MICRONIZED TALC: A COST-EFFECTIVE FUNCTIONAL FILLER FOR POLYOLEFINS. NEW SOLUTIONS FOR POLYPROPYLENE HETEROGENEOUS NUCLEATIONA AND POLYETHYLENE ANTIBLOCKING

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Abstract

Micronized talc is not just an extender for polymers, but is also a functional additive, useful in several polymer modifications. Because of its characteristics, it is a perfect modifier for polyolefins. The high degree of micronization combined with precise control in particles dimension make IMIFabi talc a unique functional additive for polyolefins.

In this paper heterogeneous polypropylene nucleation and polyethylene antiblocking will be discussed and the latest findings on these applications presented. Thanks to its lamellar structure, talc is a perfect reinforcer for polymers, able to enhance stiffness even with limited loading amounts. The latest developed products for enhanced performances in PP and TPO will be summarized as well.

The excellent performances achievable with talc associated with its limited cost make it a real cost-effective functional additive for polyolefins and other thermoplastic polymers.

Introduction

Cost reduction by means of filling materials has been applied in modern production methods for many years. As a general rule, fillers are defined as materials that are added to the (plastic) formulation to lower the overall cost of the compound. In such situation, fillers are used as extenders; but extenders generally provide minor mechanical improvements (or even some properties degradation). When certain properties variations are requested, functional fillers must be used. A filler can be considered as "functional" when a certain property will result better in the final composite than in the unfilled material. A typical mechanical property enhanced by functional fillers is rigidity: by adding a functional filler to a certain polymeric matrix, a significant variation in stiffness can be achieved.

Talc is generally considered as a functional material because it is able to modify significantly some properties in the polymeric matrix, when talc is properly dispersed. It is important to highlight that not all talc grades available on the market are eligible to become "functional fillers". Lamellarity in talc is intrinsic in its structure, but it is fundamental to process it maintaining or (if possible) enhancing the lamella aspect ratio. In order to maximize the final performances of the modified polymeric matrix, the production process must preserve the natural lamellarity of talc. In Figure 1, an image of fine micronized talc is shown. A production process which is not able to harness this characteristic will produce just a filler. In fact, a generic size reduction process with a generic talc source cannot provide the proper final characteristics of fine talc: similar particle size distribution could be reached, but performances in the final application could result significantly different. A consolidated know-how in source selection, processing and downstream applications is necessary to produce an effective functional filler based on talc ore.

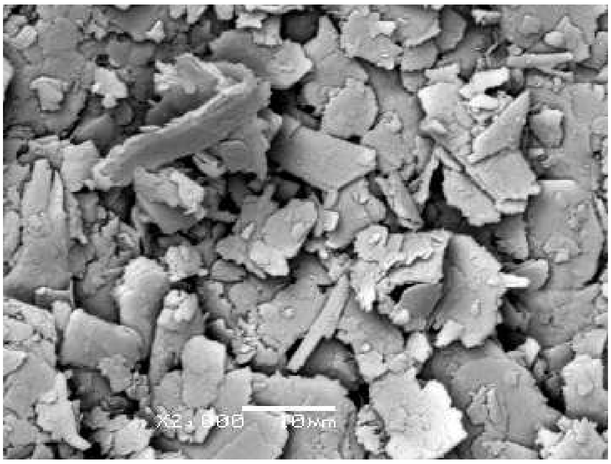

Figure 1. SEM image of micronized talc

The above statement becomes even more true when micronized talc is used in low concentration as an additive, to modify some specific polymer properties. Two of the main applications, subject of this paper, are talc's ability to modify the crystallization behavior of semi-crystalline polymers (heterogeneous nucleation) and its effect in reducing the adhesion force between two adjacent layers of plastic film (antiblocking).

Heterogeneous Nucleation

As polypropylene (PP) cools from the molten state, individual chains begin to form crystalline structures around nucleation sites. These nucleation sites can either be imperfections or inconsistencies in a polymer chain or foreign particles in the melt. As the polymer continues to cool, more chains crystallize around the nucleation site, forming spherulites.

When PP cools completely, it is made up of approximately 60% crystalline and 40% amorphous, or non-crystalline, areas. The crystallization rate of PP is increased by the presence of foreign particles in the melt. The polypropylene chains crystallize around these particles.

While it is cooling, PP also undergoes supercooling. Supercooling refers to the difference between the melting temperature and the temperature at which crystallization of the polymer begins. This temperature is called the "onset of crystallization temperature." For example, homopolymer PP (without a nucleating agent) melts at about 166°C, but crystallizes at about 104°C. This temperature difference means that molded parts must be cooled well below the melting point of PP before the resin begins to crystallize (see Figure 7).

Nucleating agents (nucleators) work by altering the way the PP chains crystallize and agglomerate in the molten state. With specific reference to heterogeneous nucleation, typical additives consist of fine particles having either organic or inorganic nature. Such particles must show a melting point above the PP processing temperature. Micronized talc is generally used as a nucleator in PP. IMI Fabi produces several micronized talc grades suitable for PP nucleation and the most common one is talc HTP1, characterized both by a very fine particle size distribution (D_{50} 1.9 µm) and by a high degree of pureness.

Micronized talc reduces the degree of supercooling in the resins by increasing the onset of the crystallization temperature, and by providing numerous nucleating sites around which the PP chains can crystallize. These numerous nucleating sites also increase the amount of crystallinity in the resin, decrease the average size and narrow the size range of the spherulites. Micronized talc also increases the stiffness of the end product without affecting the impact strength. An important advantage in using talc as a nucleator is the very limited (or negligible) warpage on molded parts because of the very high dimensional stability achieved.

The effectiveness of micronized talc in homopolymer PP is well known and talc HTP1 is already effective starting at 2000 ppm loading with appreciable variation in crystallization temperature and mechanical performances. It is typically dosed at 1% for maximum efficiency.

In block copolymer PP, micronized talc is effective as well: in figure 2 nucleating behavior of different loadings of talc HTP1 in block copolymer PP is highlighted. The progressive increase in crystallization temperature with talc loading can be observed. In the experiment shown in figure 2, a certain loading threshold for nucleation has been reached, recording little increments in crystallization temperature with talc loadings higher than 1.0%.

In terms of mechanical properties, in figure 3, stiffness behavior Vs. talc loading is highlighted. The significant increment in rigidity achievable in block copolymer PP nucleation with talc HTP1 (D_{50} 1.9 µm) is evident.

For even better results in PP nucleation, a more micronized talc than HTP1 can be used. Specifically, talc HTPultra5, exhibiting a very fine particle size distribution (D_{50}=0,8 µm) provides, at the same loading, higher mechanical performances than HTP1, as highlighted in figure 3. A coarser talc (D_{50}=2.4µm) offers lower mechanical properties in the same conditions. The same behavior is valid for homopolymer PP too.

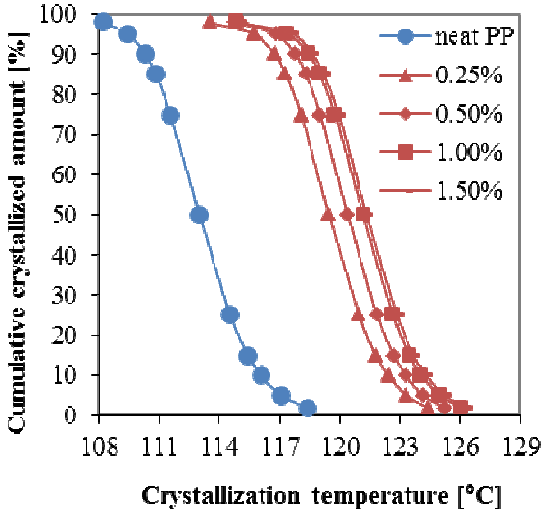

Figure 2. Crystallization behavior of different loadings of talc HTP1 on block copolymer PP

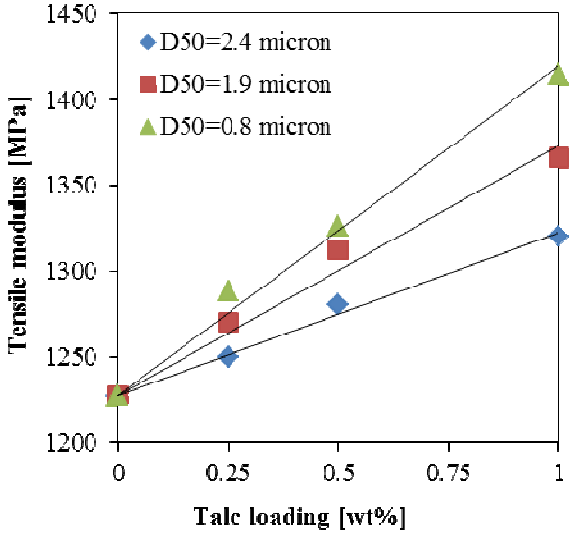

Figure 3. Stiffness achievable with different talc fineness at different loadings on block copolymer PP

In terms of crystallization temperature, different talc fineness shows a similar trend as per mechanical performances showed in figure 3: the finer the talc is, the higher the crystallization temperature is recorded.

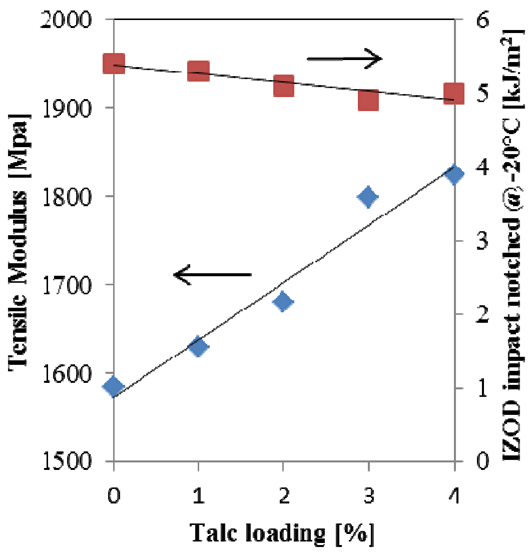

Figure 4: Modification of block copolymer PP with small loadings of talc HTPultra5 (D_{50}= 0.8µm)

At small loadings, talc is very effective in enhancing rigidity with minor reductions in impact resistance. In Figure 4, data related to block copolymer polypropylene modification with talc HTPultra5 are showed. In the experiment described in Figure 4, block copolymer PP is already nucleated with a high efficiency nucleator (phosphate salt). Despite the background nucleation of the resin, talc is able to improve rigidity even at low loadings; such a modification doesn't affect the yield strength of the resin, enabling usage in applications where strength design criteria is requested (i.e. pressure pipes).

Talc grade	Appearance	Flowability	Dust release	Bulk density [g/cm^3]
HTP1	Loose powder	Poor	High	0.2
HTP1L	Compacted powder	Poor	High	0.6
HTP1c	Pellets and powder	Good	Limited	0.9
HTP1s	Spherical agglomerates	Excellent	Minor	0.6

Table 1: Summary of compacted talc bulk properties .

As a micronized powder talc can be fluffy and dusty, for practical applications, it might be necessary to use it in compacted form. Compaction is a process developed to reduce the volume of micronized talc powder to make it easier for handling. Different technologies in talc compaction are available, characterized by both bulk density and powder flowability. In Table 1, main bulk properties for different talc compaction technologies are summarized.

The latest innovation in talc compaction is represented by a truly free flowing and dust free form for highly micronized talc. This innovative product, named talc HTP1s, offers all the advantages of a dust free additive where avoiding pollution problems is impotant. In Figure 5, the appearance of such innovative product versus both standard loose powder and highly compacted talc is showed. All compacted talc grades are designed for both proper re-dispersion (in standard devices for polymer processing) and easier handling.

Figure 5: visual aspect of different highly micronized talc grades. From the left: loose powder talc HTP1, compacted talc HTP1c, free flowing talc HTP1s.

Talc is also effective in nucleation activity on other semi-crystalline thermoplastic polymers such as polyamide 6, polyamide 66, polybuthyleneterephthalate, polyethyleneterephthalate, polylacticacid, …, always recording a visible improvement in stiffness with very limited loadings, with no negative effects on impact resistance and showing a faster crystal growth for shorter cycle times.

Antiblocking in PE film

Polyethylene (PE) films are widely used for packaging applications because of their excellent properties: transparency, mechanical resistance, inertness, low cost,….

When such films are produced, however, there is a tendency for two or more contacting layers of the PE films to stick together ("block"), making separation of the film layers, opening of a plastic bag, finding the end of the roll difficult. The addition of functional inorganic fillers to PE films to minimize blocking is a common practice. The presence of functional fillers makes the film surface rougher, reducing the intimate contact between adjacent layers of film and hence reducing blocking forces ("antiblocking").

Several functional fillers, available on the market, are offered for this specific function, but not all of them are really effective in antiblocking or some aspects limit their practical applications, such as excessive cost, high abrasiveness, processability, health concerns, etc.

One of the commercially available antiblocking additives on the market is micronized talc which is normally used in several PE applications, such as Low density polyethylene (LDPE), linear low density polyethylene (LLDPPE), high density polyethylene (HDPE). In particular, IMI Fabi has developed a specific class of micronized talc for such application. NB ("No Block") talc is a family of products based on pure highly platy white talc. NB products provide the right balance between high optical and mechanical properties, processability, low additive absorption and antiblocking function. NB products are available in both powder and compacted form, for easier handling and higher productivity. Compacted grades are specifically designed for the easiest re-dispersability of talc during the mixing process.

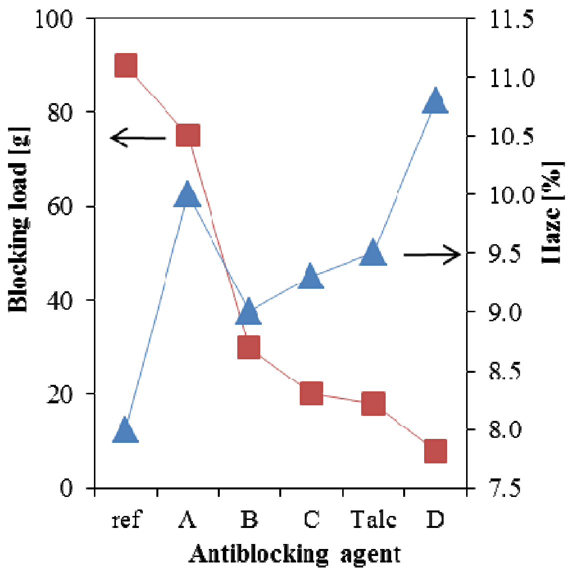

Figure 6: effect of loading of 1500ppm of different antiblocking agents on linear low density polyethylene (LLDPE). A: calcium carbonate; B: calcined clay; C: DE; D: synthetic silica

Compared to other typical antiblocking minerals, talc has the lowest abrasiveness (for reduced equipment wearing) and hence NB grades allow the user to avoid reduction in the maintenance time interval for extruders.

A general outlook on antiblock effectiveness vs. haze is highlighted in figure 7. Talc NB240 exhibits an excellent compromise between blocking force and haze. Such result can be associated with a very neutral color (any or minimum yellowness effect) and very low abrasion. Some antiblocking agents (such as calcined clay) impart a visible yellow shade to the extruded film, while talc imparts almost neutral coloration. Because of the very good AB effect, NB240 can even be dosed at lower loading, reducing the value of haze.

When antiblock superior performances are required in combination with excellent clarity, IMI Fabi offers a novel functional additive, developed to maximize the antiblock effect in PE films. This additive is named NB240T and it is surface treated with a proprietary process to maximize its effectiveness in PE. Because of the specific surface treatment, NB240T minimizes additive adsorption improving in effectiveness both the slip agent and processing aid. A significant reduction in the friction coefficient (at the same slip agent loading) versus standard un-treated talc can be recorded. As far as blocking force is concerned, surface treated talc NB240T, at least, halves the blocking force compared to standard talc.

Conclusions

The usage of (properly) micronized talc as a functional additive in polyolefins for both heterogeneous nucleation and antiblocking must be evaluated also in light of the opportunities in cost savings it provides compared to other additives. For such applications, other additives are available on the market, which provide a good balance in properties, but at a much higher cost than micronized talc. In heterogeneous nucleation, for example, some very efficient additives can have a cost 10 to 50 times higher than micronized talc and, even if dosed at a lower loadings if compared to talc, they have a significantly strong incidence on final cost formula. It is therefore important to consider the cost per specific performance in order to evaluate the best additive for each specific application. In some cases, talc can also be used in combination with other additives to maximize the effectiveness of both and using micronized talc as a carrier for more expensive additives to achieve proper additive dispersion.

Another advantage of micronized talc is the handling in the polymer process: it can be used directly in the polyolefin modification process, without passing through masterbatch pre-dispersion, with significant saving in processing costs. The possibilities offered by higher bulk density micronized talc (when compacted) further improves the processability of talc, minimizing the impact both on logistics (lower volumes) and on the environment (no dust). Products characterized by extremely high flowability such as talc HTP1s can be used in many critical applications where a previously a masterbatch was the only solution. It's also important to highlight that talc doesn't exhibit any specific health concern.

In other words, micronized talc is the cost effective functional additive for heterogeneous nucleation and antiblocking in polyolefins..

References

1. Polypropylene Handbook, ed Moore, E.P., Carl Hansen Verlag, Munchen (D) 1996
2. Ercoli Malacari P., *Effect of both talc fineness and talc loading on heterogeneous nucleation of block copolymer polypropylene*, ANTEC conference proceedings, Orlando-FL, (2010)
3. Ercoli Malacari P, *Heterogeneous nucleation of Polypropylene: a new line of extremely efficient talc functional additives*, SPE Polyolefin conference proceedings, Houston, TX (2008)
4. Ercoli Malacari P., *Micronised talc as nucleant in semi-crystalline technopolymers*, Advanced in plastics technology ATP'05 proceedings, Katowice, Poland (2005)

Key Words: Talc, Micronized talc, Heterogeneous nucleation, antiblocking.

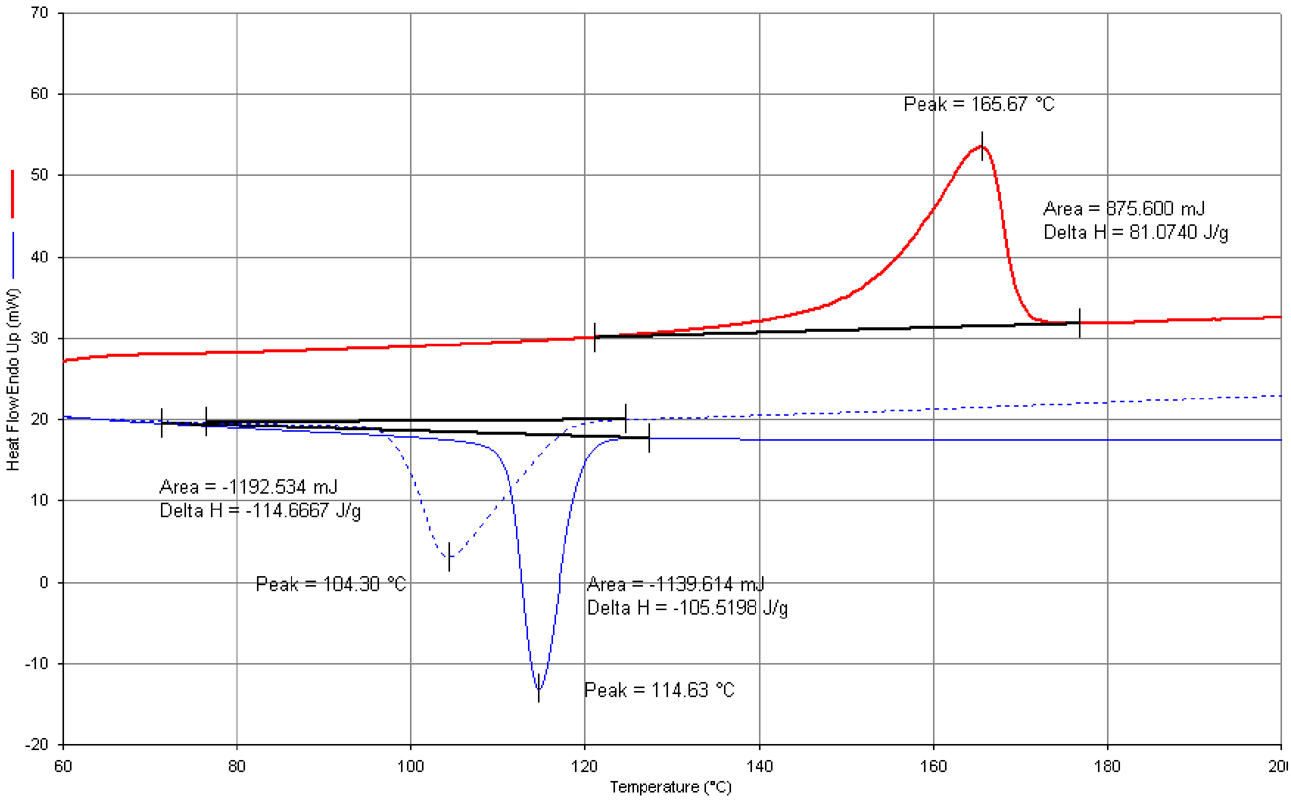

Figure 7. DSC graph of both melting (endothermic) and cooling (exothermic) processes of homopolymer polypropylene. For cooling process, dashed line shows the behavior of not nucleated homopolymer PP, while the solid line represents the same polymer nucleated with 0.5% (w/w) of talc powder (talc HTP1).