THE FABRICATION OF FIBROUS NANOCOMPOSITES BY DRY PARTICLE BONDING TECHNIQUE

C. C. Huang

Hosokawa Micron Powder Systems (USA), 10 Chatham Road, Summit, NJ 07901 USA

Summary:

The applications of dry particle bonding technique to fabricate nanocomposites have been investigated for some time. This technique is proven capable of producing nanocomposites using mechanical energy without binders of any kind, which resolves the cost, handling, and safety issues of nanoparticle applications. Various nano-scale multi-functional composite materials contributing to the development of advanced materials[1, 2, 3] for rechargeable batteries, fuel cells, ceramics, superconductors, metals, and pharmaceuticals were reported. In this presentation the fabrication of fibrous nanocomposites using dry particle bonding technique is illustrated. This further demonstrates the flexibility of the proposed dry particle bonding technique in particle design applications.

Introduction:

In dry powder processing, it has been an industrial practice to customize the particle size, distribution, and shape of powders by using particle size reduction and classification equipment with an aim to achieve better product performance. However, for many advanced functional and structural applications, multi-phase materials are required and it is necessary to make composite powders, in which totally different particles having dissimilar physical and chemical properties are combined or joined together to show new functions or to improve the characteristics of known materials.

Powder mixing is a common way to develop composite powders. But, the process is inevitably accompanied by segregation and agglomeration, when particles of different powder characteristics are mixed. This makes it difficult to secure a uniform composition, which is one of the essential prerequisites for improved composite characteristics. Segregation is particularly occurred when the powder components differ in particle sizes and densities, such as metal-ceramics. And, agglomeration is unavoidable when the powder components become very small in sizes, such as nano or submicron powders. Moreover, when it is necessary to keep aspect ratio of particles and allow each component in the composite powder to express its inherent designed functions, it becomes very challenging to powder processing professionals. The proposed dry particle bonding technique has shown its ability to disperse nano powders and coat them onto the surface of fibrous materials without causing segregation, agglomeration, or particle shape change.

The proposed dry particle bonding technique is a novel method that can chemically bond particles together using mechanical energy without any binders in the dry phase. This technique can easily produce composite powders, especially nanocomposites, in a large scale without contaminating the composite materials with liquid of any kind (solvents, binders or water) and it is environmentally friendly.

Methodology and Equipment:

In principle, the particle bonding technique takes the advantages of passing dry powder mixtures with preferred particle size ratios through a narrow gap, so that smaller guest particles are dispersed and bonded onto the surface of larger core particles under the influences of various types of mechanical forces. The overall design of the dry particle bonding process is proprietary and being technically updated as new application arises. It can practically produce any type of composite powders without the constraint of chemical compositions from 0.5 to 300 liters per batch. A typical commercial equipment was shown in Figure 1.

Figure 1. Photos of Nobilta™ NOB-300

Results and Application Examples:

The dry particle bonding technique has been shown to work well with various material compositions. Depending on the particle size and mass ratio of guest particles to core particles, core-shell or surface-embedded type of composite particles could be fabricated. In this study, particle bonding on the fibrous type of core particles was demonstrated.

Carbon nanofibers can be used as additives to improve the mechanical strength and electrical conductivity of plastics. However, their wettability to plastics is often undesirable. Figure 2 demonstrated the possibility of coating carbon nanofiers (a) with polymeric nanoparticles (b) to form nanocomposites (c) by the dry particle bonding technique, so that the coated carbon nanofibers could well be dispersed in the plastic matrix to achieve their designed functionalities.

(a) (ø100nm x 3µ) (b) (~150nm)

(c)

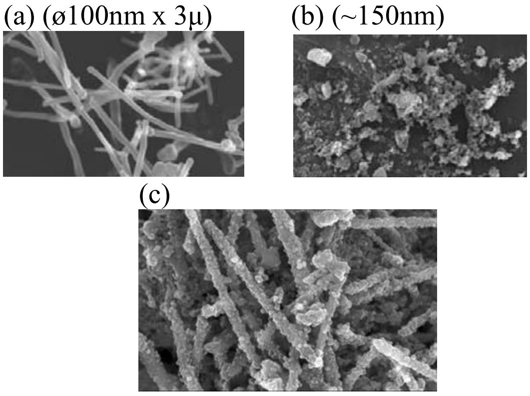

Figure 2. SEM photos of carbon nanofibers with nano resins.

Fumed silica board is known for its superb thermal insulation efficiency. However, it is very fragile and must be handled with great care. To improve the mechanical reliability and quality of fumed silica board, the glass fiber was loosely coated with silica nanoparticles by the proposed dry particle bonding technique[4], as shown in Figure 3. The glass fiber nanocomposites were then be compacted to make fumed silica board with about 80% porosity, which had thermal conductivity of 0.00266W/mK at 100ºC and 0.00269~0.00282W/mK at 400ºC respectively, lower than still air (0.03W/mK at ~100ºC; 0.05W/mK at ~400ºC) and at the same level as those made from silica aerogel. More importantly, the fumed silica board would have higher loading of nano-silica insolated glass fibers, which increased its mechanical strength for handling and machining if necessary.

Figure 3. Photo of nano-silica coated glass fiber

The dry particle bonding techniques can also be applied to other types of fibrous materials. For examples, PTFE fibers coated with carbon, as shown in Figure 4 (a), can be used to make separator for fuel cells. Also, the Titania coated fibrous polymer, as shown in Figure 4 (b) can be used as cosmetic ingredient.

(a) (b)

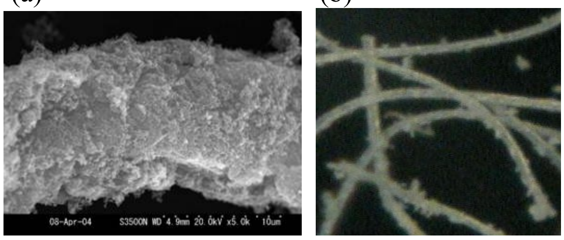

Figure 4. (a) Photo of carbon coated PTFE fiber
(b) Photo of oxide coated polymer

Conclusion:

The proposed dry particle bonding technique is an enabling technology for various nano and submicron particle applications. It is not only suitable for particles but also for materials with high aspect ratios. It opens the door for composite material applications required fibrous structures.

Reference:

[1]H. Abe, etc. Physica C 391 (2003) p. 211.
[2]T. Fukui, etc. J. of Power Sources 125 (2004) p.17.
[3]C. Huang, etc. Pro. Nanotech. & PM^2 (2003) p.105.
[4]H. Abe, etc. J. Am. Ceram. Soc., 88 (2005) p. 1359.