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Spatial Variation in Carrier Concentration in Nanocrystal Ni-Si Films Measured by Multimode Scanning Probe Microscopy

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Nanocrystalline nickel silicide film has considered to be a promising thermoelectric material because the material has high density of states in the electron bands, contains cheap, abandoned, non-toxic elements, and is compatible with the modern device fabrication technology. Recently, we have demonstrated the enhanced thermoelectric efficiency in nanocrystal Ni-Si composite films where formation of silicide nanocrystals (NCs) resulted in the high figure of merit for the boron-doped films.[1] Here, we examined spatial variations in the carrier concentration and the surface potential along the films by multimode scanning probe microscopy (MSPM) to elucidate the conducting mechanism.

Nanocrystal Ni-Si composite films were synthesized at 600-800°C by phase separation from amorphous alloy films (Ni:Si=1:20, 2% Boron). The surfaces were passivated by ultrathin oxide. Force–bias voltage (*Δf-Vs*) spectra, capacitive force (F_{tip}) maps and topographs were acquired in a constant-gap mode. Variations in the carrier concentration and the surface potential was evaluated from the contact potential difference (CPD) and the curvature (dC/dZ) derived from (*Δf-Vs*) spectra as shown in Fig.1(b). [2]

Fabricated Ni-Si films showed NC inclusions with a hexagonal shape and a size of 50~300 nm. The $NiSi_x$ inclusions appeared as bright islands in SEM image in Fig.1(a), and showed large capacitive interaction with the SPM tip seen in Fig.1(d), indicating the metallic conductance. Analysis of profiles in Fig.1(e-g) showed (i) small potential barriers between NCs (ΔCPD <0.17V), (ii) large carrier concentration in $NiSi_x$ NCs, which suggest the “mobility edge” conducting model.[3] The results shed a light on the conductance mechanism in the p-type Ni-Si composite film. A part of this work was supported by the JST-ALCA.

[1] Uchida N. et al., J. Appl. Phys. **114**, 134311(2013); [2] Bolotov L., et al., JJAP **51**, 088005 (2012); [3] Aoyama I., et al., Jpn. J. Appl. Phys. **44**, 8562(2005).

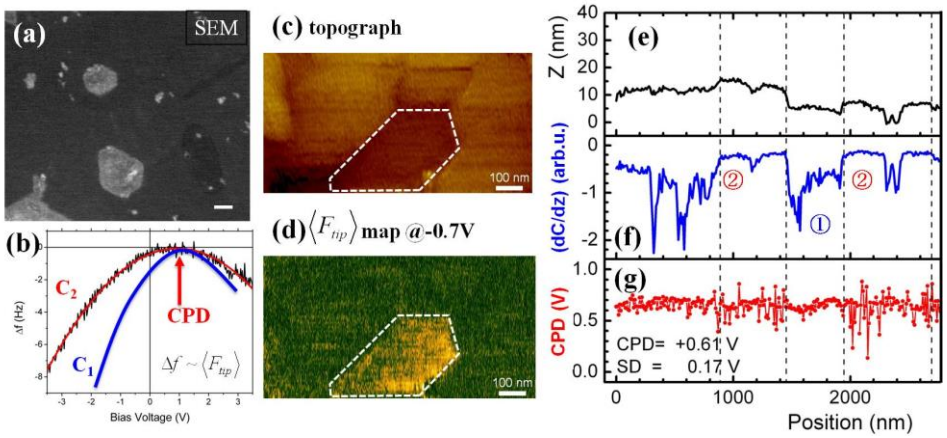

Fig.1 (a) SEM image of a NC Ni-Si (B-doped) film. (b) (*Δf-Vs*) spectra of a Ni-Si NC (C_1) and Si (C_2). (c-d) Topograph and the force map of a Ni-Si NC. (e-g) Line profiles across Ni-Si NC ① and Si ②.