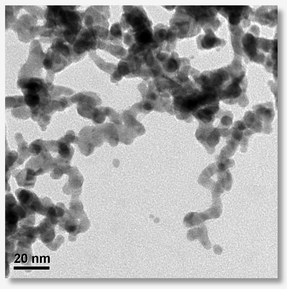
Room Temperature aging in nano-crystalline porous gold coatings

Deep Panjwani, Aniruddha Dutta, Janardan Nath, Helge Heinrich, Robert Peale

Department of Physics, University of Central Florida

Introduction



Porous gold layers are produced by thermal evaporation in presence of inert gas such as N_2, He and Ar. Particles in the gold cloud collide with inert gas molecules, they lose energy while colliding with other gold particles, causing them to form nano-crystalline chains.

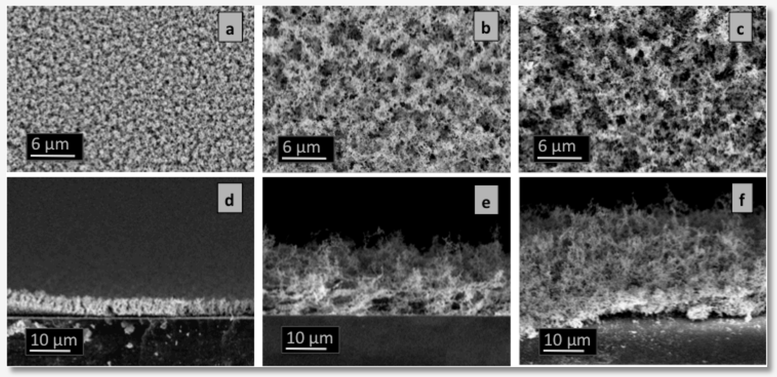
These chains diffuse towards the cooled substrate and overlap, resulting in loosely bound three-dimensional porous structure. High porosity makes these coatings fragile and prone to aging. We present here a study of aging on electrical and optical properties and on microstructure. Their primary application is as an absorbing coating for infrared bolometers.

Results

The porosity of the coating was controlled by the N_2 pressure inside the chamber during the evaporation.

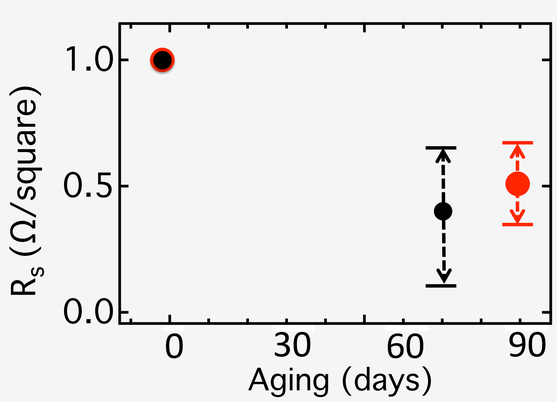
Porosity, average sheet resistance & resistivity of coatings prepared with different N_2 pressure inside the chamber.

Coating Type	N_2 Pressure (Torr)	Mass of gold (mg)	Deposition Rate (mg/s)	Porosity (%)	Average Sheet Resistance (Ω/Square)	Average Resistivity (Ω•m)
1	0.3	121	1.59	97.5	313	1.24E-03
2	1.5	121	0.97	98.8	1935	3.25E-02
3	3.0	121	1.47	99.6	32330	8.01E-01



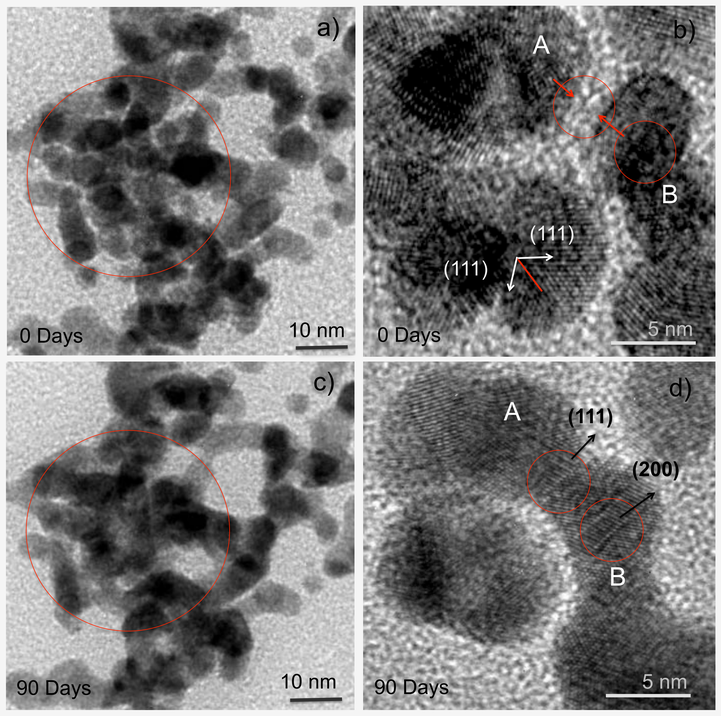
SEM top-view images of porous gold coating prepared with different N_2 pressure of 0.3 (a) 1.5 (b) & 3.0 Torr (c). Cross-sectional SEM images of similar porous gold (d), (e) & (f).

In batch 1 & 2 the normalized sheet resistance mean value was 0.55 ± 0.37 and 0.43 ± 0.18 after sixty and ninety days of aging respectively. No collapse of the structure was observed.



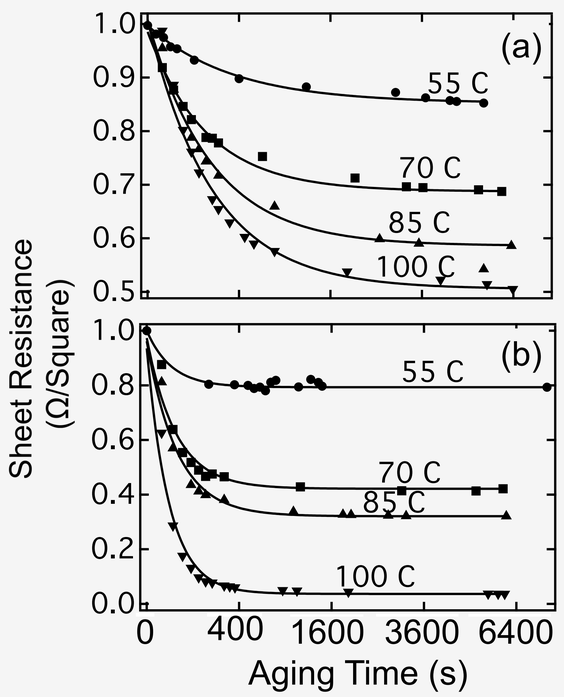
Aging of sheet resistance at room temperature.

HR-TEM revealed many grain boundaries and twinning defects. The particles coalesce and degree of crystallinity increases over time at room temperature.



TEM image of gold black feature before (a,b) and after (c,d) Aging of 90 days.

Nanoparticles coalesce more rapidly at higher temperatures, allowing accelerated aging studies.

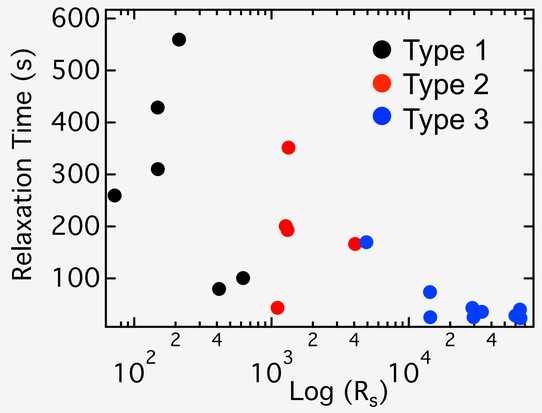


Sheet resistance is plotted against time at different temperatures for porous gold coatings prepared at 1500 (Type 2) (a) and 3000 mTorr (Type 3) (b)

A relaxation model (Eq.1) was applied to estimate structural relaxation time in the coatings prepared with different porosities.

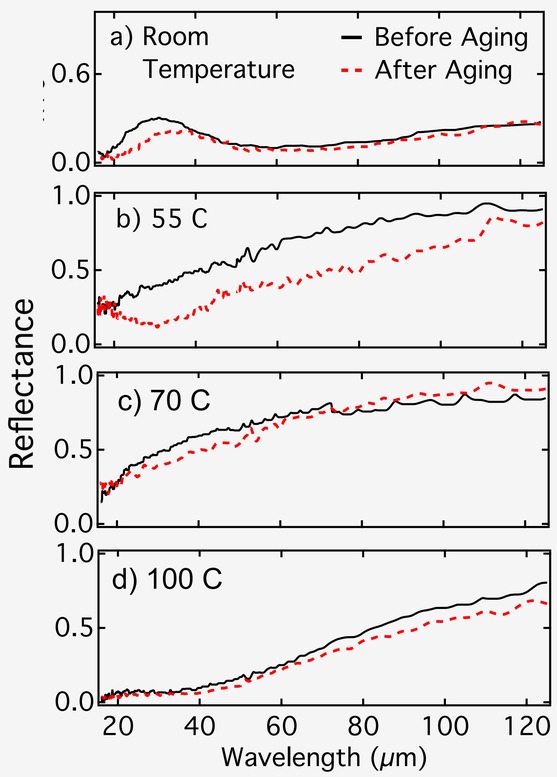
$$R_s(t) = R_{s\infty} + (R_{s0} - R_{s\infty})exp\left(-\left(\frac{t}{\tau}\right)^z\right) \quad (1)$$

Coatings with lower initial sheet resistance higher relaxation time.



Relaxation time is plotted against initial sheet resistance of porous gold coatings

The effect on the reflectance spectrum appears to depend mainly on the temperature, but in most cases is it weak.



Spectral aging in 90 days at room temperature (a)
Spectral aging in 5 hours at 65 C (b) 80 C (c) and 105 C (d).

Summary

- Nanopartical coalescence at room temperature correlates with a drop in electrical resistance, independent of thickness.
- The effect on infrared absorption was small at most temperatures.

deep_panjwani@knights.ucf.edu

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