RESEARCH FROM ISOLATED TO COMPACT CLUSTERS

Wang Guanghou (王广厚)

(Nanjing University, Nanjing 210008, China)

(Received November 1989)

ABSTRACT

Structures and properties of both isolated and compacted clusters can be studied by SINS, RBS.NMR and Mössbauer effect, etc. Some important properties of these microclusters, such as magic numbers, isotopic effect, gas-like structures are discussed.

Key words: Microclusters Atomic structures Abnormal properties

I. INTRODUCTION

Microcluster physics is a rapidly growing field in science because many faceted aspects of cluster research pertain to important questions of both fundamental and applied interest, and bridge the gap between atomic and molecular physics on the one hand, and the condensed matter on the other. We have studied the structures and properties of microclusters from the atom towards the solid (*a*) and from the solid towards the atom (*b*).

II. ISOTOPIC EFFECT IN THE FORMATION OF SPUTTERED ION CLUSTERS

8 keV argon atoms were used to bombard high polycrystal copper specimen and large amount of copper ion clusters were produced and identified in two groups: *(a)* homoisotopic clusters as $Cu(63)_2^+$, $Cu(65)_2^+$, $Cu(63)_2^-$, ... and *(b)* hetero-isotopic clusters as $[Cu(63)_3(65)_1]^+$, $[Cu(63)_2(65)_1]^-$, ... The relative yields of these clusters are listed in table 1. If $I(n)$ is taken to be the yield sum of the clusters Cu_n with same number of copper atoms and $I_{he}(n)$ for the hetero-isotopic cluster, $R(n)=I_{he}(n)/I(n)$ implies that the isotopic effect exhibits in the formation of the cluster ions by sputtering[1], i.e., $I(Cu_{2p-1})$, $I_{he}(Cu_{2p+1})$ and $R(Cu_{2p-1})$ are greater than $I(Cu_{2p})$, $I_{he}(Cu_{2p})$ and $R(Cu_{2p})$, respectively (p is positive integer), but the intensities of the homo-isotopic clusters $Cu(63)_n^-$ do not have an odd-even oscillation. The results indicate that: (1) the secondary emission of hetero-isotopic clusters are preferential and (2) the isotopic effect may play an important role in the sputtering process when bombarding materials contained different isotopes. These may be understood by statistical collision theory and isotopic fractionation in sputtering. The last column of table 1 lists the calculated results.

Table 1

Copper ion cluster observed by FAB/SIMS methods

Ion clusters Cu	Isotopes	Mass	Relative yields	Calculated results
Cu_1	$Cu(63)_1$	63	100.0	0.706
	$Cu(65)_1$	65	41.68(2.88)	0.294
Cu_2	$Cu(63)_2$	126	3.53(0.45)	0.498
	$Cu(63)_1(65)_1$	128	3.66(0.44)	0.415
	$Cu(65)_2$	130	1.21(0.24)	0.086
Cu_3	$Cu(63)_3$	189	8.90(1.24)	0.352
	$Cu(63)_2(65)_1$	191	11.30(1.32)	0.493
	$Cu(63)_1(65)_2$	193	8.50(1.00)	0.183
	$Cu(65)_3$	195	1.25(0.22)	0.025
Cu_4	$Cu(63)_4$	252	0.99(0.19)	0.245
	$Cu(63)_3(65)_1$	254	0.36(0.08)	0.419
	$Cu(63)_2(65)_2$	256	0.54(0.11)	0.043
Cu_5	$Cu(63)_5$	315	0.34(0.05)	0.175
	$Cu(63)_4(65)_1$	317	1.09(0.15)	0.365
	$Cu(63)_3(65)_2$	319	0.63(0.08)	0.309
Cu_6	$Cu(63)_6$	378	0.08(0.03)	0.124
	$Cu(63)_5(65)_1$	380	0.20(0.05)	0.309
	$Cu(63)_4(65)_2$	382	0.0	0.322
	$Cu(63)_3(65)_3$	384	0.09(0.04)	0.178
Cu_7	$Cu(63)_7$	441	0.30(0.05)	0.087
	$Cu(63)_6(65)_1$	443	0.70(0.08)	0.254
	$Cu(63)_5(65)_2$	445	0.27(0.05)	0.318
	$Cu(63)_4(65)_3$	447	0.65(0.11)	0.221
Cu_8	$Cu(63)_8$	504	0.08(0.03)	0.062
	$Cu(63)_7(65)_1$	506	0.0	0.205
Cu_9	$Cu(63)_9$	567	0.0	0.045
	$Cu(63)_8(65)_1$	569	0.29(0.04)	0.163

III. THE INTERFACE STRUCTURES AND THE PROPERTIES OF THE COMPACT NANOPHASE CLUSTERS

A new class of cluster– compact nanophase clusters has been obtained by the gas condensation and in–situ compaction methods and it has a structure neither like a crystal with long range order nor amorphous materials with short range order. Various nuclear techniques as RBS, positron annihilation, NMR and Mössbauer effect can be used to study its atomic structures and abnormal properties of the interfaces between the clusters. For instance, a Mössbauer spectrum of a Fe nanocluster pellet shown in Fig.1 could be fitted with two components which correnspond to the crystal and interface i.e., sub–spectra 1 and 2 represent the crystalline α –Fe grains and interfacial component, respectively. Fig.2 shows 3.2 MeV ^{4}He backscattering spectra for a nanocluster Pd sample with an 80 nm thick Bi film deposited onto its surface after sputter cleaning: before annealing (solid curve) and after 24 hours at 395 K (dashed curve). The Pd Bi phase with a fixed composition can be seen clearly at the

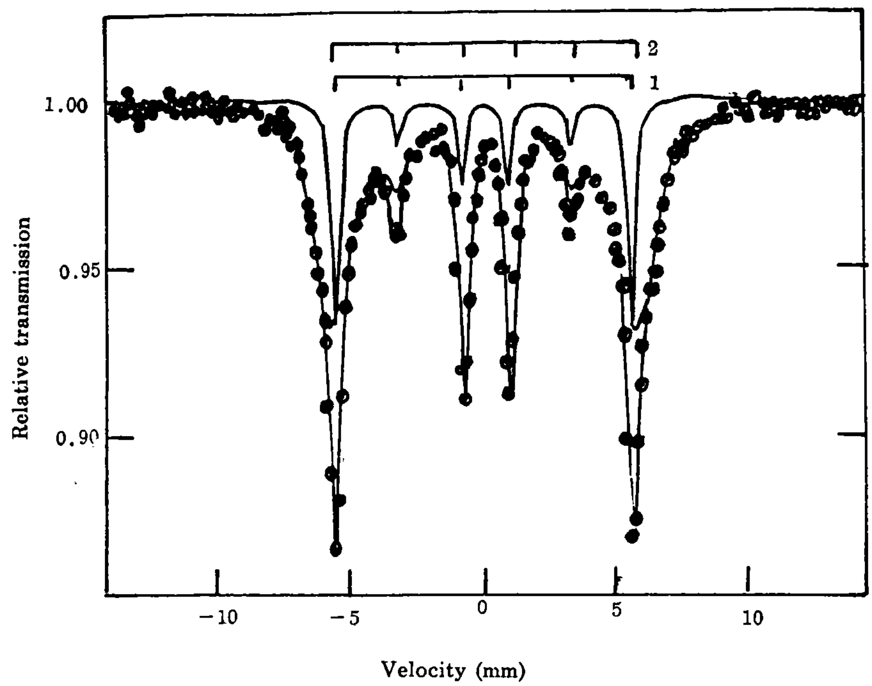

Fig. 1 Mössbauer spectrum of Fe－ nanophase cluster compact sample

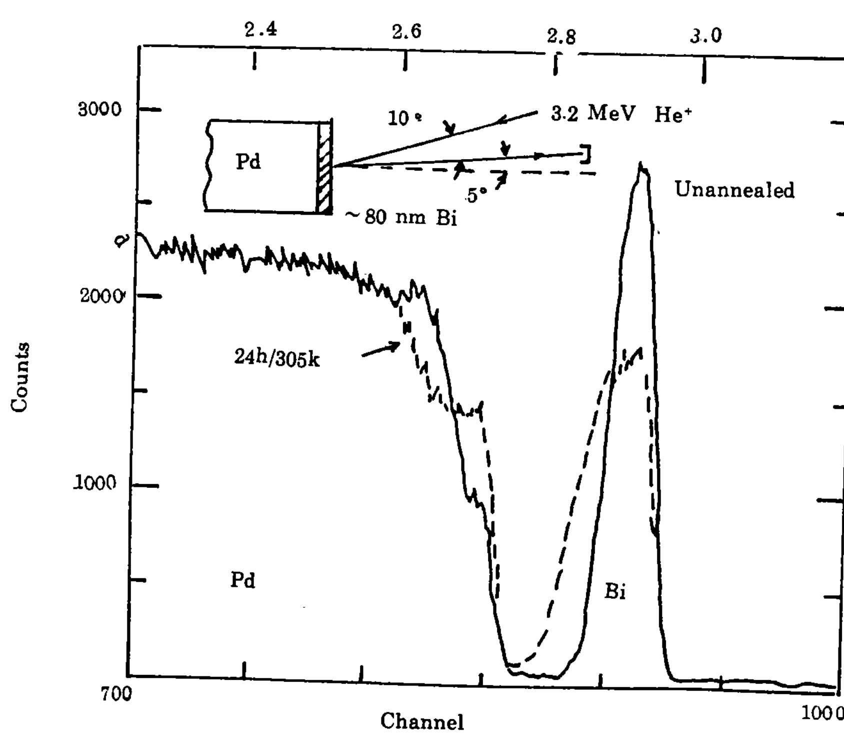

Fig.2 3.2 MeV ⁴He RBS spectra for a Pd nanocluster compact sample front edge of Pd, indicating a grain – growth process by chemical driving forces similar to diffusion induced grain – boundary migration.

IV.DISCUSSIONS

Both the isolated and compact clusters have many unusual physical and chemical properties. It is a great step of the research from the former to the latter because new materials can be synthesized by compact cluster in a controlled manner. In this respect various nuclear techniques are quite useful.

ACKNOWLEDGEMENT

This work is financed by National Natural Science Foundation of China.

REFERENCES

[1] G.H.Wang, *Nucl. Instr. Meth.*, **B33** (1988), 502.

[2] M.Yussouff eds,. Current trends in the physics of material, World Sci. Publ. Co., Singapare, 1987, p.403.