The Mechanical Fabrication of Nanocomposites and Engineered Particles

C. C. Huang
Hosokawa Micron Powder Systems
10 Chatham Road, Summit, NJ 07901 USA, chuang@hmps.hosokawa.com

ABSTRACT

The development of nanotechnology is closely related to the new economy full with high tech products towards 21st century. Although the production technologies of nanoparticles have had significant progress in the past few years, the commercial applications of nanoparticles are often limited by the cost, handling, and safety issues. To address these application problems, a proprietary Mechano-Chemical-Bonding technology has been developed to fabricate nanocomposite powders. With the technology, the nano materials can be bonded together using mechanical energy without any binders in a dry process. It can create nano-scale multifunctional composite materials contributing to the development of advanced materials and devices for rechargeable batteries, fuel cells, ceramics, metals, superconductors, cosmetics and pharmaceuticals. This presentation illustrates the development of the Mechano-Chemical-Bonding technology and application examples.

Keywords: composites, nanocomposite, coating, bonding

1 INTRODUCTION

Almost every consumer products, at some stages of their manufacturing processes, have been in the particulate form. In dry powder processing, it has been an industrial practice to customize the particle sizes, distributions, and shapes of the starting materials 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. To allow each component in the composite powder to express its inherent designed functions, the Mechano-Chemical-Bonding technique was developed for making ordered mixtures consisting components of different particle size, shape, density, and chemistry that are difficult to mix without causing segregation and agglomeration, or difficult to dissolve in each other by other methods, such as chemical synthesis.

The Mechano-Chemical-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 produce composites powders, especially nano composites, easily and in a large scale without contaminating the composite materials with liquid of any kind (solvents, binders or water) and it is environmentally friendly.

2 METHODOLOGY AND EQUIPMENT

In principle, the Mechano-Chemical-Bonding technique takes the advantages of passing dry powder mixtures through a narrow gap in a rotating device, as shown in Figure 1. The powders are repeatedly subjected to various types of mechanical forces during the processing. As a result, smaller guest particles can be bonded onto the surface of larger core particles; very small particles can be precisely mixed together; and, jagged particles can be rounded as shown in Figure 2.

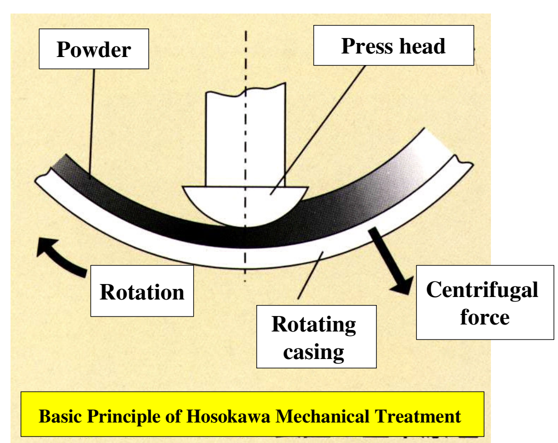

Figure 1. Principle of the dry particle coating technique

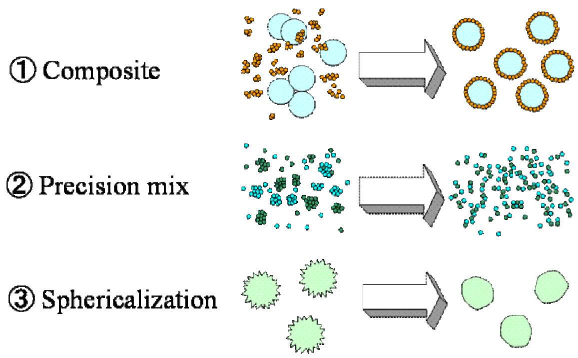

Figure 2. Powder mixtures treated by Mechano-Chemical-Bonding processes

The overall design of the Mechano-Chemical-Bonding process is proprietary and being technically updated as new application arises. Figures 3 and 4 showed two types of equipment designs in commercial scales that can practically produce any type of composite powders in tons of quantities per week without the constraint of chemical compositions.

Figure 3. Nobilta for making composites

Figure 4. Mechanofusion AMS for making composites

3 RESULTS AND EXAMPLES

The Mechano-Chemical-Bonding technique has been shown to work well with various material compositions. Depending on the particle size and mass ratios of guest particles to core particles, a core-shell type of composite particles or particles with surface-embedded guest particles can be fabricated. Typical examples are explained below.

Figure 5 showed nano titania particles (~60nm) were bonded onto the surface of metal core particle (~15μ) to form core-shell type of composite particles. The composite particles could then be used to fabricate high performance magnetic components with very dense structure for motors and solenoid valves.

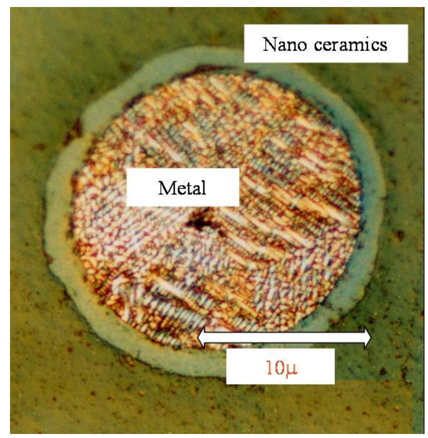

Figure 5. SEM cross section view of the core-shell type of composite particles made by Mechano-Chemical-Bonding technique

For producing MgB_2 superconductive materials, the magnesium particles (~40μ) are typically mixed with boron particles (~0.8μ); and, the powder mixture is then annealed at 650 ºC to develop its superconductivity. Figure 6 showed the effectiveness of applying the Mechano-Chemical-Bonding technique to disperse and embed submicron boron particles onto the surface of magnesium particles [1]. The highly dispersed boron particles on the magnesium particles has enabled the formation of superconducting MgB_2 phase at a lower annealing temperature (~500 ºC), which ensured finer gain sizes of MgB_2 phase and simplified its manufacturing processes.

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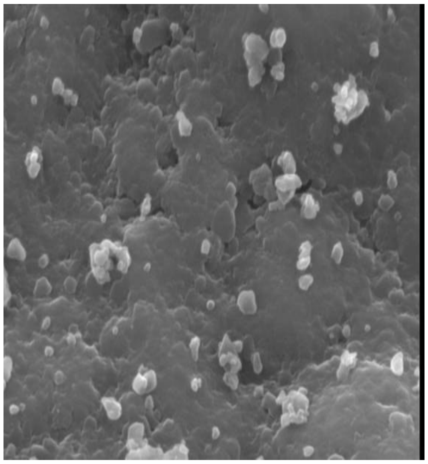
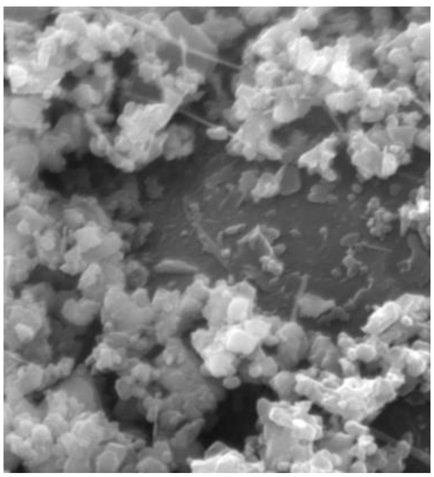


(Top)



(Bottom)

Figure 6. SEM photos of the submicron boron particles embedded on the magnesium core particles by the Mechano-Chemical-Bonding technique (Top) comparing to those loosely mixed by the conventional mixing process (Bottom)

As to solid oxide fuel cell applications, the technique has been successfully applied to make composite particles for fabricating conductive anodes, cathodes, and interlayer materials. Figure 7 showed very fine YSZ particles were bonded onto the surface of submicron sized NiO by the Mechano-Chemical-Bonding technique as well as the morphology of the anode made of the composite particles [2].

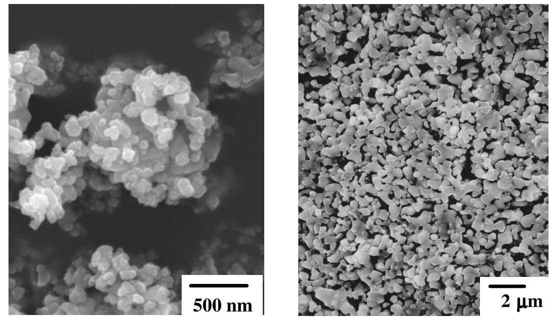


Figure 7. SEM photos of the NiO/YSZ composite particles (left) and the anode (right)

The performance improvement of the new anode was evident as shown in the Trafel Plot (Figure 8). The new anode made of bonded composites had lower Trafel slope with higher exchange current density comparing to those of the conventional electrodes even at a lower operating temperature [3].

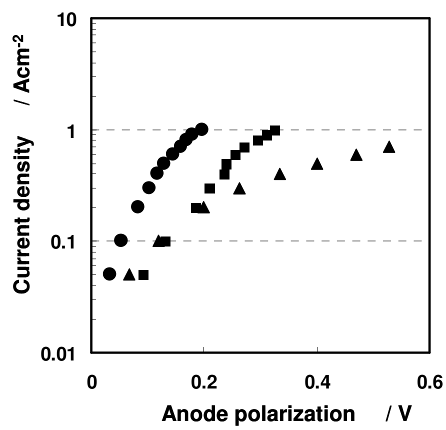


Figure 8. Conventional anode at 800 ºC (▲)
bonded composite anode at 700 ºC (■)
bonded composite anode at 800 ºC (●)

4 CONCLUSION

The newly developed Mechano-Chemical-Bonding technique is an enabling technology for various nano and submicron particle applications. It opens the door for composite material applications sensitive to powder dispersion and liquid contaminations.

REFERENCES

[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.