ISSN: 2181-3337 | SCIENTISTS.UZ VOLUME 5 ISSUE 9 | SEPTEMBER 2026

THERMAL STABILITY AND DECOMPOSITION STAGES OF A CORROSION-RESISTANT EPOXY-COAL TAR COMPOSITE COATING: TGA/DTA STUDY

Eshqobilov Jamshid[1], **Abdukarimov Mirzokhid**[2]
Doctoral student, Tashkent State Technical University, 2 Universitet Street, 100000 Tashkent, Uzbekistan. Corresponding author: jamshideshqobilov883@gmail.com[1]
DSc in Engineering, Associate Professor, Tashkent State Technical University, 2 Universitet Street, 100000 Tashkent, Uzbekistan[2]

DOI: 10.67620/sai.59a0006

ABSTRACT

A previously patented epoxy-coal tar coating was examined by thermogravimetric analysis (TGA) and differential thermal analysis (DTA) in order to clarify its thermal response and the sequence of mass-loss processes. The coating contains an ED-20 epoxy resin/coal tar binder, DTB-2 hardener, furfuryl alcohol distillation residue, wollastonite, andesite flour and saponified tall pitch. The thermogram indicates limited mass change below about 150 °C, followed by the dominant decomposition region between approximately 150 and 330 °C. The sample mass decreases from about 8.2 mg at the beginning of heating to roughly 2.6-2.7 mg after the main decomposition step. Between about 330 and 430 °C the TG curve becomes nearly horizontal, whereas above 430 °C a slower secondary mass loss continues to the end of the record. The remaining mass at about 700 °C is approximately 1.6-1.7 mg, corresponding to about 20% of the starting mass.

This value is close to the nominal 21 wt.% content of wollastonite and andesite flour in the formulation, which is consistent with a predominantly mineral residue; the possible contribution of carbonaceous material cannot be separated without information on the test atmosphere. The DTA trace contains overlapping thermal effects in the same temperature domain as the main TG drop. The results provide a thermal characterization of the patented coating and define the temperature interval in which major mass degradation becomes significant.

ACCEPTED

30.09.26

Keywords: *epoxy coating, coal tar, corrosion protection, thermogravimetric analysis, differential thermal analysis, wollastonite, andesite flour.*

CC BY

Introduction

Epoxy binders are widely used in protective coatings because they combine strong adhesion with low permeability and chemical resistance. Their long-term corrosion performance, however, is governed not only by the cured polymer network but also by fillers, modifiers, residual low-molecular species and defects formed during curing (Verma et al., 2020). Thermal analysis is useful in this context because a mass-loss curve separates low-temperature release of volatile species from the principal degradation of the network, while the residual mass provides information about non-volatile constituents (Brown, 2001).

Recent studies of modified epoxy coatings have shown that changes in cross-link density and inorganic filler content can shift the degradation profile and alter the high-temperature residue (Adnan et al., 2026; Farrer et al., 2025; Wu et al., 2025; Wu et al., 2026; Xia et al., 2024; Zhao et al., 2024).

The coating considered here was developed earlier as a corrosion-resistant composition for metal surfaces and is protected by Uzbekistan patent UZ IAP 8558 (Eshqobilov et al., 2026). Its formulation combines an ED-20 epoxy resin/coal tar binder with DTB-2 hardener, furfuryl alcohol distillation residue, wollastonite, andesite flour and saponified tall pitch. The patent reports high adhesion and resistance to water exposure, cathodic disbonding and penetration (Eshqobilov et al., 2026). Those previously reported data are not treated as new measurements in this paper; they are used only to identify the material whose thermal behavior is examined.

The present work focuses on a different question: how the patented coating loses mass during heating, which temperature intervals dominate this process, and how the final residue relates to the formulation. The aim was therefore to interpret the available combined TGA/DTA thermogram without extending the analysis beyond the information actually contained in the experimental record. Particular attention was given to the main degradation interval, the high-temperature residue and the limitations imposed by the absence of the original instrument metadata.

MATERIALS AND METHODS. The object of investigation was the optimized formulation described in patent UZ IAP 8558 (Eshqobilov et al., 2026). The component ratio used for the thermal specimen is summarized in Table 1. The 60 wt.% binder fraction consisted of ED-20 epoxy resin and coal tar at a mass ratio of 1:0.4. The mineral fraction was formed by wollastonite (13 wt.%) and andesite flour (8 wt.%), giving a nominal inorganic filler content of 21 wt.%.

Table 1

Composition of the Coating Examined by TGA/DTA

Component	Content, wt.%
ED-20 epoxy resin/coal tar mixture (mass ratio 1:0.4)	60
DTB-2 hardener	7
Furfuryl alcohol distillation residue	5
Wollastonite	13
Andesite flour	8
Saponified tall pitch, grade B	7

According to the patented preparation procedure, the ED-20/coal tar binder was mixed at about 80 °C. The modifier, andesite flour, wollastonite and saponified tall pitch were introduced after cooling to about 50 °C, and the compound was homogenized before addition of DTB-2 immediately prior to use (Eshqobilov et al., 2026). These processing data are cited from the patent rather than presented as a new experiment.

Thermal analysis was evaluated from the combined TGA/DTA plot supplied for the coating sample (Figure 1). The initial sample mass read from the graph is approximately 8.2 mg. The blue trace represents mass change (TGA, mg) and the red trace represents the differential thermal signal (DTA, μV). The original export does not state the instrument model, heating rate, purge atmosphere, gas flow, crucible material, reference material or calibration procedure. Because these parameters materially affect onset temperatures and the direction of DTA effects, the present analysis uses approximate temperature intervals and visually estimated mass fractions only. No kinetic constants, activation energies, enthalpies or formal

ISSN: 2181-3337 | SCIENTISTS.UZ

T5/T10 values are calculated. This restriction follows established guidance that kinetic interpretation requires well-defined experimental conditions and suitable datasets (Vyazovkin et al., 2011).

RESULTS.

The TG curve is not characterized by a single abrupt event. Instead, four practical temperature regions can be distinguished from the plotted mass trend. Below about 150 °C, the mass remains close to its initial value and decreases only slightly. This part of the curve is compatible with removal of physically retained moisture or a small amount of volatile material, but the graph alone does not permit identification of individual species. The observation is relevant because retained volatiles are known to influence the low-temperature thermal response of cured epoxy-amine coatings (Farrer et al., 2025).

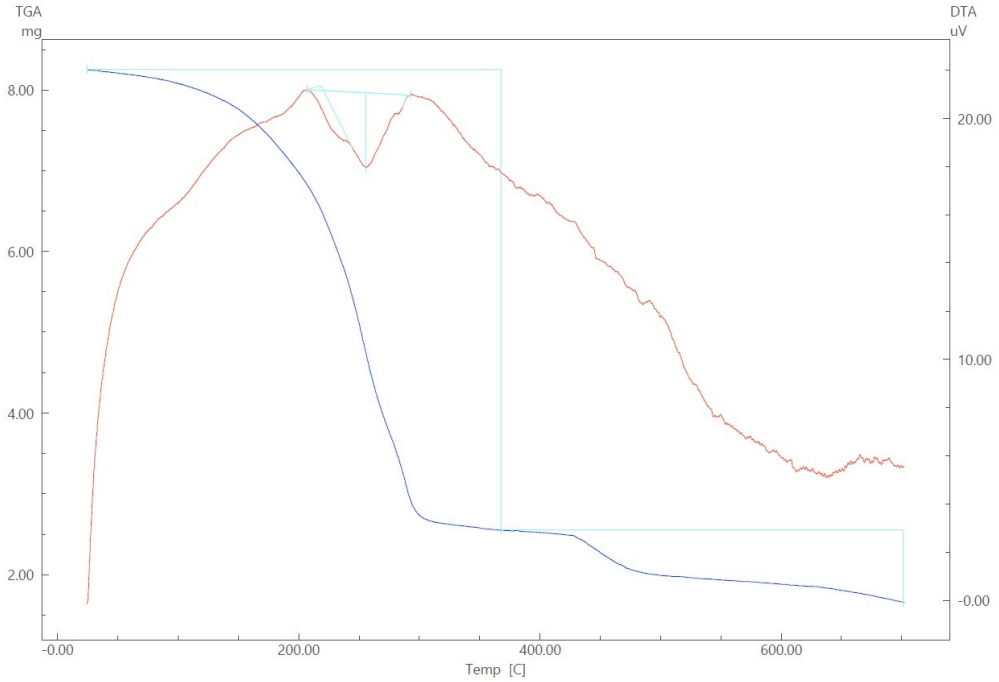


Figure 1. Combined TGA/DTA thermogram of the epoxy-coal tar composite coating (experimental graph supplied by the authors)

The dominant mass-loss region extends from roughly 150 to 330 °C. Over this interval the mass falls from approximately 7.8-8.0 mg to about 2.6-2.7 mg. In other words, only about one-third of the starting mass remains after the principal degradation step. Because the formulation contains coal tar, a furfuryl-derived modifier and a cured epoxy network, several organic processes are expected to overlap in this temperature range; the available DTA trace confirms that the event is not thermally simple.

Table 2

Thermal Regions Estimated From the Supplied Thermogram

Approx. temperature interval	Observed behavior	Evidence-based interpretation
25-150 °C	Small mass decrease; TGA remains near the initial mass	Release of a limited amount of moisture and/or low-boiling material is possible.
150-330 °C	Steepest TGA decrease; mass falls to about 2.6-2.7 mg	Principal degradation of the organic part of the coating; several reactions overlap.
330-430 °C	Low-slope / near-plateau region around 2.5-2.6 mg	Temporary stabilization of the remaining condensed and mineral-rich fraction.

ISSN: 2181-3337 | SCIENTISTS.UZ

Approx. temperature interval	Observed behavior	Evidence-based interpretation
430-700 °C	Slow secondary mass decrease; final residue about 1.6-1.7 mg (~20%)	Further transformation of the remaining organic fraction; residue is consistent with predominantly mineral matter.

From approximately 330 to 430 °C, the TG trace becomes much flatter and remains near 2.5-2.6 mg. A further gradual mass decrease begins above about 430 °C and continues to the end of the plot. At approximately 700 °C the remaining mass is about 1.6-1.7 mg, equivalent to roughly 20% of the starting sample mass. The nominal mineral fraction of the formulation is 21 wt.% (13 wt.% wollastonite plus 8 wt.% andesite flour). The close numerical agreement between these two values is consistent with a residue dominated by thermally persistent mineral matter. However, the unknown test atmosphere prevents a quantitative separation of inorganic residue from any possible carbonaceous contribution.

The DTA trace contains a broad high-temperature response rather than isolated sharp peaks. An initial broad feature develops near 180-210 °C, followed by a change in direction around approximately 240-270 °C and another broad feature near 290-320 °C. These effects overlap the main TG mass-loss region. Since the plot does not specify whether upward deflection is endothermic or exothermic, assigning them to specific reactions would be speculative. They are therefore described here only as thermal events accompanying the principal decomposition process.

DISCUSSION. The most useful quantitative result from the present thermogram is the separation between the low-temperature region and the major mass-loss interval. The coating shows no large TG drop below about 150 °C, whereas the majority of the organic mass is lost between approximately 150 and 330 °C. This does not define a safe service-temperature limit. Glass transition, softening, adhesion loss or stress relaxation can occur before a pronounced TGA mass change. Consequently, the TG curve should be interpreted as a decomposition profile rather than as a direct operating-temperature specification.

The onset of major mass loss in the present graph appears lower than values reported for some recently engineered epoxy systems. For example, an organic-inorganic hybrid epoxy coating reported by Zhao et al. (2024) showed a 5% mass-loss temperature increasing from 327 to 372 °C after silane-based modification. Wu et al. (2026) reported T5 values of about 275-288 °C for ZrO2-modified epoxy coatings, while polyimide-modified epoxy coatings with inorganic fillers retained approximately 90% of their mass near 270 °C (Wu et al., 2025). These values should not be used to rank the current coating directly, because heating rate, atmosphere, formulation and the criterion used to define onset differ among studies. The comparison nevertheless shows that the lower-temperature fraction in the epoxy-coal tar formulation deserves attention and may reflect the presence of coal-tar constituents, furfuryl-derived material or other low-molecular components.

The final residue is particularly informative. Modern filled epoxy coatings often display higher residue when non-volatile inorganic fillers are present (Wu et al., 2025; Wu et al., 2026). In the present formulation, the nominal 21 wt.% mineral fraction is remarkably close to the approximately 20% residue estimated at 700 °C. This supports, without proving, the interpretation that wollastonite and andesite flour account for most of the final non-volatile material. If the experiment was performed under inert gas, some char from the organic binder may also remain; if it was performed in an oxidative atmosphere, that contribution would be smaller. The atmosphere therefore needs to be reported in any future repeated measurement before carbonization mechanisms are discussed quantitatively.

The role of mineral filler in protective epoxy coatings extends beyond its contribution to residual mass. Inorganic particles can increase diffusion path length and reduce the effective fraction of permeable

ISSN: 2181-3337 | SCIENTISTS.UZ

polymer, although the benefit depends strongly on particle dispersion and interfacial compatibility (Verma et al., 2020; Wu et al., 2026; Xia et al., 2024). The earlier patent reports for the same formulation include a pull-off adhesion of 14.5 MPa, an 11% decrease in adhesion after 1000 h water exposure, cathodic disbonding of 1.20 cm^2, penetration of 0.07 mm and tensile strength of 42.1 MPa (Eshqobilov et al., 2026). Those values were obtained previously and are cited here only as context. The current TGA/DTA data add a different dimension: they show that the material retains a substantial non-volatile fraction after the main organic decomposition step.

A limitation of the present study is that only the graphical thermogram was available, without raw numerical data or instrument metadata. This prevents calculation of derivative TG peak temperatures, statistically reproducible onset values, reaction kinetics or mass-loss uncertainty. A follow-up study should repeat TGA under a stated atmosphere and heating rate, preferably at more than one heating program if kinetic analysis is intended (Vyazovkin et al., 2011). A DTG or DSC trace would also help distinguish overlapping transitions that cannot be resolved reliably from the present DTA plot.

CONCLUSION. The TGA/DTA thermogram of the patented epoxy-coal tar composite coating reveals a multistage thermal response. Only a limited mass change is visible below about 150 °C, while the principal degradation occurs between approximately 150 and 330 °C. A low-slope region follows, and a slower secondary mass loss continues above about 430 °C. The residue near 700 °C is approximately 20% of the initial mass, close to the 21 wt.% nominal content of wollastonite and andesite flour. This agreement is consistent with a residue dominated by mineral components, although the contribution of carbonaceous material cannot be determined without the test atmosphere. The DTA curve confirms that several thermal events overlap with the main mass-loss region, but their endothermic or exothermic nature cannot be assigned from the supplied plot. The analysis therefore provides a conservative thermal characterization of the coating and identifies the temperature range in which its organic matrix undergoes substantial decomposition.

CONFLICT OF INTEREST

The authors declare no conflict of interest related to this work.

REFERENCES

1. Adnan, S. N. A., Kahar, N. E. A., Sobari, M. S., Mohamed, S. H., Chen, L. J., Lee, E., Pargi, M. N. F., & Musa, M. S. (2026). Effect of epoxy content on the corrosion properties of waterborne epoxy-acrylate coating. *Journal of Coatings Technology and Research*, *23*(2), 883–898. https://doi.org/10.1007/s11998-025-01175-8
2. Brown, M. E. (2001). *Introduction to thermal analysis: Techniques and applications* (2nd ed.). Kluwer Academic Publishers.
3. Eshqobilov, J. H., Abdukarimov, M. M., Yodgorov, N., & Nurkulov, F. N. (2026). *Polymer composition for obtaining a corrosion-resistant coating* (Uzbekistan Patent No. UZ IAP 8558). Republic of Uzbekistan.
4. Farrer, N., Intaphan, W., Lyon, S., Edwards, W., Beaumont, D., & Morsch, S. (2025). Insights into volatile presence within epoxy amine coatings using nano-thermal analysis. *Progress in Organic Coatings*, *207*, Article 109406. https://doi.org/10.1016/j.porgcoat.2025.109406
5. Verma, C., Olasunkanmi, L. O., Akpan, E. D., Quraishi, M. A., Dagdag, O., El Gouri, M., Sherif, E. S. M., & Ebenso, E. E. (2020). Epoxy resins as anticorrosive polymeric materials: A review. *Reactive and Functional Polymers*, *156*, Article 104741. https://doi.org/10.1016/j.reactfunctpolym.2020.104741
6. Vyazovkin, S., Burnham, A. K., Criado, J. M., Pérez-Maqueda, L. A., Popescu, C., & Sbirrazzuoli, N. (2011). ICTAC Kinetics Committee recommendations for performing kinetic computations on thermal analysis data. *Thermochimica Acta*, *520*(1–2), 1–19. https://doi.org/10.1016/j.tca.2011.03.034

ISSN: 2181-3337 | SCIENTISTS.UZ

7. Wu, M., Cao, G., & Xiao, Z. (2025). Polyimide-modified epoxy coatings reinforced with functional fillers for enhanced thermal stability and corrosion resistance. *Advanced Composites and Hybrid Materials*, *8*, Article 172. https://doi.org/10.1007/s42114-025-01265-6
8. Wu, Y., Yang, Q., Zhang, H., Zhou, Y., Guo, H., Wang, Z., & Li, G. (2026). Enhancing hydrophobicity and corrosion resistance of epoxy resin coatings using KH570-ZrO2 nanoparticles. *Polymer Testing*, *154*, Article 109070. https://doi.org/10.1016/j.polymertesting.2025.109070
9. Xia, Y., Tong, L., Feng, X., Zhang, S., Xiang, H., He, Y., & Liu, X. (2024). An investigation on the mechanical and corrosion protection properties of poly(arylene ether nitrile) reinforced epoxy coating. *Progress in Organic Coatings*, *192*, Article 108463. https://doi.org/10.1016/j.porgcoat.2024.108463
10. Zhao, H., Liang, X., & Gao, Y. (2024). Organic-inorganic hybrid epoxy resin coating with high thermal stability and hydrophobicity for corrosion protection prepared by (3-aminopropyl) triethoxysilane as a bridging agent. *Materials Today Communications*, *39*, Article 108950. https://doi.org/10.1016/j.mtcomm.2024.108950

ISSN: 2181-3337 | SCIENTISTS.UZ