Formation Morphology of $YBa_2Cu_3O_{7-\delta}$

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With precise control of chemical stoichiometry, we succeeded novel formations of new nanopowders with crystal sizes as low as 5 nm [1]. Importantly, some powders have a fluid-like flow behavior, a unique property prompting further investigations.

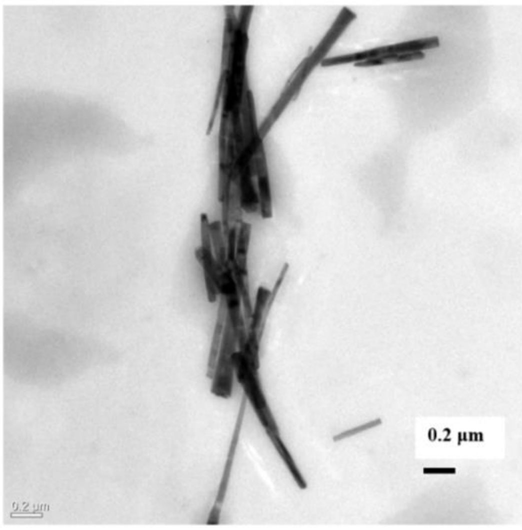

Fig. 1 TEM image of superconducting nanorods and nanotubes showing thickness as little as 50 nm and lengths as large as several micrometers.

The process starts with a raw material, which is then rapidly dissolved in acid making an ionic solution where the ions are precipitated using gelling agents. The precipitate is subsequently calcined to obtain a powder of molecular sizes. In the case of a powder consisting of nanorods and nanotubes, (Fig. 1) the X-ray diffraction showed a $YBa_2Cu_3O_{x-7}$ phase predominantly. A critical superconducting transition temperature T_c of 92 K in a magnetic field of 10 Oe was achieved, along with observation of the Meissner effect.

We have reported improved processes since the initial development of the wet chemical process for HTSC materials in the 1990s [2]. The formation of the novel morphology of HTSC nanotubes and other morphologies, such as the wafer structures (Fig. 2), bi-wafers, and spiral sheets exhibit the potential of this process to have a wide range of possibilities in creating new materials. Further, some of the new morphologies of HTSC materials manifest novel properties which we are currently researching.

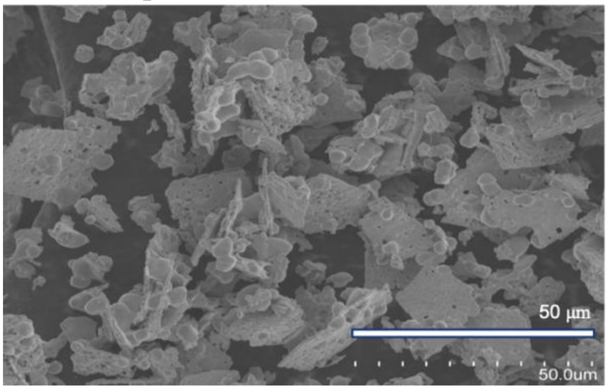

Fig. 2 SEM image of superconducting YBCO showing flat square shapes known as wafers

[1] S.P. Naik and P.M.S. Raju, *AIMS Materials Science*, **3(3)**, 916 (2016).
[2] A. Bhargava, I. Mackinnon, T. Yamashita, and D. Page, *Physica C*, **241**, 53 (1995).