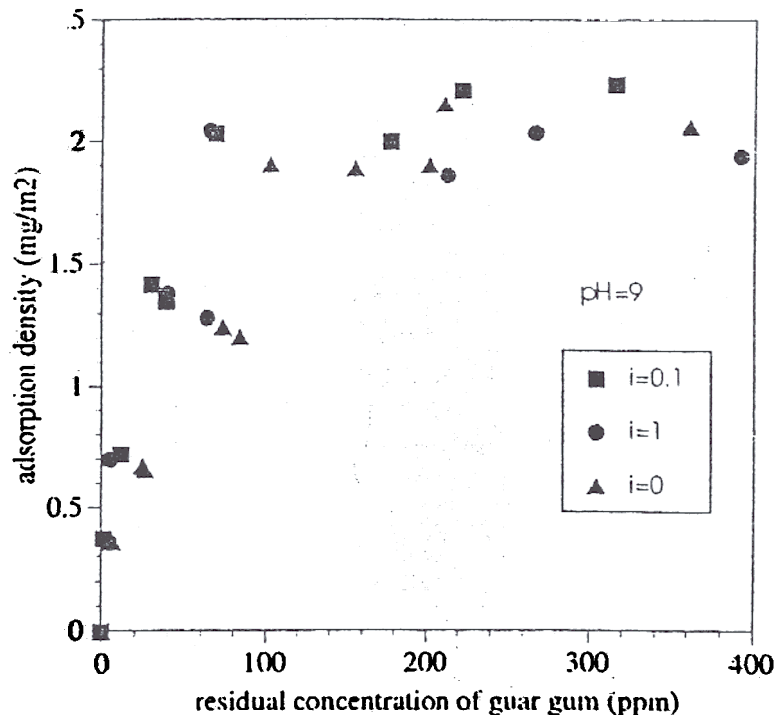


Fig. 3 Adsorption isotherm of guar gum on talc with different ionic strength

Comparison of adsorption on talc and alumina with and without urea

Adsorption isotherms for guar on talc and alumina in the presence and absence of urea at pH 8.5 are shown in Figs. 4 and 5 respectively. A comparison of the results presented in these figures indicates that urea, a hydrogen bond breaker, reduces the adsorption of guar on talc to the same extent as that on alumina. Since the driving force for the adsorption of guar gum on alumina is hydrogen bonding, it is possible that hydrogen bonding plays a similar important role in the adsorption of guar on talc as in guar/alumina system.

Electrokinetic Studies

It is evident from the electrokinetic data shown in Fig. 6 that the surface of talc is anionic and the isoelectric point of talc is located around pH 2.5. Above pH 2.5, the electronegative character increases with increase in pH up to pH 7 and thereafter remains almost constant. Addition of different concentrations of guar gum correspondingly reduces, but does not reverse the negative zeta potential of talc without any shift in the isoelectric point. Possible reason is that the adsorption of guar gum on the surface of talc only "masks" the negative charge on talc. It is certain that electrostatic force is not the dominant driving force for the adsorption process.

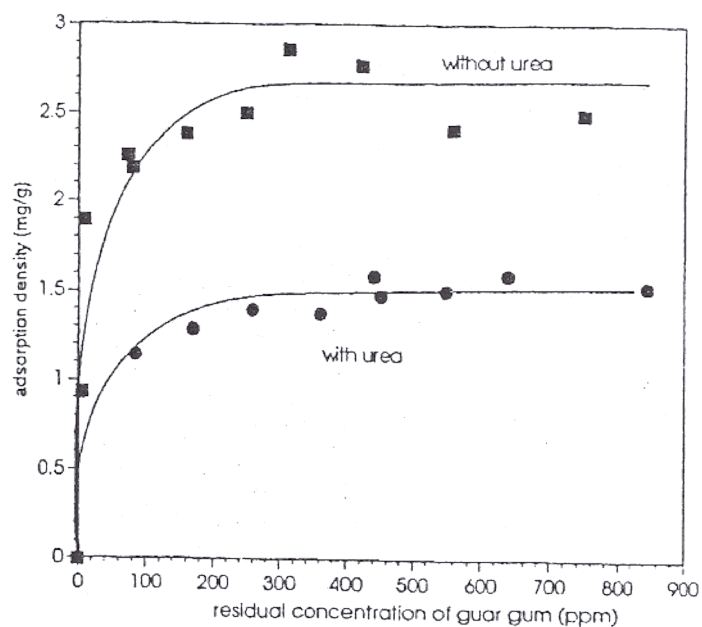


Fig. 4 Adsorption isotherm of guar gum on talc with and without urea (I=0)

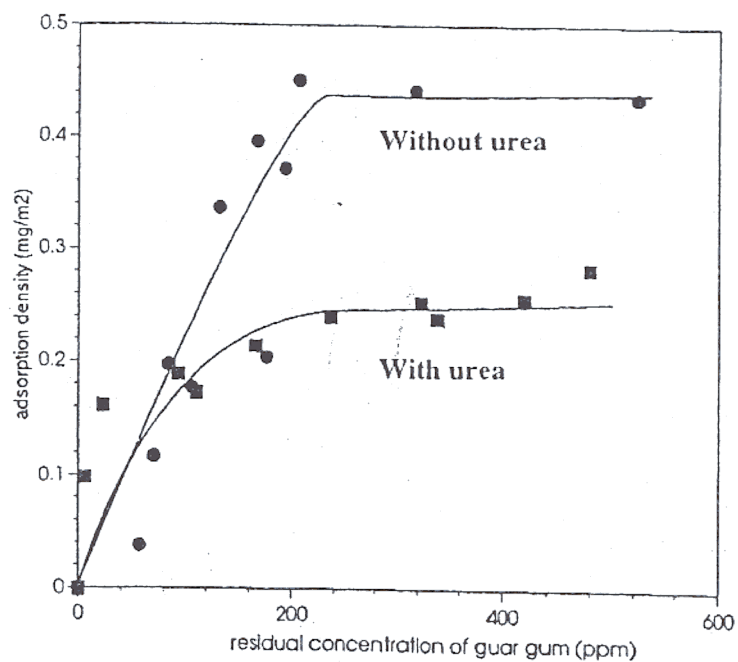


Fig. 5 Adsorption isotherm of guar gum on alumina with and without urea

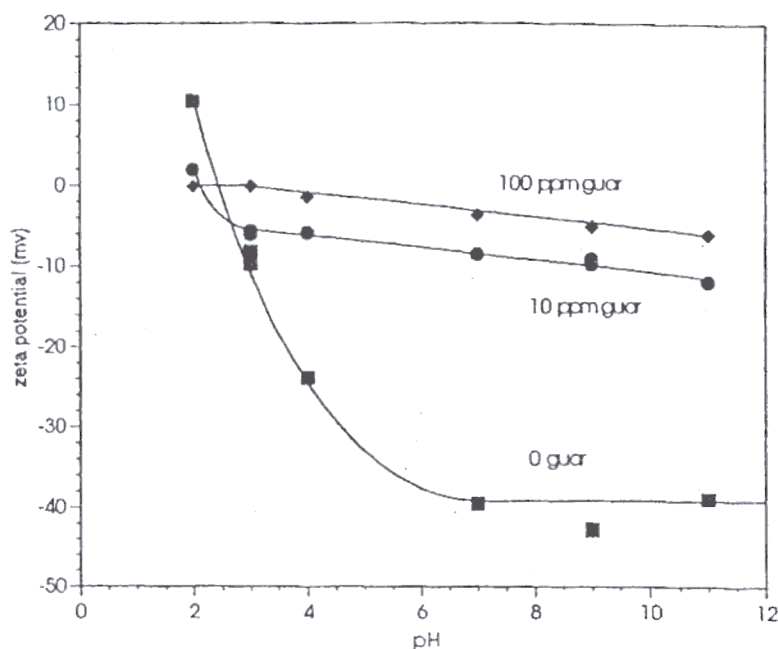


Fig. 6 Zeta potential of talc as a function of pH in the presence and absence of guar gum

Fluorescence Studies

To better understand the nature of guar gum adsorption, microstructure of the adsorbed layer was probed using fluorescence spectroscopy. Fluorescence spectroscopy is a well-developed method for testing hydrophobic domain formation during adsorption. Fluorescence data for pyrene and dansyl probes for the talc-solution interface (after guar adsorption) and for the supernatant are shown in Figs. 7 and 8. Pyrene fluorescence showed no hydrophobic domain at the talc-aqueous interface because the polarity parameter remained almost constant at 0.92 for both the guar adsorbed talc and its supernatant with change in concentration of guar gum. Study with a new fluorescence probe, dansyl, supports the role of hydrophilic force. From the dansyl fluorescence, it is evident that the wavelengths of maximal emission of the dansyl fluorescence for guar adsorbed talc are all far beyond 513nm-the wavelength separating hydrophilicity from hydrophobicity- suggesting the formation of hydrophilic domains for the adsorption of guar gum on talc.

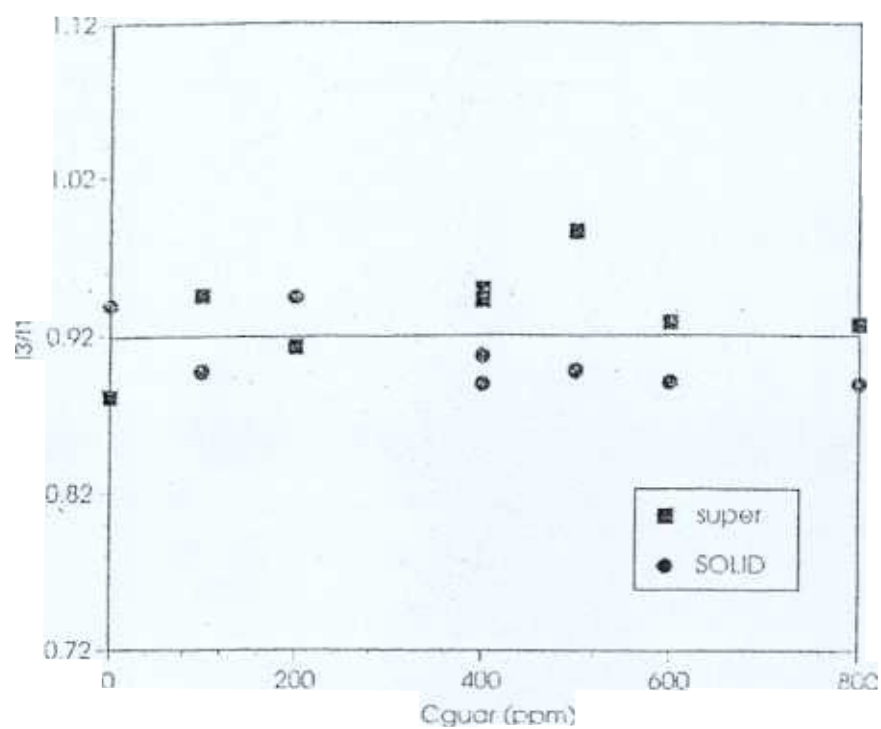


Fig. 7 Pyrene fluorescence for guar gum and talc interface

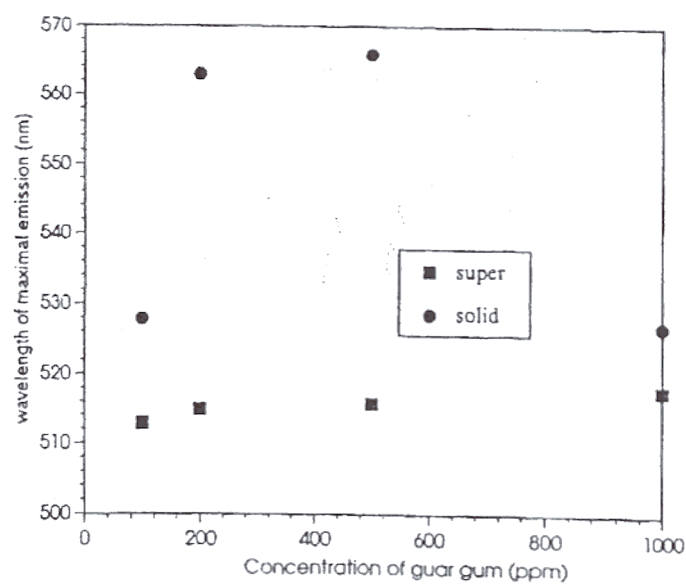


Fig. 8 Dansyl fluorescence for labeled guar gum adsorbed talc

CONCLUSIONS

Electrokinetic studies of adsorption of guar on talc in the pH range 2-11 showed that guar gum decreased the negative zeta potential of talc but did not reverse the charge.

2. Adsorption studies also showed that the adsorption isotherms of guar gum on talc are not affected by change in pH. These results suggest that the electrostatic force is not the dominant force for the adsorption process.
3. The adsorption of guar gum on talc was not affected by ionic strength.
Pyrene Fluorescence showed no hydrophobic domains' formation for the adsorption of guar gum at talc-aqueous interface. Measurements with a new fluorescence probe, dansyl, supports the role of hydrophilic forces.
5. Urea, a hydrogen bond breaker, reduces the adsorption of guar on talc to the same extent as that on alumina.
6. These results support a mechanism involving hydrogen bonding rather than hydrophobic force.

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