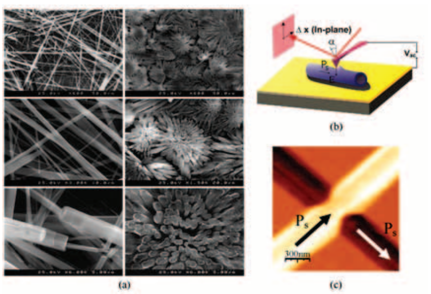
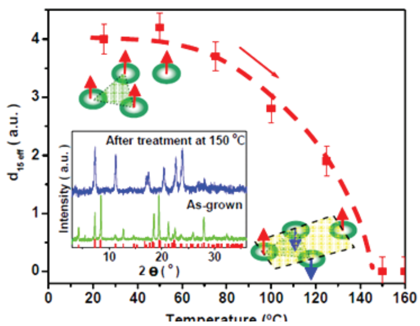
strong piezoelectricity in peptide nanotubes

alejandro heredia[1], eric bosne[1] vladimir bystrov[1], andrei kholkin[1], igor bdikin[2], svitlana kopyl[2], josé gracio[2]

1 department of ceramics and glass engineering & CICECO, university of aveiro
2 department of mechanical engineering & TEMA, university of aveiro





Piezoelectricity, the ability of noncentrosymmetric materials to produce mechanical stress/strain under an electric field or charge/voltage under a mechanical force, is widely used in many areas, e.g. in medical ultrasound transducers and filters for mobile phones. Until recently, only inorganic piezoelectrics (such as PZT or $LiNbO_3$) have been used based on their high piezoelectric coefficients. In view of growing interest in biomedical applications and green technologies, bioorganic materials having a significant piezoactivity are required for ever expanding area of piezodevices. Several natural biomaterials were found to be piezoelectric but their piezoelectric properties were by far insufficient to be used in the devices.

In 2010, a strong piezoelectricity (of the order of that in the classical transducer material $LiNbO_3$) was discovered in artificially prepared biomaterials: peptide nanotubes (PNTs) made by a self-assembly process of small diphenylalanine, NH2-Phe-Phe-COOH, peptide monomers. These PNTs are derived from the smallest recognition motif of the famous amyloid-β protein, associated with over 30 diseases, mostly neurodegenerative ones such as Alzheimer, Huntington, Parkinson, Creutzfeldt-Jacob and prions. They conveniently self-assemble in stable and rigid tubular nanostructures where piezoelectric polarization is directed along the tube axis. Both horizontal and vertical tubes were prepared in UA and characterized by Piezoresponse Force Microscopy – a novel method actively developed in CICECO group Among the recent findings of the joint CICECO/TEMA team is the discovery of irreversible transformation of PNTs to another crystalline (possibly orthorhohombic) so that two stable polymorphic phases can exist at room temperature. The polarization was found to decrease from room temperature to 140 ºC and antiferroelectric-like ordering with opposite polarization orientations in adjacent aromatic rings is observed. Amazingly, polarization switching was observed in such tubes proving their ferroelectric nature. These findings were supported by rigorous molecular simulations showing that ferroelectric-like behavior is originated from the hydrogen bonds connecting individual FF monomers, which break upon the temperature increase.

This discovery opens up an avenue for using PNTs (currently considered as a dielectric analog of carbon nanotubes) as bioorganic sensors, actuators and molecular motors.