УДК 66.091:648
DOI: https://doi.org/10.20535/2218-93002612020199834

TECHNICAL DETERGENT FOR EQUIPMENT OF ALTERNATIVE ENERGY SOURCES BASED ON HELIO SYSTEM

H. M. Prokofyeva, P. V. Sudarushkina, M. Jn. Berkut*
National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute»,
Kyiv, Ukraine
*e-mail: kxtp@kpi.ua

Silicon wafers of solar panels are cleaned by flushing using technical detergents. The study using various physicochemical methods (IR spectroscopy, spectral, X-ray diffraction, X-ray fluorescence, atomic absorption, flame photometry, thermogravimetric, electron paramagnetic resonance, electron spectroscopy, polarization resistance) showed that the introduction of triethylenetetramine in the composition of TD promotes the formation of persistent complex compounds with pollution ions. Also was found that the modified TD has anti-corrosion properties. From this we can conclude that the introduction of triethylenetetramine into TD improves the washing properties of the product and increases its environmental safety, since it has a multifunctional effect, thereby contributing to a decrease in the salt content in TD.
Keywords: *pollution; silicon wafer; solar power; surfactants; TD; washing by aqueous solutions.*

Introduction

The widespread introduction of alternative energy sources, especially in decentralized independent power engineering, among which solar energy is a priority, contributes to the improvement of industrial production of solar and terrestrial space batteries, the quality of which depends on the purity of the silicon wafer.

Among the various developer methods for cleaning solid surfaces from contamination, the most effective are physical and chemical methods using technical detergents. Therefore, studies aimed at the development of effervescent technical determents are relevant.

One of the main directions in improving existing and developing new technical detergents is the introduction of multifunctional ingredients into their composition. Them reduces the amount of salt and increases environmental safety. Of particular interest are nonionic surfactants.

Experimental Part

The composition of the silicon wafer pollution was determined, with the help of different physicochemical methods: spectral, X-ray fluorescence, X-ray crystallography, atomic absorption, thermal gravimetric, IR spectroscopy, polarization resistance, electron spectroscopy and other. The main component is iron cation, which support processes of resorption. Interestingly, triethylenetetramine with the amide group can demonstrate anticorrosive properties in the detergent.

For the determine of the mechanism of interaction of RNH_2 in a technical detergent with cations of the pollutant, substance behavior was investigated using a spectrophotometric method if there was RNH_2 in an aqueous medium. The dependency graph $A = f(\lambda)$ of Fe (III) - RNH_2 system indicates the formation of colorless complex, that are stable in time, which are characterized by two maxima in the ultraviolet part of the spectrum: $\lambda = 256$ nm and $\lambda = 290$ nm (Fig. 1).

To definition of optimal conditions that would ensure the complete binding of Fe (III) into the complex, the influence on the complexation by the concentrations of RNH_2 and the acid-base condition was researched. The most complete binding is observed with a hundredfold excess of RNH_2 (Fig. 2). The result of the research of the dependency $A = f(\lambda)$ for various ratios of Fe(III): RNH_2 revealed the displacement of the maxima in a long-wavelength part of the spectrum.

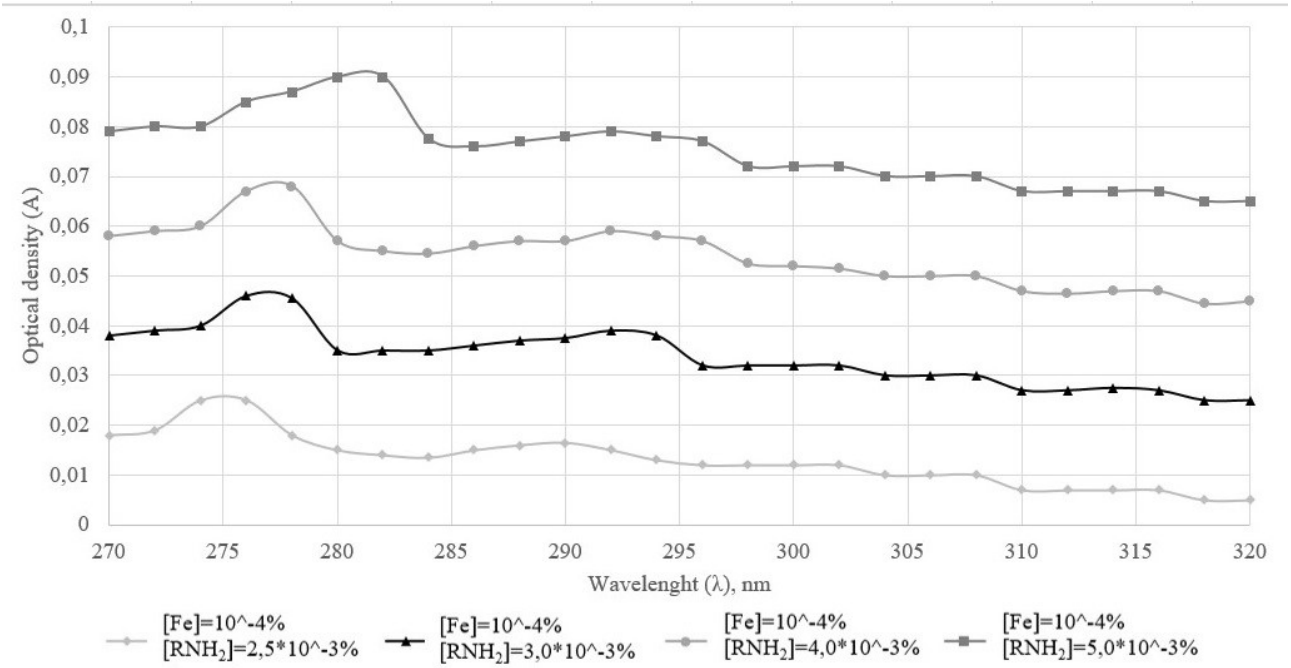

Fig. 1. Effect of light absorption on the wavelength in the Fe(III): RNH_2 system

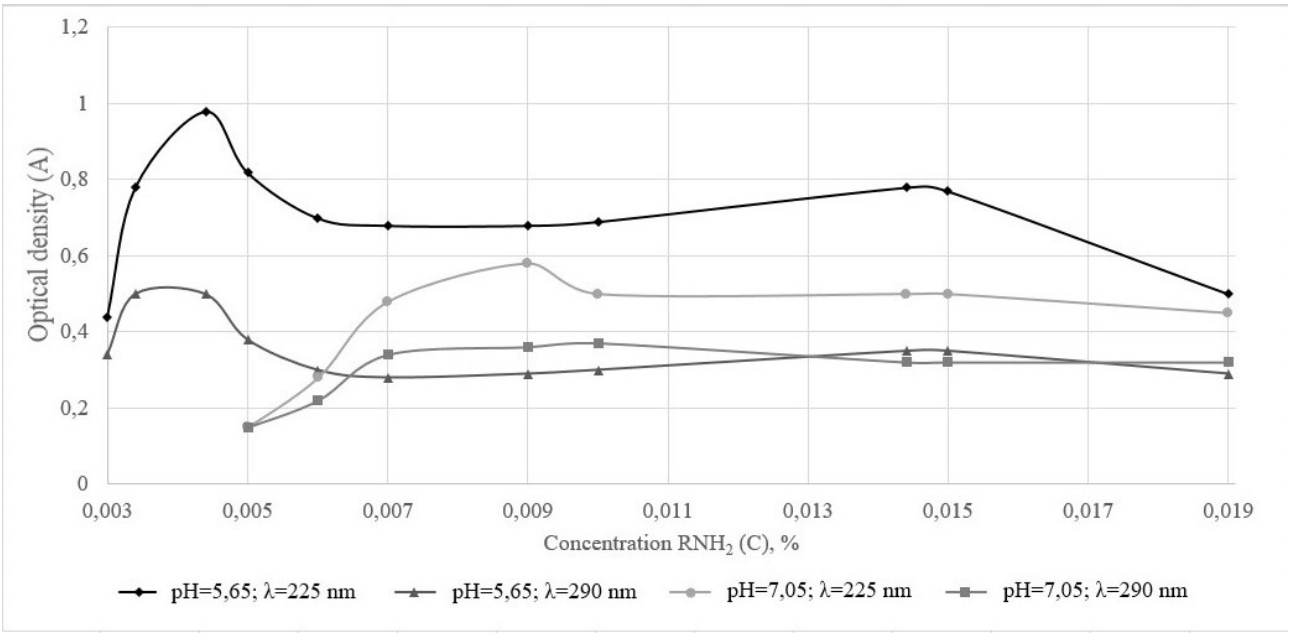

Fig. 2. Effect of light adsorption on the Fe (III) - RNH_2 system

The effect of acid-base condition on the complex substance formation process was investigated in the pH range of 1 to 11. The reason of existence of two complex formation pieces on the dependency A = f(λ) (pH = 5.65; pH = 7.05) may occur due to involvement of the Fe ions into this process and to different RNH_2 tautomers. That is why it's necessary to research the impact of RNH_2 concentration on equilibrium in the Fe (III) - RNH_2 system. The most complete binding is observed with correlation Fe (III) : RNH_2 1:50 for pH = 5.65 and 1:75 for pH = 7.05

Mathematical processing of the dependency A = f(RNH_2) made possible to conclude about compound of the formed complex. The process is characterized by the formation of complexes with the ratios Fe (III) : RNH_2 = 1:1 and 1:2. It was established using limited logarithm method.

Based on the result the process of complex formation can be shown as:

$Fe^{3+} + RNH_2 = FeHNR^{2+} + H^+$ (1)
$FeHNR^{2+} + RNH_2 = Fe(HNR)_2^{+} + H^+$ (2)

The results of light absorption of solution with a constant concentration of Fe ions and increasing concentration of RNH_2 were used to calculate the constant of the instability constant:

$$K_1 = \frac{[FeHNR^{2+}]}{[Fe^{3+}][RNH_2]}, \quad (3)$$

$$K_2 = \frac{[Fe(HNR)_2{}^{+}]}{[Fe^{3+}][RNH_2]^2}. \quad (4)$$

Concentration of Fe were calculated on equation of simple and complex substance:

$$[Fe^{3+}] = [Fe^{3+}]_{tot} - [FeHNR^{2+}] = [Fe^{3+}]_{tot} - \frac{A_1}{\varepsilon}, \quad (5)$$

$$[Fe^{3+}] = [Fe^{3+}]_{tot} - [FeHNR^{2+}] = [Fe^{3+}]_{tot} - \frac{A_2}{\varepsilon}, \quad (6)$$

where A – optical density of ligands, ε - extinction number, $\varepsilon = \frac{A_{max}}{\lambda}$, where λ – solution layer thickness (λ = 1 cm)

To calculate the concentration of free ligand the amendment that takes into account the process of dissociation is used:

$$[HNR^-] = \left(c - 2\frac{A}{\varepsilon}\right)\left(1 + \frac{[H^+]}{K'}\right), \quad (7)$$

where c – total concentration of RNH_2, K' – dissociation constant RNH_2

The results of calculation show that formation mainly occurs with correlation metal:ligand = 1:1.
Produced complex compounds have sufficient strength, as can be evidenced by the result of the research of the complexation process in the presence of some other ligands that have high complexing ability: acetate, oxalate, fluoride, citrate, tartaric acid ions.
The effect of ligands (metal:ligand = 1:50) grows in a next way:

$Ac^- > C_2H_4O_6^{2-} > C_2O_4^{2-} > F^- > C_6H_5O_7^{2-}$ (8)

The process mechanism of complex formation in the Fe (III) : RNH_2 system can also be proved by the IR spectroscopy analysis. The comparative analysis of IR-specters of triethylenetetramine and solid triethylenetetramine Fe(III)-complex produced in different pH conditions shows that the interaction in system "metal:ligand" is done by amine group. The interaction is proved by the missing NH_2 band (υ = 3300 cm^{-1}) and the increasing intensity of CN-band (υ = 1210-1315 cm^{-1}) and group of bands –CO-CH_3 (υ = 1355-1360 cm^{-1}). There is a strong decrease of valence and deformation fluctuation of the second amide band (N-H, C-N) (υ = 1550 cm^{-1}). The displacement of CH_3-band (υ = 2860 cm^{-1}) is observed in IR-spectrum. The change of intensity and placement of symmetric and asymmetric CH_2-band of carbon chain (υ = 720; 755; 1130 cm^{-1}) also proves RNH_2 takes part in complex formation.
The results of previously held spectrophotometry analysis prove that the tydrated form of Fe is involved in complex formation process. It can be shown on the IR-spectrum where system Fe (III) : RNH_2 is present on Me-O band (pH = 5.65). the increase of intensity of Me-O band (υ = 620 cm^{-1}) in the complex substances obtained at pH = 7.05 and pH = 9.5 condition, proves the increase of Fe(III) hydration level.

The research of the corrosion activity of technical determent with help of the method of polarization resistance showed a low corrosion rate. For the obtained substances washing properties were investigated, which showed good characteristics in the laboratory and at the production.

Conclusion

Complex of Fe(III)- triethylenetetramine was researched with help of various physical and chemical methods.

The determine of the dependency light absorption from concentration ions of ligand and pH an aqueous medium by spectrophotometric method. Reveal the process of step complex formation.

Defined corrosive activity of the technical detergent, $\omega = 6.5 \cdot 10^{-3}$ mm/year

Technical detergent, that was modified by triethylenetetramine, is shown a high washing quality.

References

Abramzon L.A. *Surfactants. Properties and application*. Leningrad: Khimiya, 1981. [In Russian].

Corrosion resistance of chemical process equipment. Corrosion under the influence of coolants, refrigerants and working fluids. Ref. Izd. / A.M. Sukhotin, A.F. Bagachev, V.G. Polish et al. / Ed. A.M. Sukhotina. V.M. Barenbilt. Leningrad: Khimiya, 1988. [In Russian].

Degtyarev G. *The use of detergents*. Moscow: Kolos, 1981. [In Russian].

Emelen M.I., Gerasimenko A.A. *Protection of machines against corrosion in the field.* Moscow: Mashunostroenie, 1980. [In Russian].

Ignatiev R.A., Mikhailova A.A. *Protection of equipment against corrosion, aging and biodeterioration*. Moscow: Rosselkhozizdat, 1987[In Russian].

Kozlov Ju., Kuznecov O., Tel`nov A. *Cleaning products in mechanical engineering*. Moscow: Masunostroenie, 1982. [In Russian].

Nakamoto K. *Infrakrasnyie spektryi neorganicheskih i koordinatsionnyih soedineniy.* Moscow: Mir, 1966. [In Russian].

Nakanicu K. *Infrakrasnyie spektryi i stroenie organicheskih soedineniy*. Moscow: Mir, 1965. [In Russian].

Prokofyeva G., Belousova N., Bilenko N. The study of anti-corrosion ingredients in technical detergents. VIII International Conference" Problems of Corrosion and Corrosion Protection of Structural Materials Physicomechanical Institute named by G. Karpenko NASU. 6-8 June, Lviv, 2006. [In Ukrainian].

Prokofyeva G., Stolyarova I. The theoretical basis for the development of an environmentally friendly system for cleaning technological equipment // Collection of scientific papers of the international scientific conference: - v.2. - Odessa: Astroprint, 2001 [In Ukrainian].

Shtupel G. *Synthetic detergents and cleaners*. Moscow: Gosudarstvennoe scientific tehniçeskoe izdatel`stvo himiçeskoy literaturı 1960 [In Russian].

Silatov B.M., Ermakov A.A., Stepanov N.I., Ryizhinskiy I.N., Polukarov A.B. & Maychenkov A.M. (2004) Patent No1598535.

Stahov Jn.A. *Ochistka neftesoderzhaschih stochnyih vod predpriyatiy hraneniya i transporta nefteproduktov*. Leningrad: Nedra, 1983. [In Russian].

Volkov V. *Surfactants in detergents and chemical cleaning enhancers*. Moscow: Legprombytizdat, 1985. [In Russian].

Received 26.12.2019
Revised 18.02.2020
Accepted 06.03.2020

ТЕХНІЧНІ МИЙНІ ЗАСОБИ ДЛЯ УСТАТКУВАННЯ В АЛЬТЕРНАТИВНИХ ДЖЕРЕЛАХ ЕНЕРГІЇ НА ОСНОВІ ГЕЛІОСИСТЕМ

Г. М. Прокоф'єва, Т. В. Сударушкіна, М. Є. Беркут*
НТУУ «Київський політехнічний інститут ім. І. Сікорського», Київ, Україна
*e-mail: kxtp@kpi.ua

Серед методів очищення кремнієвих пластин сонячних батарей найбільш ефективним є фізико-хімічний, тобто промивка з використанням технічного мийного засобу (ТМЗ). Тому покращення мийних характеристик ТМЗ та забезпечення їх безпечності для навколишнього середовища є актуальною проблемою.

Різними фізико-хімічними методами (ІК-спектроскопічний, спектральний, рентгеноструктурний, рентгено-флуоресцентний, атомної абсорбції, полум'яної фотометрії, термогравіметричний, електронного парамагнітного резонансу, електронної спектроскопії, поляризаційного опору) було досліджено взаємодію триетилентетрамина з іонами забруднення. Доведено утворення безбарвних комплексних сполук у системах забрудник - компонент ТМЗ. Їх стійкість була перевірена у порівнянні з рядом неорганічних та органічних лігандів. Математична обробка даних дала змогу оцінити вплив кислотно-основних умов середовища та концентрації триетилентетрамина на ефективність зв'язування іонів забрудника в комплекс. Шляхом ІК-спектроскопії було досліджено механізм процесу комплексоутворення: взаємодія в системі метал-ліганд здійснюється через амідну групу. Результати спектроскопічних досліджень свідчать про участь Fe у процесі комплексоутворення в гідратованій формі. Вивчення корозійної активності модифікованого ТМЗ методом поляризаційного опору показало низьку швидкість корозії.

Уведення до складу технічного мийного засобу триетилентетрамину збільшує ефективність продукту та підвищує його екологічну безпечність, оскільки має поліфункціональну дію, що дозволяє зменшити солевміст ТМЗ.

Ключові слова: *забруднення; кремнієві пластини; ПАР; промивка водними розчинами; сонячна енергетика; ТМЗ.*

ТЕХНИЧЕСКИЕ МОЮЩИЕ СРЕДСТВА ДЛЯ ОБОРУДОВАНИЯ В АЛЬТЕРНАТИВНЫХ ИСТОЧНИКАХ ЭНЕРГИИ НА ОСНОВЕ ГЕЛИОСИСТЕМ

Г. М. Прокофьева, Т. В. Сударушкина, М. Е. Беркут*
НТУУ «Киевский политехнический институт имени Игоря Сикорского», Киев, Украина
*e-mail: kxtp@kpi.ua

Очистка кремниевых пластин солнечных батарей происходит путём промывок с использованием технических моющих средств (ТМС). Исследование при помощи различных физико-химических методов (ИК-спектроскопия, спектральный, рентгеноструктурный, рентгено-флуоресцентный, атомной абсорбции, пламенной фотометрии, термогравиметрический, электронного парамагнитного резонанса, электронной спектроскопии, поляризационного сопротивления) показало, что введение триэтилентетрамина в состав ТМС способствует образованию стойких комплексных соединений с ионами загрязнений. Также было установлено, что модифицированное ТМС имеет антикоррозионные свойства. Из этого можно сделать вывод, что введение в ТМС триэтилентетрамина улучшает моющие свойства продукта и повышает его экологическую безопасность, поскольку имеет полифункциональное действие, тем самым способствует уменьшению солесодержания в ТМС.

Ключевые слова: *загрязнение; кремниевые пластины; ПАВ; промывка водними растворами; солнечная энергетика; ТМС.*