# Supporting Information

## Enhancement of Dielectric Performance upto GHz of the Composites with Polymer Encapsulated Hybrid BaTiO3-Cu as Fillers: Multiple Interfacial Polarizations Playing a Key Role

*ChengliangLi,[ab] Shuhui Yu,*[a] Suibin Luo,[a] Wenhu Yang,[a] Zaochuan Ge,[b] Haitao Huang,[c] Rong Sun,*[a] Ching-Ping Wong[d]*

[a]Center for Advanced Materials, Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen, Guangdong 518055, China. E-mail: yuushu@gmail.com; rong.sun@siat.ac.cn; Fax: +86-755-86392299; Tel: +86-755-86392104; +86-755-86392158
[b]College of Material Science and Engineering, Shenzhen University, Shenzhen, Guangdong 518061, China
[c]Department of Applied Physics and Materials Research Center, The Hong Kong Polytechnic University, Hong Kong, China
[d]Department of Electronic Engineering, The Chinese University of Hong Kong, Shatin, NT, Hong Kong, China

The mass and volume fractions of a mixture are respectively the sum of eachcomponent. Where the $m_{BT\text{-}Cu}$, $m_{BT}$, $m_{Cu}$, $m_{PVDF}$, $m_c$, are the mass of BT-Cu hybrid particles, BT particles, Cu particles, PVDF and BT-Cu/PVDF composites respectively; $\rho_{BT\text{-}Cu}$, $\rho_{BT}$, $\rho_{Cu}$, $\rho_{PVDF}$, $\rho_c$ stand for the density of BT-Cu hybrid particles, BT particles, Cu particles, PVDF and BT-Cu/PVDF composites, $V_{BT\text{-}Cu}$, $V_{BT}$, $V_{Cu}$, $V_{PVDF}$, and $V_c$ are the volume of BT-Cu hybrid particles, BT particles, Cu particles, PVDF and BT-Cu/PVDF composites respectively, $t_{pvdf}$ and $t_c$ are the thickness of the sample of PVDF and BT-Cu/PVDF composites, wt% is the mass fraction of BT-Cu hybrid particles in BT-Cu/PVDF composites. The volume fraction of BT-Cu (BT-Cu vol%), BT(BT vol%) and Cu (Cu vol%) are calculated according to the following equations:

（1） $m_{BT} + m_{Cu} = m_{BT-Cu} \rightarrow \rho_{BT} \cdot V_{BT} + \rho_{Cu} \cdot V_{Cu} = \rho_{BT-Cu} \cdot (V_{BT} + V_{Cu})$；

（2） From (1) we can get： $\frac{V_{BT}}{V_{Cu}} = \frac{\rho_{Cu} - \rho_{BT-Cu}}{\rho_{BT-Cu} - \rho_{BT}}$ and

$$\frac{m_{Cu}}{m_{BT}} = \frac{\rho_{Cu} \cdot V_{Cu}}{\rho_{BT} \cdot V_{BT} + \rho_{Cu} \cdot V_{Cu}} = \frac{\rho_{Cu}}{\rho_{BT}\frac{V_{BT}}{V_{Cu}} + \rho_{Cu}};$$

（3） Mass fraction of Cu in BT-Cu hybrid particles:, $wt\%(Cu)=\frac{\frac{1}{\rho_{BT}}-\frac{1}{\rho_{BT-Cu}}}{\frac{1}{\rho_{BT}}-\frac{1}{\rho_{Cu}}}$ ;

（4） Mass fraction of BT in BT-Cu hybrid particles: $wt\%(BT)=1-\frac{\frac{1}{\rho_{BT}}-\frac{1}{\rho_{BT-Cu}}}{\frac{1}{\rho_{BT}}-\frac{1}{\rho_{Cu}}}$ ;

（5） Volume fraction of BT-Cu hybrid particles in BT-Cu/PVDF composites：

$$BT-Cu(vol\%)=\frac{wt\%}{wt\%+\frac{\rho_{BT-Cu}\cdot(1-wt\%)}{\rho_{PVDF}}};$$

（6） The density of PVDF: $\rho_{PVDF}=\frac{4m_{PVDF}}{\pi D_{PVDF}{}^{2}t_{PVDF}}$ ;

（7） The density of BT-Cu/PVDF： $\rho_{c}=\frac{1}{\frac{wt\%}{\rho_{BT-Cu}}-\frac{1-wt\%}{\rho_{PVDF}}}$ ;

（8） Volume fraction of BT in BT-Cu/PVDF：

$$BT(vol\%)=\frac{wt\%(BT)\cdot wt\%\cdot\rho_{BT-Cu}/\rho_{Cu}}{wt\%+\frac{\rho_{BT-Cu}\cdot(1-wt\%)}{\rho_{PVDF}}};$$

（9） Volume fraction of Cu in BT-Cu/PVDF：

$$Cu(vol\%)=\frac{wt\%(Cu)\cdot wt\%\cdot\rho_{BT-Cu}/\rho_{BT}}{wt\%+\frac{\rho_{BT-Cu}\cdot(1-wt\%)}{\rho_{PVDF}}}.$$

The reason of inoxidizability of BT-Cu particles lies on the polymer layer capped on the surface of BT-Cu particles, because the thickness of oleic acid layer is extremely thin, it is hardly to detect the existence of this polymer through XRD. So FT-IR was used to analyze the chemical composition of thesurface of BT-Cu particles.As is shown in Fig 6, the two strong absorption peaks at578.6 $cm^{-1}$and 437.8 $cm^{-1}$and absorption at 1442.7 $cm^{-1}$are assigned to thecharacteristic peaks of BT.

contrast withthe spectra of BT powder, the difference of BT-Cu hybrid particles absorption peaks of 3413.8 $cm^{-1}$ is stretching vibration band of hydroxyl, 2889.3 $cm^{-1}$ and 1340.4 $cm^{-1}$ are respectivelyassigned to stretching vibration band and scissoring vibration band of methylene, 1110.9 $cm^{-1}$ is the stretching vibration from C-O-C of PEG-4000 repeating unit. These above indicate that polyethylene glycol 4000 was successfully coatedon the surface of BT-Cu particles, presenting the BT-Cu hybrid particles with antioxidant properties.

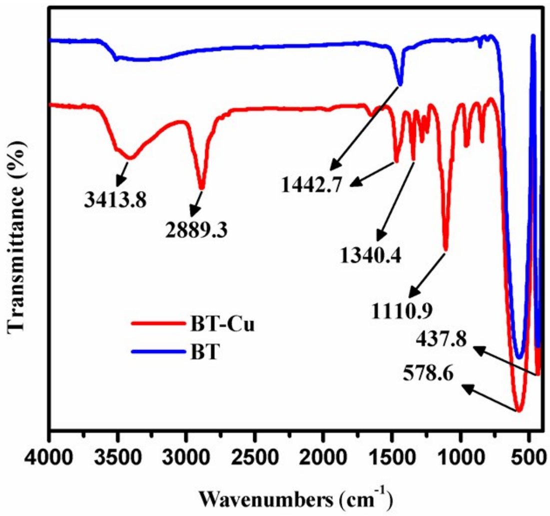


**Fig. S1** FT-IR spectra of oleic acid capped BT-Cu nanoparticles