Significant power factor improvement in a hybrid solid-liquid thermoelectric device formed by Sb:SnO_2 in contact with a chromium complex solution

Castro-Ruiz. Sergio, *Solís-De La Fuente. Mauricio, Márquez-García. Lourdes, Beltrán-Pitarch. Braulio, Mota-Babiloni. Adrián, Vidan. Francisco, García-Cañadas, Jorge*

Thermal and Electrical Systems Laboratory (http://teslab.uji.es)
Department of Industrial Systems Engineering and Design
Universitat Jaume I, Castelló de la Plana (Spain)
E-mail: scastro@uji.es

Outline

1. Introduction
2. Experimental part
3. Results
4. Summary
5. Acknowledgements

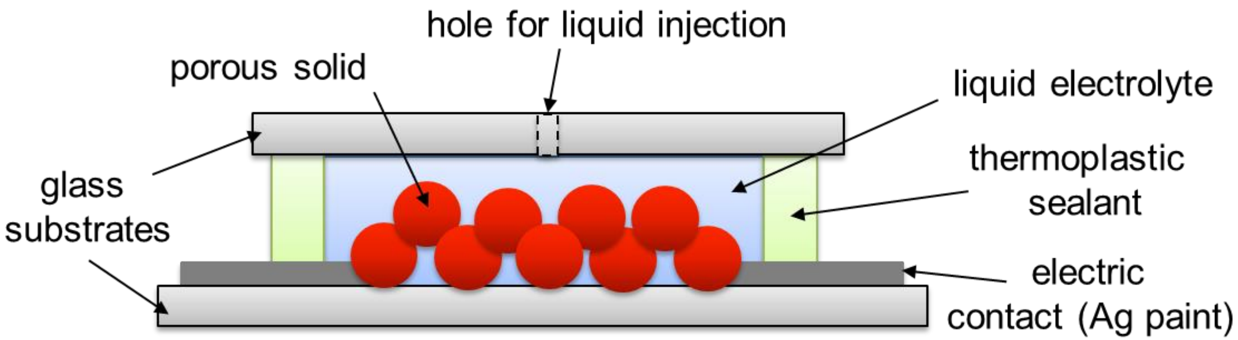
- ✓ A **new hybrid solid-liquid thermoelectric (TE)** device was published in **2018 by our group**: **TE solid** which is **permeated by a liquid electrolyte** that was able to **improve the power factor (PF) more than 3 times**.

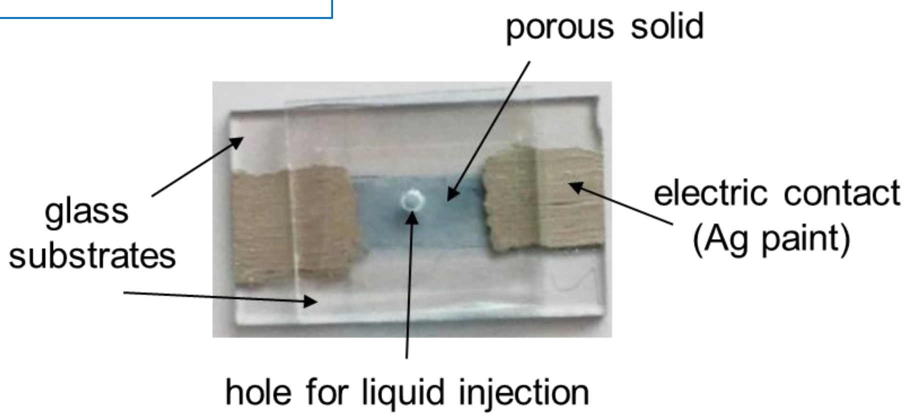
ACS APPLIED ENERGY MATERIALS Letter
Cite This: ACS Appl. Energy Mater. 2018, 1, 254−259 www.acsaem.org

Large Power Factor Improvement in a Novel Solid−Liquid Thermoelectric Hybrid Device

Lourdes Márquez-García,[†] Braulio Beltrán-Pitarch,[†] Damian Powell,[‡] Gao Min,[‡] and Jorge García-Cañadas*,[†]

[†]Department of Industrial Systems Engineering and Design, Universitat Jaume I, Campus del Riu Sec, 12071 Castellón, Spain
[‡]School of Engineering, Cardiff University, The Parade, CF24 3AA Cardiff, United Kingdom



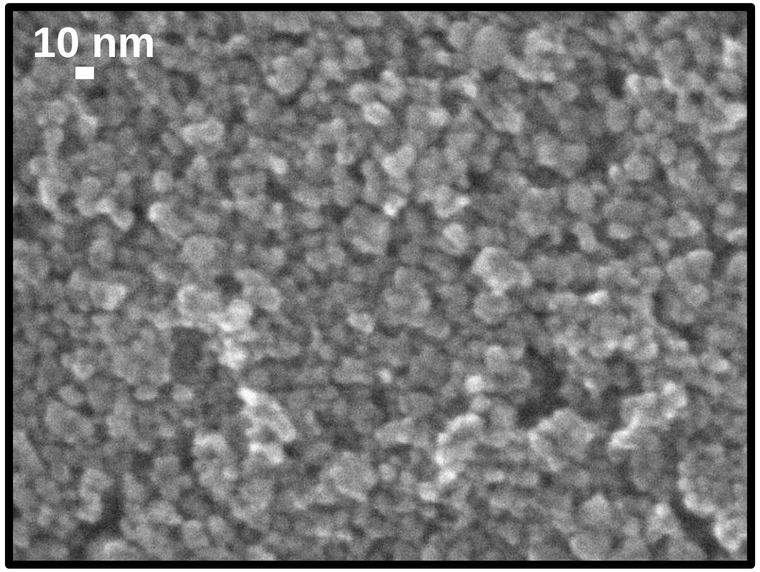


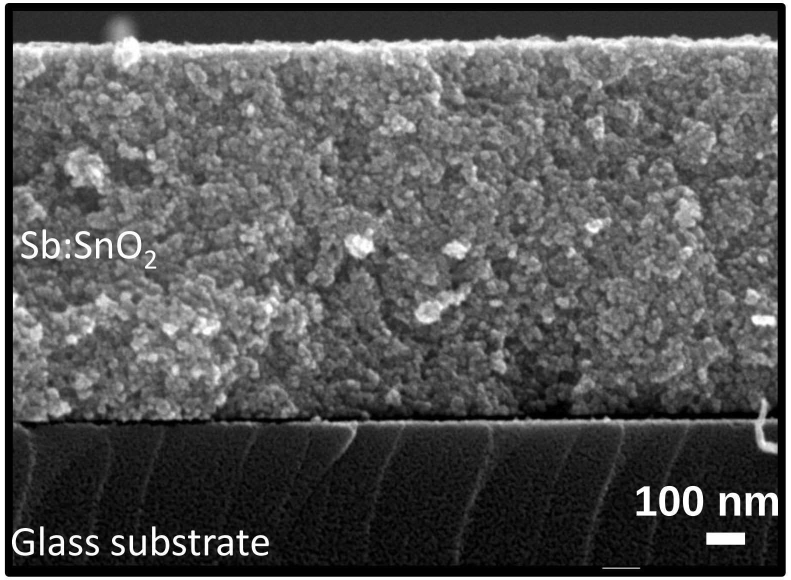
In this study, a **Cr complex solution** will be employed to prove if the approach can be extended to **this kind of electrolyte.**

2. Experimental part

The porous solid: nanostructured Sb:SnO$_2$ (ATO)

- ✓ Prepared from commercial **colloidal water dispersion** (Keeling and Walker Ltd., UK). Deposited by **spin coating** (5 layers) onto a glass substrate and **annealed at 550 ºC** for 45 min.
- ✓ Film is formed by interconnected **nanoparticles** of around **4 to 10 nm** diameter. The film thickness is ≈1.0 µm (SEM) and it shows certain porosity (≈10%).



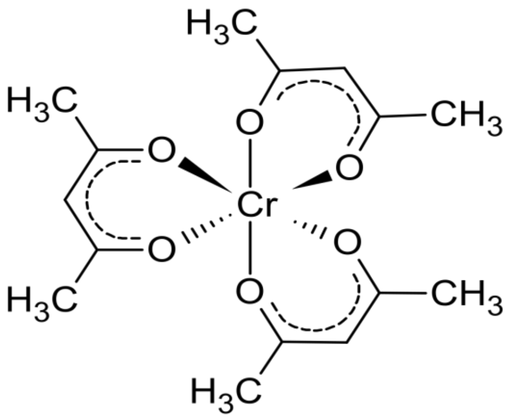


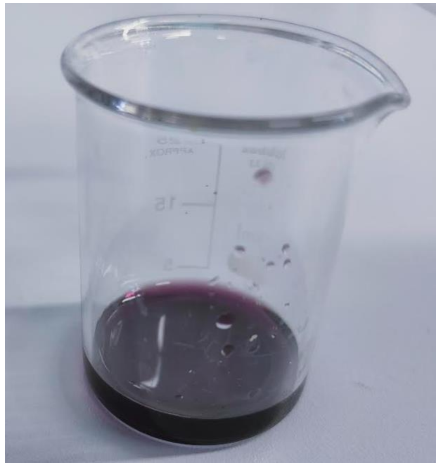
(SEM images)

The electrolyte: Chromium acetylacetonate ([Cr(acac)$_3$]) in 3-MPN

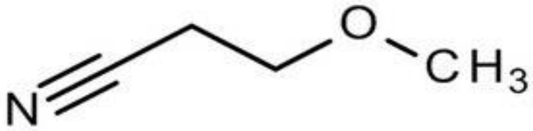
- ✓ It is prepared by dissolving the **Cr complex** into the **3-methoxypropionitrile (3-MPN) solvent** to obtain a **0.1M solution**.

Chromium acetylacetonate [Cr(acac)$_3$]



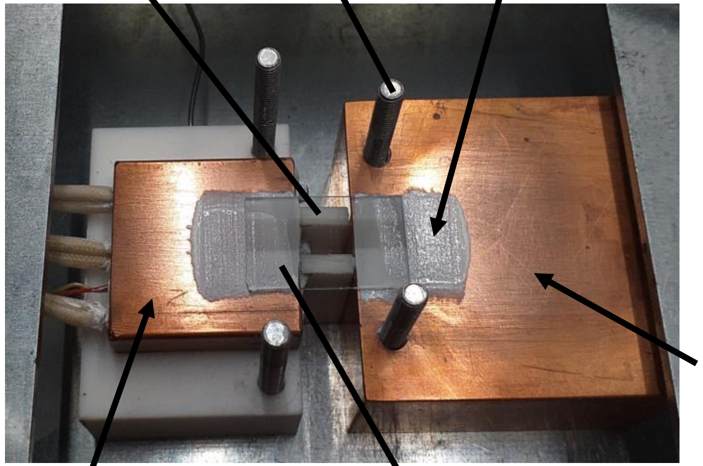


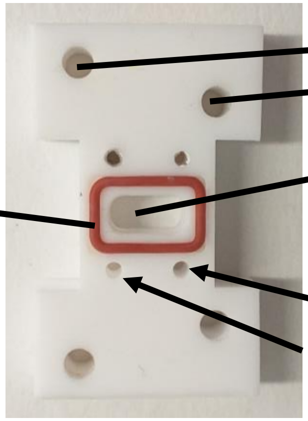
3-methoxypropionitrile



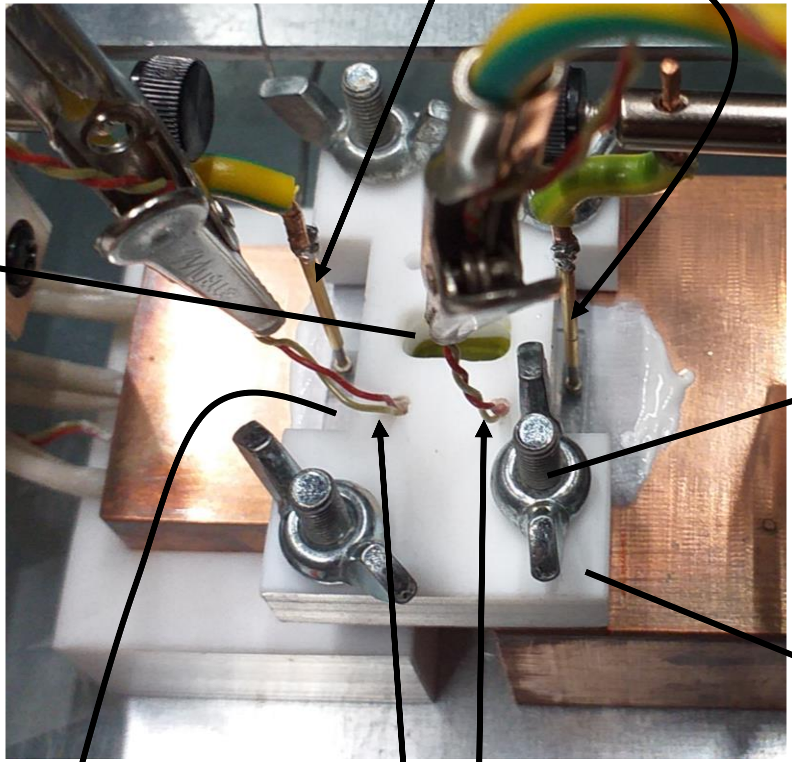
2. Experimental part

Measurement setup



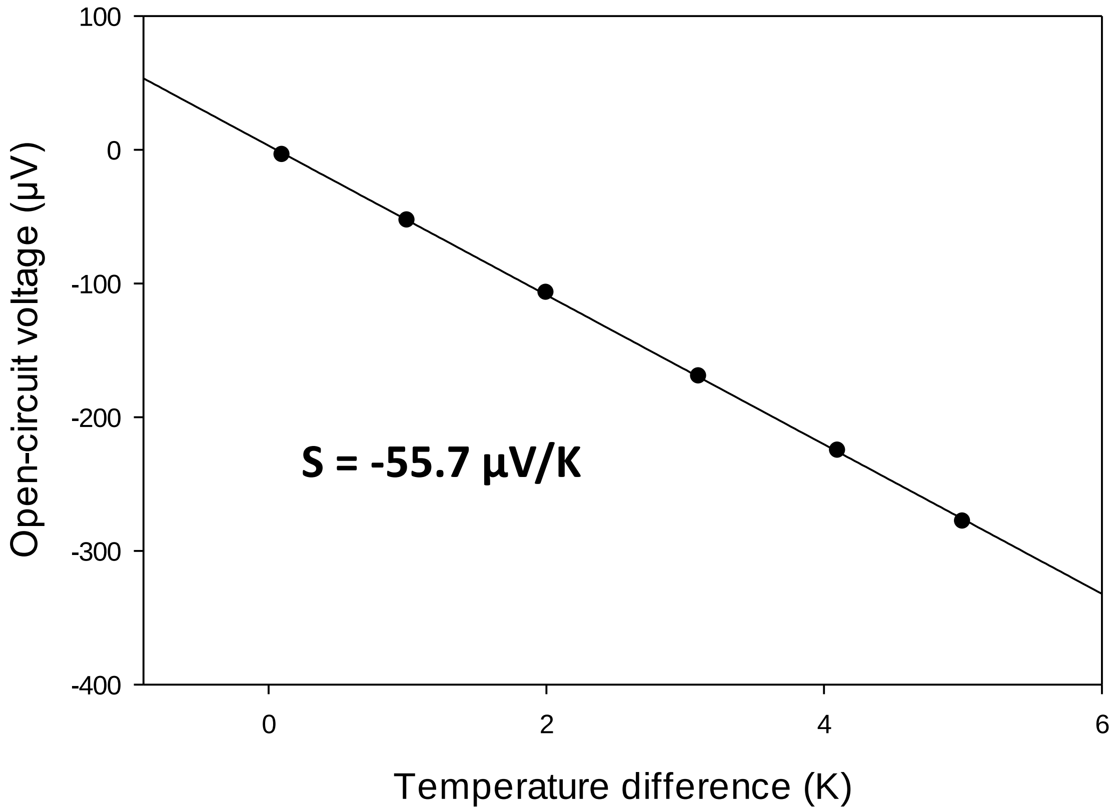


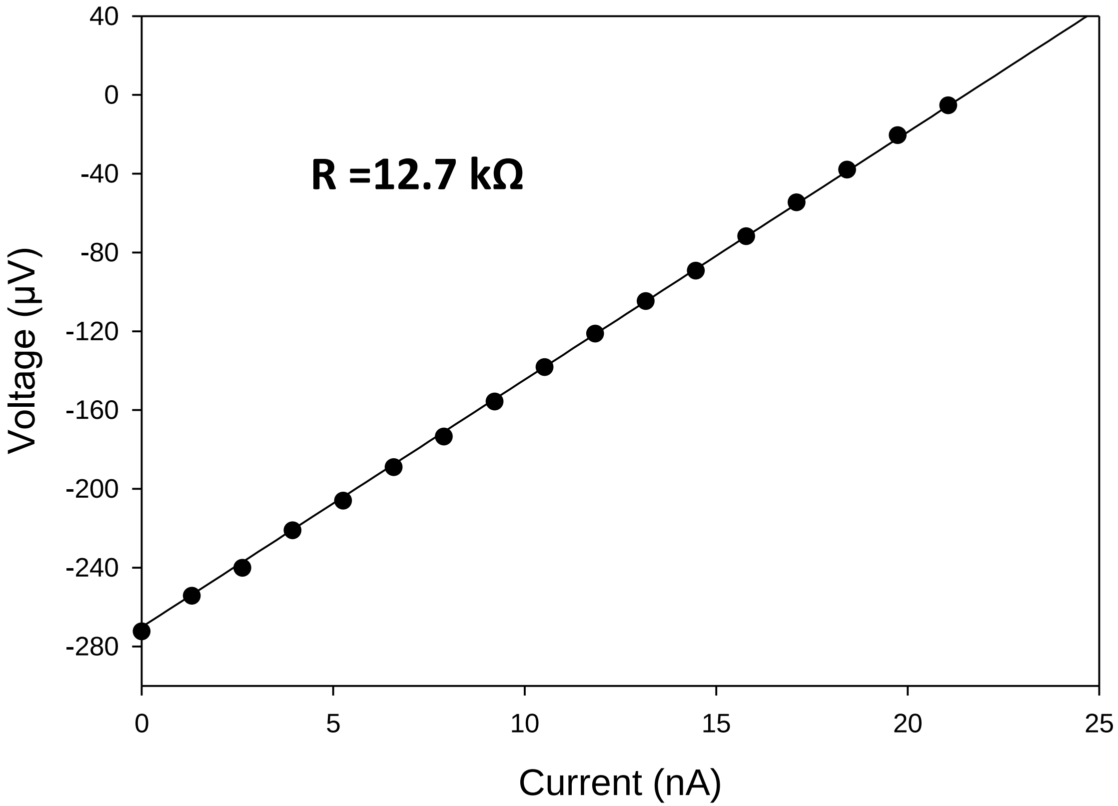
(bottom part of superior PTFE part)



Thermoelectric measurements

- ✓ **Seebeck coefficient**: Extracted from the slope of the V_{oc} – ΔT plot.
- ✓ **Device electrical resistance**: Extracted from the slope of the I – V curve at ΔT=5 K.





(measurements of ATO film with no electrolyte)

3. Results

✓ **ATO samples contacted by Ag paint** were tested **with and without** the presence of **0.1M $Cr(acac)_3$** dissolved in **3-MPN** to evaluate the variation in the thermoelectric properties.

Sample	Seebeck coefficient (μV/K)			Device electric resistance (kΩ)			$PF_{with}/PF_{without}$
	Without electrolyte	With electrolyte	S variation (%)	Without electrolyte	With electrolyte	R variation (%)	
S1	-55.7	**-40.1**	-27.9	12.7	**3.89**	-69.3	**1.71**
S2	-57.3	**-42.3**	-26.2	18.5	**7.56**	-58.9	**1.34**
S3	-59.4	**-51.2**	-13.9	10.2	**5.08**	-50.1	**1.48**

Seebeck

⇩ **22.7%**

Resistance

⇩ **59.4%**

Power Factor

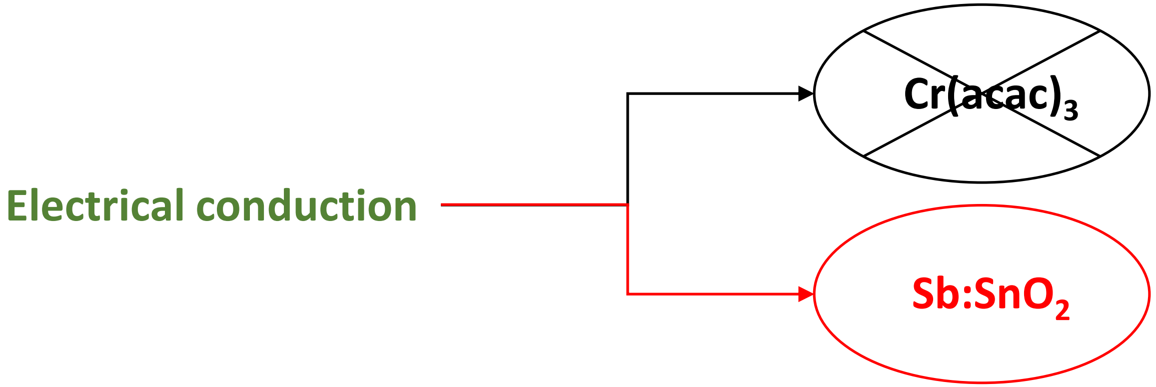
⇧ **1.51 times**

3. Results

✓ **One sample** was fabricated **without ATO**, to evaluate if the **electrical conduction** occurs **through the electrolyte**.

Sample	Seebeck coefficient (µV/K)	Device electric resistance (kΩ)
	With electrolyte	With electrolyte
Glass substrate with Ag paint contacts and $Cr(acac)_3$	**-**	**4,580**

✓ Seebeck could not be measured due to the large resistance of the device. A value in the order of MΩ was obtained for the device resistance, which proves that **electronic conduction is not possible through the electrolyte** and takes place mainly through the ATO.



✓ **Samples in contact with only 3-MPN** (no Cr complex) were tested to understand the system further.

Sample	Seebeck coefficient (µV/K)			Device electric resistance (kΩ)			$PF_{with}/PF_{without}$
	Without electrolyte	With electrolyte	S variation (%)	Without electrolyte	With electrolyte	R variation (%)	
S4	-57.7	**-36.9**	-35.9	16.5	**9.40**	-43.1	**0.72**
S5	-57.1	**-43.1**	-24.7	8.70	**5.39**	-38.0	**1.00**
S6	-49.1	**-35.5**	-27.8	13.4	**8.88**	-33.4	**0.80**

Seebeck

⇩ **29.5%**

Resistance

⇩ **38.2%**

Power Factor

⇩ **0.84 times**

✓ **If $Cr(acac)_3$ is not present, PF improvement is not shown**, since the device resistance does not reach lower values [only 38% reduction, while 59% was obtained with $Cr(acac)_3$].

4. Summary

- ✓ **A hybrid system** formed by nanostructured **Sb:SnO_2** permeated by a **Cr complex electrolyte** has been investigated to **improve** the thermoelectric **power factor**.

- ✓ More than **1.50 times improvement** in the power factor has been achieved due to a **59.4 % reduction of the device electric resistance** and a **22.7% drop** in the absolute value of the **Seebeck coefficient**.

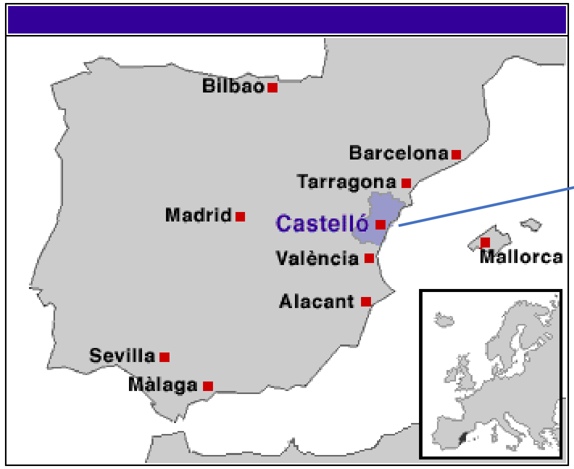
- ✓ It was demonstrated that the **drop in the resistance** is **not due to the conduction through the electrolyte**.

- ✓ It has been shown that when **the Cr complex is not present in the system** (only **3-MPN as a electrolyte**), no PF improvement (0.82 times) is obtained.

$S^2\sigma$ ↑

*This electrolyte will be **tested using state-of-the-art TE materials** (e.g. Bi_2Te_3) within the EU **UncorrelaTEd project***

✓ This project has received funding from the European Union's Horizon 2020 research and innovation programme under **grant agreement No 863222**.



UNIVERSITAT JAUME I

TESLab

http://teslab.uji.es

E-mail: scastro@uji.es

UncorrelaTEd

http://uncorrelated.uji.es/