Journal of Thermal Analysis, Vol. 9 (1976) 395–400

THERMAL ANALYSIS OF POLY(METHYL METHACRYLATE)–COPPER COMPOSITE

N. K. NAG, R. MUKHOPADHYAY, SADHAN K. DE* and S. BASU

Department of Chemistry, Indian Institute of Technology, and
**Material Science Centre, Indian Institute of Technology Kharagpur–2, India*

(Received October 27, 1975)

Thermal characteristics of the composites of poly(methyl methacrylate) and copper are reported, including the order of reaction and activation energy of the major second stage of pyrolysis. The randomly-distributed metal particles in the polymer matrix can form paths for heat transfer which determine the mechanism of thermal degradation.

Lately metal–polymer composites have emerged as a new class of engineering materials [1–3]. In many applications, however, thermal stability of the materials is of importance. The present communication reports results of our preliminary investigations on the thermal characteristics of the composites of polymethyl methacrylate and copper. Different stages of pyrolysis were determined from the DTG and DTA curves. Kinetic parameters, namely order of reaction and activation energy of the major second step of pyrolysis were determined from the TG curves.

Experimental

Particle size distributions of poly(methyl methacrylate) [Fisher Scientific Co.] and copper powders [Assam Carbon Products Pvt. Ltd.] are as follows:

Poly(methyl methacrylate):		*Copper*:	
150–100 μ	28%	150–100 μ	1%
100– 75 μ	34%	100– 75 μ	9%
75– 50 μ	33%	75– 50 μ	26%
Less than 50 μ	5%	50 μ	64%

The molecular weight of the polymer was found to be 3.14×10^5, as determined by viscosity measurements. Polymer powder and copper powder in different ratios by weight were compacted at 100 kg/cm^2 and at 145°. Thermal analysis was carried out in air using a MOM Derivatograph. The kinetic parameters were calculated by the Freeman–Carroll method [4].

The polished surface of the composites was examined by Soviet made МИМ-8М Horizontal Metallographical Microscope.

Results and discussion

The DTA, TG and DTG curves of pure polymer and the metal–polymer composites are shown in Figs 1–3. Range of decomposition temperatures, per cent

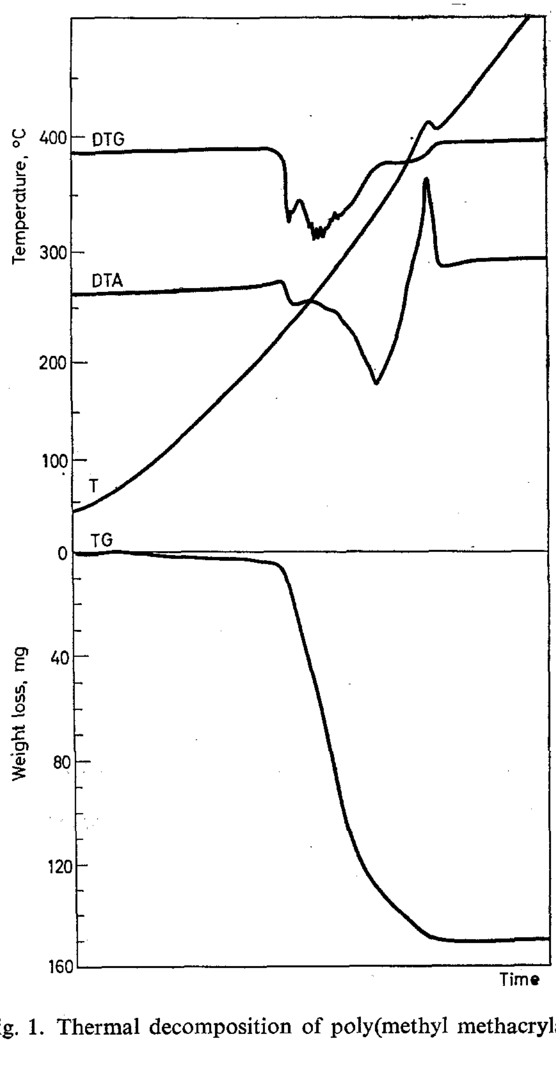

Fig. 1. Thermal decomposition of poly(methyl methacrylate)

weight loss at different stages of pyrolysis, and the exothermic/endothermic peak temperatures are included in Table 1. The order of reaction and activation energy of the major second step are shown in Table 2.

Table 1

Results of thermal analysis of poly(methyl methacrylate)-copper composites

Composition, per cent metal by weight	First step			Second step			Third step		
	Temperature range, °C	weight loss, %	Endothermic peak temp., °C	Temperature range, °C	weight loss, %	Endothermic peak temp., °C	Temperature range, °C	weight loss, %	Endothermic peak temp., °C
0	220–240	6.6	230	240–365	88.0	335	365–417	5.3	405
10	200–290	18.3	250	290–390	66.6	370	390–410	3.8	400
20	200–290	14.7	?	290–400	54.7	370	400–430	3.6	420

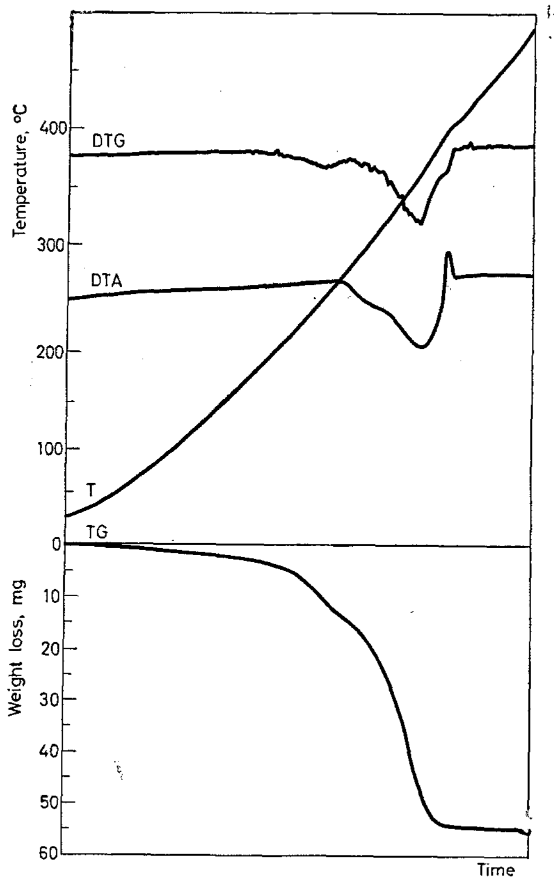

Fig. 2. Thermal decomposition of poly(methyl methacrylate)-copper composite (10% by weight of copper)

Table 2

Kinetic parameters of the second step of degradation of the composites

Composition, % metal by weight	Activation energy KJ/mole	Order of reaction
0	46.4	1
10	83.2	0.4
20	85.3	0.4

DTA and DTG curves indicate that thermal decomposition of the polymer occurs, possibly in three stages: initial degradation starting at 240°, followed by the major step of decomposition and finally the oxidation of the residual decom-

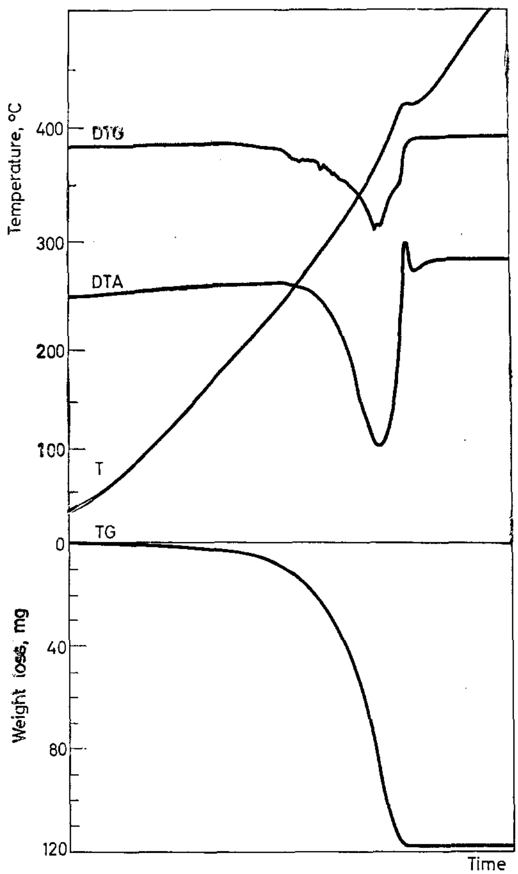

Fig. 3. Thermal decomposition of polymethyl methacrylate-copper composite (20% by weight of copper)

posed product. Addition of increasing amounts of copper largely suppresses the initial degradation and the final oxidation steps. Figures 2 and 3 indicate that the major second step (endothermic peak temperature, 370°) becomes more prominent in the composites. Analysis of kinetic parameters shows that the activation energy

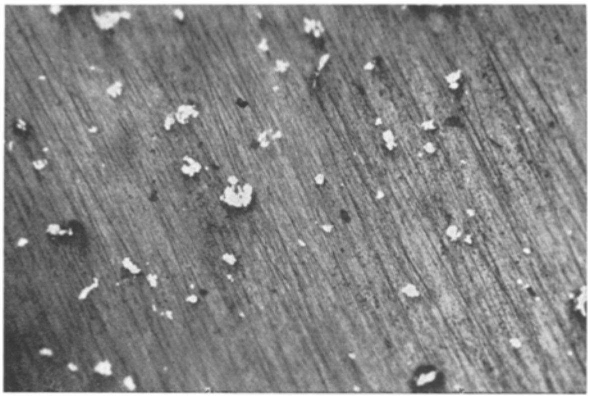

Fig. 4. Photomicrograph of the composite (10% by weight of copper)

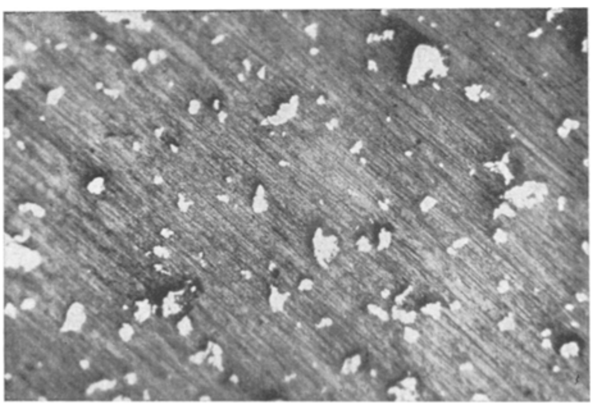

Fig. 5. Photomicrograph of the composite (20% by weight of copper)

of the major second step increases and the order of reaction decreases in presence of metal, indicating an increase in thermal stability of the composite and a different mechanism of thermal degradation as compared to the pure polymer. Copper itself undergoes oxidation starting around 200° [5]. It appears that the poymer matrix offers protection against oxidation of the metal. The weight loss in the TG curve corresponds well with the initial polymer content of the composite. The polymer is almost completely decomposed and volatilized at 500°.

Photomicrographs of the metal–polymer composites (Figs 4 and 5) indicate that the metal particles are randomly distributed in the polymer matrix and can form a path for heat transfer. It appears that the available paths of heat transfer in the composites change the mechanism of thermal degradation.

References

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Résumé — On décrit les caractéristiques thermiques de composites du polyméthylméthacrylate avec le cuivre, parmi lesquelles l'ordre de réaction et l'énergie d'activation de la seconde étape de la pyrolyse qui est la principale. Les particules du métal distribuées au hasard dans la matrice du polymère peuvent constituer des voies pour le transfert de chaleur qui déterminent le mécanisme de la dégradation thermique.

Zusammenfassung — Die thermischen Charakteristika der Verbindungen von Polymethylmethacrylat mit Kupfer werden zusammen mit der Reaktionsordnung und der Aktivierungsenergie der grösseren zweiten Stufe der Pyrolyse beschrieben. Die zufallsbestimmt verteilten Metallpartikel in der Polymermatrix können Wege des Wärmetransfers formen, welche den Mechanismus der thermischen Zersetzung bestimmen.

Резюме — Представлены термические характеристики составов полиметилакрилата и меди, включая порядок реакции и энергию активации второй главной стадии пиролиза. Беспорядочно распределенные в полимерной матрице частицы металла могут служить переноещиками тепла, что и определяет механизм термической деградации.