

## SCOPE

Our Laboratory is active in the (I) preparation/processing and (II) investigation of physical properties, of polycrystalline and monocrystalline materials: superconductors, ferro-magnetic/electric, biological, in the form of three (compact bulk), two (film), one (wire-shaped oxides) and zero (nanoscopic particles) dimensions. In addition, attention has been given on combinatorial/hybrid metamaterials due to their multifunctional character and the accompanying possible applications.

### (I) EXPERIMENTAL SETUPS FOR THE PREPARATION/PROCESSING OF SAMPLES

#### Setup for sintering under controlled environment (vacuum or desired gas):

One-open-end quartz tubes adjustable to a two-stage pump unit (rotary and diffusion pumps Edwards, SpeedvacED50 and Diffstak 63/150c, respectively) with base pressure  $\sim 5 \times 10^{-6}$  Torr at  $T=25^\circ\text{C}$  and  $\sim 5 \times 10^{-5}$  Torr at  $T=1000^\circ\text{C}$ . Two-open-ends quartz tubes with appropriate fittings for the controlled application of the desired gas (reductive  $4\% \text{H}_2 + \text{Ar}$ , inert Ar etc). The units are used in combination with a shared furnace (Carbolyte, TZF12/65/550,  $T \leq 1200^\circ\text{C}$ ).



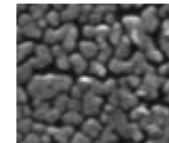
**Setups/instruments used in solid/wet chemistry:** Autoclave unit for wet chemistry reactions up to  $200^\circ\text{C}$ . Precision scale (DS-26), Agate mortar/pestle, hydraulic press (Express, TY10003), centrifuges (Phoenix, CD2012 Plus), vortex (Scilogex, MX-S), precision pipettes (Scilogex, 0-10,100,1000 $\mu\text{L}$ ), home-made spin coaters etc.



**Setup of dc magnetron sputtering:** setup of single gun, comprising of a two-stage pump unit (rotary, ELNOR, and diffusion, Leybold-DO121L), liquid nitrogen cryotrap, dc current source (Advanced Energy MDX-1.5K) and manual control of the employed gas pressure. Achieved base pressure  $\sim 5 \times 10^{-7}$  Torr.



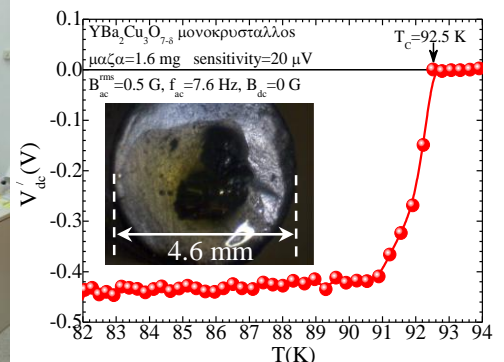
**Setup for thermal evaporation of low-melting point metals:** setup of single source, comprising of a two-stage pump unit (rotary and diffusion, Leybold D2,5E and Edwards EO50/60, respectively) and a controlled temperature furnace up to  $700^\circ\text{C}$  with accuracy  $\pm 1^\circ\text{C}$  (WEST 3810). Achieved base pressure  $\sim 5 \times 10^{-6}$  Torr.



Pb on Si  
570 °C  
15 sec

### (II) EXPERIMENTAL SETUPS FOR THE INVESTIGATION OF PHYSICAL PROPERTIES

**Setup for ac magnetic susceptibility:** Independent, automated setup for recording the alternating magnetic moment of a sample, finally given in the form of a dc voltage (scanner Keithley DM2000:  $0.1 \mu\text{V} \leq V_{dc} \leq 1000\text{V}$ ). The setup is based on four secondary coils in second order configuration and a Lock-In amplifier (Stanford Research Systems, SR530), with sensitivity up to  $10^9$ , in external triggering operation. Measurements are performed in the range  $78\text{K} \leq T \leq 300\text{K}$ . The excitation ac magnetic field has rms value  $0.001\text{G} \leq B_{ac}^{rms} \leq 2\text{G}$  and frequency  $0.1\text{Hz} < f_{ac} \leq 13\text{MHz}$  (function generator HP3312A). A dc magnetic field  $-500\text{G} \leq B_{dc} \leq 500\text{G}$  (current source Schroff SEC3022A) can be applied, optionally. The sensitivity of the setup, depending on the magnetic susceptibility of the material, is better than  $1 \mu\text{V}/\text{mgGauss}$  (signal/noise  $> 10^4$  for polycrystalline samples of mass 100-300 mg, while signal/noise  $\approx 10^2$  for single crystals of mass 0.1-10mg).



**Setups for electrical resistivity:** Two independent, automated setups for recording the electrical response of samples, finally given in the form of a dc voltage (voltmeter, scanner Keithley DM2000:  $0.1\mu V \leq V_{dc} \leq 1000V$ ), under application of a (a) dc and (b) ac current. The two setups act in a complementary fashion in the investigation of materials that reside in the entire range from superconductors to insulators. (a) The setup of dc electrical resistivity comprises of a dc current source (Keithley 224:  $5nA \leq I_{dc} \leq 100mA$ ) and the above-mentioned voltmeter. (b) The setup of ac electrical resistivity comprises of an ac voltage source (Black Star, Jupiter 500:  $0 < V_{ac}^{pp} \leq 30V$ ,  $0.1Hz < V_{ac}^{pp} \leq 500kHz$ ), an ac voltage-to-ac current converter, a Lock-In amplifier (Stanford Research Systems, SR530), with sensitivity up to  $10^9$ , in external triggering operation and the above-mentioned voltmeter. Measurements are performed in the range  $78K \leq T \leq 300K$ . A dc magnetic field  $-1000G \leq B_{dc} \leq 1000G$  (current source HP 6260B) can be applied, optionally. The sensitivity of the setup is better than  $10^{-8}\Omega cm$  for superconductors and better than  $10^{10}\Omega cm$  for insulators. Finally, for the investigation of piezoelectric materials and relevant combinatorial/hybrid metamaterials, following a special preparation of the sample, we can apply high dc electric fields in the range  $-30kV/cm \leq E_{dc} \leq 30kV/cm$  (Keithley Instruments, 246 High Voltage Supply) during the measurements in both techniques, dc and ac electrical resistivity.



**Multifaceted setup for the investigation of combinatorial magnetic-(piezo)electric-optical properties:**

Independent, multifaceted setup for the automated recording of the interference between magnetic, (piezo)electric and optical properties exhibited by combinatorial/hybrid metamaterials. The setup is based on a helium optical cryostat (Janis, CCS-150), a closed-cycle helium compressor (CTI-Cryogenics© 8200) and a turbo-based pumping station (Pfeiffer, HIPACE80).

Measurements are performed in the range  $10K \leq T \leq 325K$  with controlled temperature. The setup comprises of the following peripherals:

- Multimeter scanner of dc and ac, voltage and current (Keithley DM2000:  $100nV \leq V_{dc} \leq 1000V$ ,  $100nV \leq V_{ac}^{rms} \leq 750V$ ,  $10nA \leq I_{dc} \leq 3A$ ,  $1\mu A \leq I_{ac}^{rms} \leq 3A$ ).
- Lock-In amplifier (Stanford Research Systems, SR850), with sensitivity up to  $10^9$ , in operation of internal/external triggering.
- Amperemeter of dc current with measuring capability in the range  $2nA \leq I_{dc} \leq 20mA$  with resolution 10 fA, having a built-in dc voltage source operating in the range  $0 \leq V_{dc} \leq 500V$  with step 200  $\mu V$  (Keithley, 6487 picoameter/voltage source).



*The setup is under construction. Soon, the following temperature controller and UV-vis spectrophotometer will be installed.*

- Temperature controller with accuracy  $\pm 1$  mK (Stanford Research Systems, CTC100).
- Spectrophotometer UV-VIS 190nm-1100nm, (Rayleigh UV1601).

**Setups of optical microscopy:** Optical microscopes (5 independent units) and a stereoscope, operating in transmission and reflection modes. Each unit is connected through a digital camera to a distinct PC for imaging the samples (photo snapshots and video). Bio-molecular/chemical stains and fluorescence tracers (regime 450nm-680nm) and polarized light are used, depending on the issue under examination.



**Note:** For the operation of the cryogenic setups, proper infrastructure and accessories exist for the long-term storage (Messer Griesheim Apollo, tank 100 lt) and every-day use (Cole-Parmer, dewars 2-5 lt) of liquid nitrogen.