A novel approach to obtain graphene nano-platelets/epoxy based resins by three roll mill technology.

A. Caradonna[1*], F. Conrado[1] , M. Pavese[1], and C. Badini[1]

[1*] Dipartimento di Scienza Applicata e Tecnologia, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy

Graphene is a two-dimensional layer consisting of sp^2 carbon atoms, arranged in a honeycomb structure. In the last years, the use of graphene as reinforcement for polymers has attracted a lot of interest because of its potential to improve mechanical properties, electrical and thermal conductivity [1].

In this work, epoxy based nano-composites were prepared by dispersing graphite and two different kind of graphene nano-platelets (GNPs) within polymeric matrix, using a very simple and low cost process. The nano-fillers were dispersed in a commercial epoxy resin with stoichiometric amount of curing agent and processed with three roll mill machine. This apparatus is able to achieve a good nano- fillers disaggregation and dispersion due to the combined effect of the high shearing force with the continuous matrix mixing [2]. The mechanism of how it works is reported in figure 1.

Figure 1: The three roll mill mechanism.

With this machine is possible to work in two different modes: gap mode and contact mode. In the gap mode is possible to modulate the distance between the first roll and the second one that is fixed, and the gap between the second roll and the third one. In this way it is possible to obtain a good fillers dispersion in the polymeric matrix. In contact mode, the different rolls are in contact one to each other, then the higher shear force applied to the system, in principle, could be able to exfoliate the GNPs or graphite to reduce the number of graphene layers. The rolls speed is another parameter that it is possible to change for obtaining a better dispersion.

Ahmadi-Moghadam et al., explored the effect of the three roll mill processing parameters on the structure of epoxy/GNP nano-composites [3], while Chandrasekaran et al. analyzed the mechanical, electrical and thermal properties of different GNP/epoxy nano-composites obtained by three roll mill process with respect to the composites obtained by sonication and high speed shear mixing. They showed a better dispersion and a higher electrical conductivity in the samples processed by three roll mill.

References

[1] S. G. Prolongo ,Composite Science and technology 85 (2013) 136-141.
[2] M. A. Raza, Composites Science and Technology 72 (2012) 467-475
[3] B. Ahmadi-Moghadam, J Mater Sci 49(2014) 6180-6190
[4] S. Chandrasekaran, European Polymer Journal 49 (2013) 3878-3888

The epoxy-graphene nano-composites were prepared by mixing 2 wt.% of graphite flakes median 7-10 micron (Alfa Aesar), graphene nano-platelets 6-8 nm thick (ABCR) and graphene nano-platelets grade 4 with high surface area (Cheaptubes) with a commercial epoxy resin and processed for different times in three roll mill machine as a function of the gap distance and the number of steps. In table 1 the different three roll mill cycles are reported.

Table 1: Different sample prepared by three roll mill.

	epoxy to amine ratio wt.						
	epoxy	amine	num cycle	gap 1 (µm)	gap2 (µm)	contact	rpm
pure resin	25	3	0	0	0	no	0
As prepared	25	3	0	0	0	no	0
1	25	3	3	45	15	no	600
			3	15	5	no	600
2	25	3	3	45	15	no	600
			3	15	5	no	600
			3	0	0	yes	300
A	25	3	9	45	15	no	600
B	25	3	9	15	5	no	600
C	25	3	3	0	0	yes	300
D	25	3	3	0	0	yes	300

The samples obtained from graphite have been compared with the samples obtained with the different GNPs in terms of dispersion, exfoliation process, mechanical properties and thermal and electrical conductivity to demonstrate how strong the exfoliation operated by the three roll mill can be. A good exfoliation could allow to reach, even if starting from graphite, the properties typical of an epoxy-graphene nano-composites, however with a very low cost starting material.