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Microstructure and Superconductivity of Bi/Ni bilayers Prepared by Pulsed Laser Deposition

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In spite of crystalline bismuth (rhombohedra structure) and nickel (Face Centered Cubic structure) are not superconducting, Bi/Ni bi-layers show a superconducting transition at ~ 4 K and this has been attracted grate attention [1]. There are different interpretations of the superconductivity in Bi/Ni: Ni induced FCC Bi [2]; magnetic fluctuation at the interface of Ni/Bi induced superconductivity [3]; formation of $NiBi_3$ at the interface [4], Bi induced superconductivity in Ni layer and formation of a very thin amorphous Bi layer formed at the interface of Ni and Bi [5], etc. In this work we study the superconductivity and microstructure of the Bi/Ni bilayer by means of transport and high resolution transmission electron microscopy (HRTEM), in order to find out what induced the superconductivity in Bi/Ni bilayer system. The thickness of the first deposited Bi layer is fixed as 38 nm and the followed deposited Ni layer changes from 2 nm to ~ 40 nm. The transport measurements exhibits superconductivity as expected (as shown in Fig. 1) and the critical superconducting transition temperature (T_c) is ~ 4 K, which is in agreement with the results in the literatures. The cross-section samples for TEM study have been prepared by FIB and when the deposited Ni layer is less than 8 nm, pure Ni layer cannot be seen in the sample (Fig. 2). It indicates that the Ni atoms diffused into the Bi layer during deposition.

When increase the thickness of the Ni layer, however, three continuous layers can be clearly seen in the cross-section sample. HRTEM imaging shows that the middle layer is the intermetallic superconducting phase $NiBi_3$ (Fig. 3). The $NiBi_3$ layer could be formed during the pulsed laser deposition (PLD) or the preparation by FIB. A Bi/Ni sample have been prepared by thermo-evaporation at 4.2 K (as shown in Fig. 4) and studied by the same methods to see in which stage the $NiBi_3$ has been formed. The transport studies show that after annealing at 300 K, the low-temperature prepared sample does not show superconductivity and the cross-section structure is pure Bi and Ni layers. This confirmed that the $NiBi_3$ layer observed in the PLD prepared samples has been formed during the deposition and sample preparation for TEM with FIB does not induce the reaction of Bi and Ni. In summary, we observed a clearly $NiBi_3$ layer between the deposited Bi and Ni layers and this layer is the origin of the superconductivity in Bi/Ni systems prepared by PLD. The diffusion of Ni atoms into Bi layers and formation of $NiBi_3$ occurred during the deposition and TEM sample preparation by FIB cannot induce this reaction [6].

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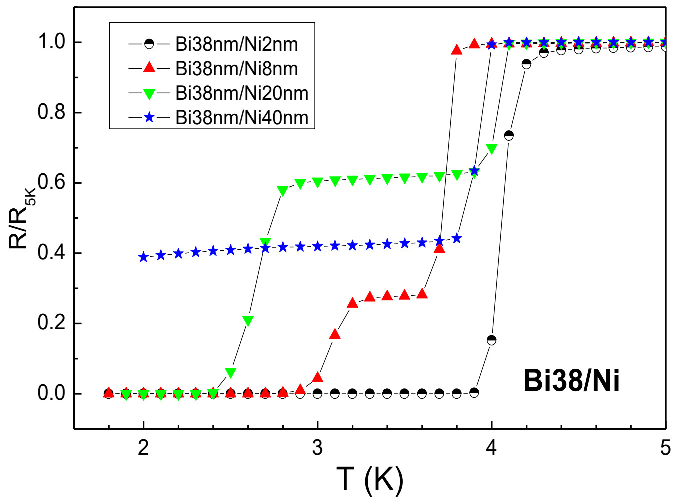

Figure 1. Normalized resistivity as a function of temperature for samples with fixed thickness of Bi and different thickness of Ni layers.

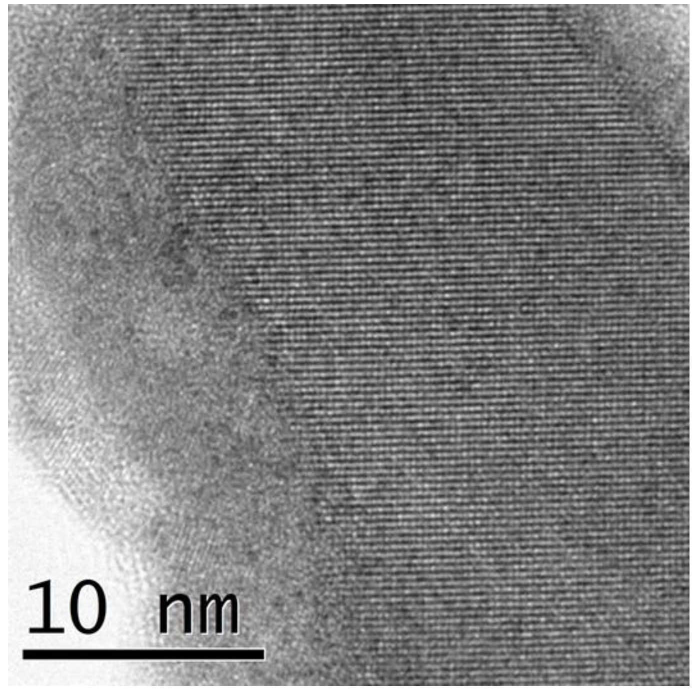

Figure 2. HRTEM image of cross-section of sample Bi38nm/Ni8nm prepared by PLD.

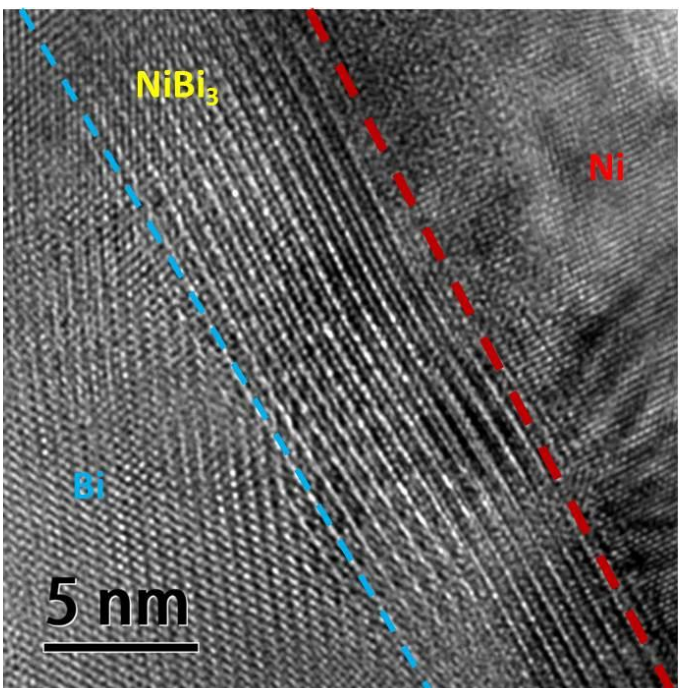

Figure 3. HRTEM image of cross-section of sample Bi38nm/Ni20nm prepared by PLD.

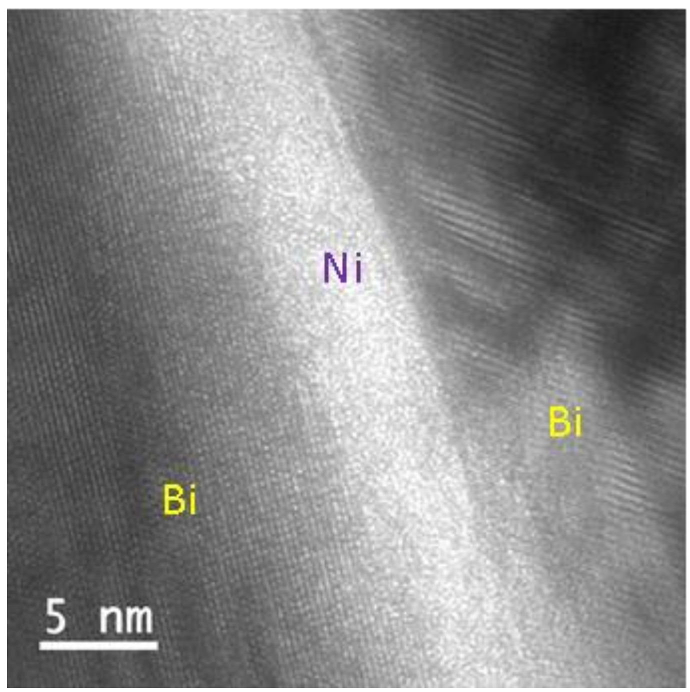

Figure 4. HRTEM image of cross-section of Bi-Ni-Bi layers prepared at 4.2 K.

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