Thickness dependence of critical temperature in Mo/Au bilayers

Maria Parra-Borderías1, Ivan Fernández-Martínez2,3, Lourdes Fábrega4, Agustín Camón1, Oscar Gil5, José L.Costa-Krämer5, Raquel González-Arrabal6, Javier Sesé5 and Fernando Briones2.

1Instituto de Ciencia de Materiales de Aragón (CSIC-Universidad de Zaragoza). C/ Pedro Cerbuna 12, 50009 Zaragoza, SPAIN
2Instituto de Microelectrónica de Madrid (CSIC). C/ Isaac Newton 8, 28070 Madrid, SPAIN
3Instituto de Energía Solar (Universidad Politécnica de Madrid). Avenida Complutense s/n, 28040 Madrid, SPAIN
4Institut de Ciencia de Materiales de Barcelona (CSIC). Campus de la UAB, 08193 Bellaterra, SPAIN
5Instituto de Fusión Nuclear (Universidad Politécnica de Madrid). C/José Gutiérrez Abascal, 2, 28006 Madrid, SPAIN
6Instituto de Nanociencia de Aragón (Universidad de Zaragoza) C/Mariano Esquillor Edif. 1+D, 50018 Zaragoza, SPAIN

ABSTRACT

We report on the sensitivity of the superconducting critical temperature (Tc) to layer thickness, as well as on Tc reproducibility in Mo/Au bilayers. Resistivity measurements on samples with a fixed Au thickness (dAu) and Mo thickness (dMo) ranging from 50 to 250 nm, and with a fixed dAu and different dMo thickness are shown. Experimental data are discussed in the framework of the Martinis model, whose application to samples with dAu above their coherence length is analysed in detail. Results show a good coupling between normal and superconducting layers and excellent Tc reproducibility, allowing to accurately correlate Mo layer thickness and bilayer Tc.

FABRICATION PROCESS

• High quality, strain-free Mo layers are deposited by RF sputtering at Room Temperature in an UHV chamber on LPCVD SiN layers deposited on Si (100) single crystal substrates.
• Protective Au layers of 15 nm are deposited insitu by DC sputtering.
• The total Au thickness is obtained by ex situ electron beam evaporation of a second Au layer in another UHV chamber.
• Further details can be found in References [1,2]

MARTINIS MODEL

One of the main problems in achieving Tc reproducibility in the Mo/Au system is to control the quality of the interface: this quality can be checked through the Martinis model [3].

This model predicts Tc from simple physical parameters: superconducting layer thickness, dM, normal metal layer thickness, dAu, and the quality of the interface, represented by a transmission parameter, t, ranging from 0 to 1. For arbitrary thick layers:

\[ Tc = Tc_0 \left( \frac{d_M}{d_M + 1} \right) \left( \frac{1}{\frac{1}{d_M} + \frac{1}{d_A} + \frac{1}{\xi_M}} \right) \]

where:

- \( Tc_0 \) is the necessary change in Tc for dM=115 nm.
- \( \xi_M \) is the coherence length.

Problem: This model does not reproduce the expected Tc saturation for dM<\xi_M/2.

Conclusions

• Bilayers with normal metal layer thickness of dAu=215 and 115 nm and variable superconducting thickness, dMo, are fabricated.
• Excellent Tc reproducibility (ΔTc<20 mK) which allow accurate determination of Tc as a function of dMo.
• No change in Tc is observed when dMo is increased between 115 nm and 215 nm \( \Delta Tc \) is 115 nm.
• \( \xi_M \) can be estimated as [5]:

\[ \xi_M \sim 107 \text{ nm} \]

When fitting experimental data to Eq. 1 different interface transparency values are found for dAu=115 nm and 215 nm: t decreases as dAu increases.

HRXTEM images show changes neither in interface nor in grain size as a function of Au layer thickness: the necessary change in t that has to be introduced in (1) to fit experimental data has no physical meaning. This indicates that some assumption have to be done in order to validate the model for thick films.

Since the Au thickness above \( \xi_M \) is not influencing Tc, to used Eq.1 in bilayers of arbitrary thickness we propose that Martinis Eq. can be used when \( d_M > \xi_M \) simply by substituting \( d_M \) by \( \xi_M \).

Under this assumption, a unique fit to \( Tc(d_M) \) and a unique t value can be obtained for different dAu:

\[ t = 0.45 \pm 0.08 \]

Our samples are extremely reproducible, and display and excellent coupling between the involved layers.

BILAYER CRITICAL TEMPERATURE AS A FUNCTION OF dMO

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Acknowledgments:

This work has been carried out with financial support from the Spanish MICINN Project DPI2009-09580-C02, AYA2006-05505-E, MAT2006-01077/NAN and MAT2009-19077/220. M.P. and DG would like to thank Spanish Education Ministry for a pre-grant and a PhD-grant.