Supporting information

Exploring the synergistic effect of alloying toward hydrogen evolution reaction: a case study of Ni_3M (*M* = Ti, Ge and Sn) series

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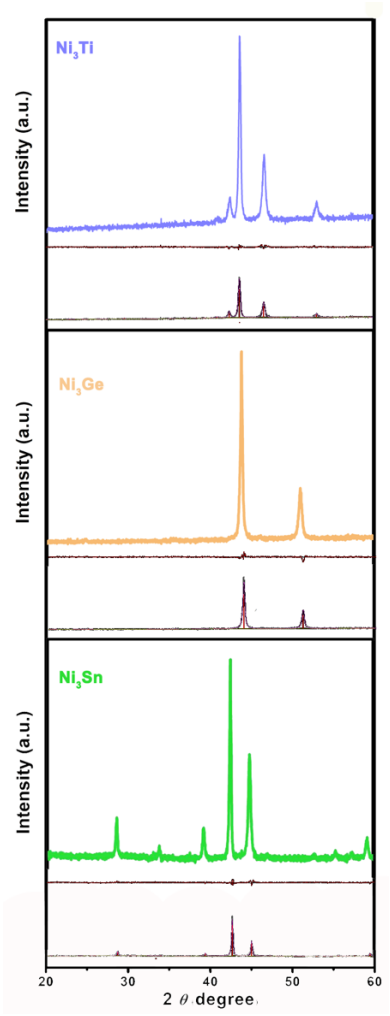

Figure S1. Experimental powder XRD patterns of Ni_3M (*M* = Ti, Ge and Sn). The simulated pattern and difference between experimental pattern and simulated one was attached below. The refined lattice constants and interatomic distances were tabulated in Table S1.

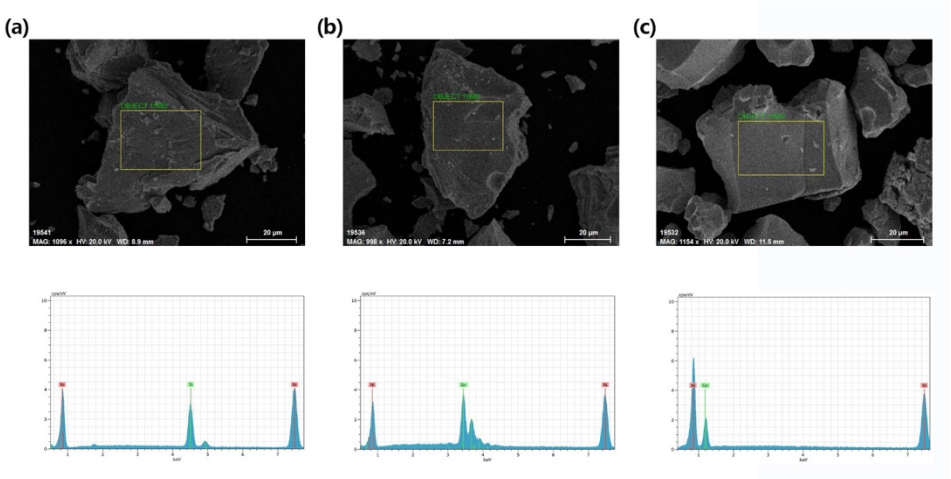

Figure S2. SEM image and EDX spectrum of Ni_3M (*M* = Ti, Ge and Sn); (a) Ni_3Ti, (b) Ni_3Ge and (c) Ni_3Sn. The atomic ratio between Ni and *M* element of each sample derived from EDX analysis was shown in Table S2.

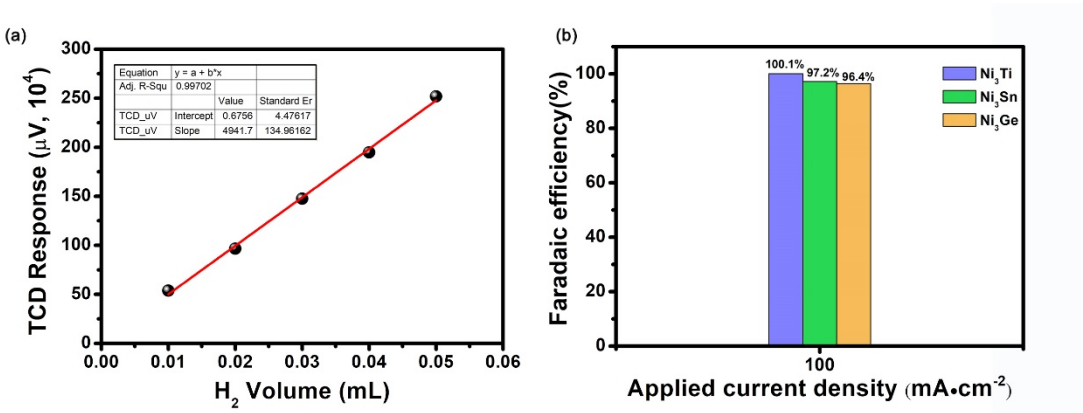

Figure S3. (a) H_2 Standard Line (b) applied current density-dependent Faraday efficiency (FE, %) curves of Hydrogen products of electrocatalytic for Ni_3M (*M* = Ti, Ge and Sn).

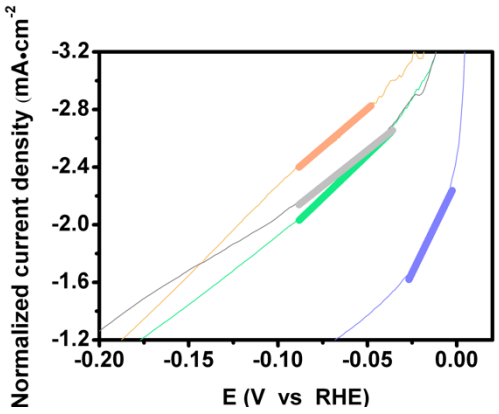

Figure S4. Tafel plots derived from normalized LSV based on roughness factor (RF) of Ni_3M (*M* = Ti, Ge and Sn) and Ni foam at 1.0 M KOH (scan rate: 5 mV s^{-1}).

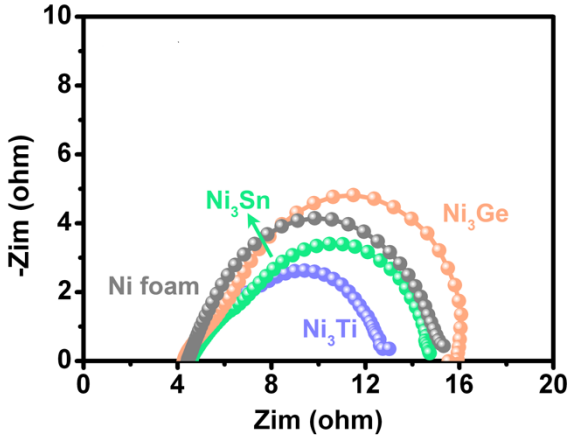

Figure S5. Electrochemical impedance spectroscopy (EIS) of Ni_3M (*M* = Ti, Ge and Sn) and Ni foam in 1.0 M KOH at -0.192 V (V vs RHE).

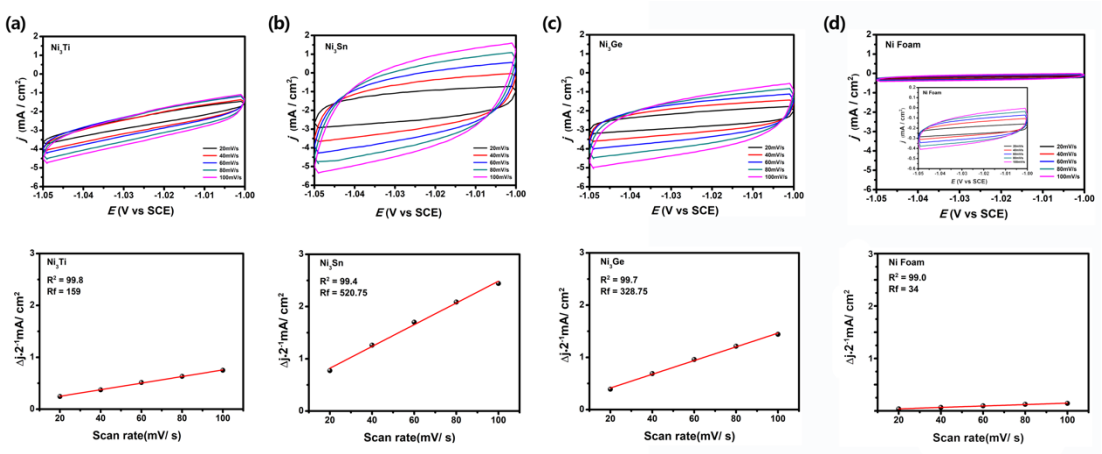

Figure S6. Cyclic voltammograms (CV) of Ni_3M (*M* = Ti, Ge and Sn) in 1.0 M KOH; (a) Ni_3Ti, (b) Ni_3Sn (c) Ni_3Ge and (d) Ni Foam. Capacitive current density as a function of scan rate (20 – 100 mV s^{-1}). The derived roughness factor (RF) of each compound from the linear regression slope (specific capacitance 40 μF cm^{-2}) is included at bottom.

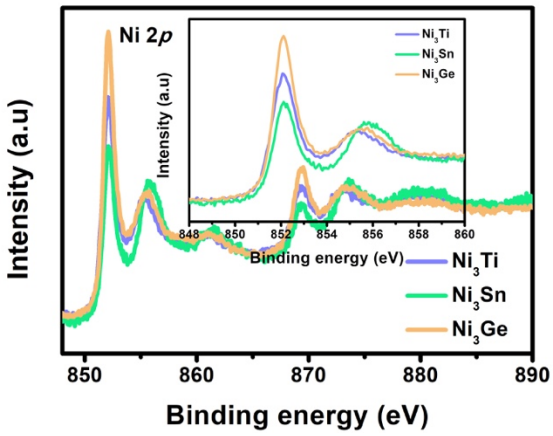

Figure S7. X-ray photoelectron spectrum (XPS) in the region of Ni 2*p* for Ni_3M (*M* = Ti, Ge and Sn).

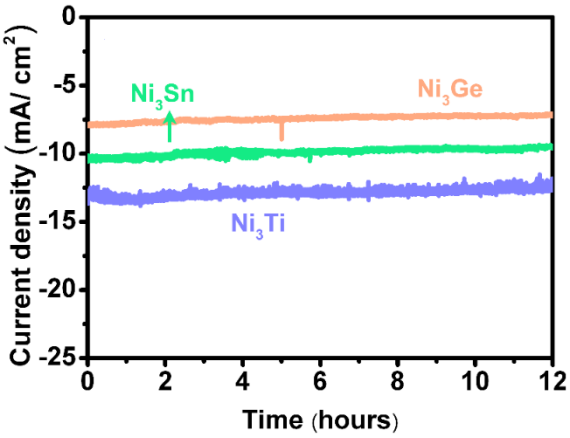

Figure S8. Chronoamperometry measurement of Ni_3M (*M* = Ti, Sn, Ge) series over a period of 12 hours in 1.0 M KOH.

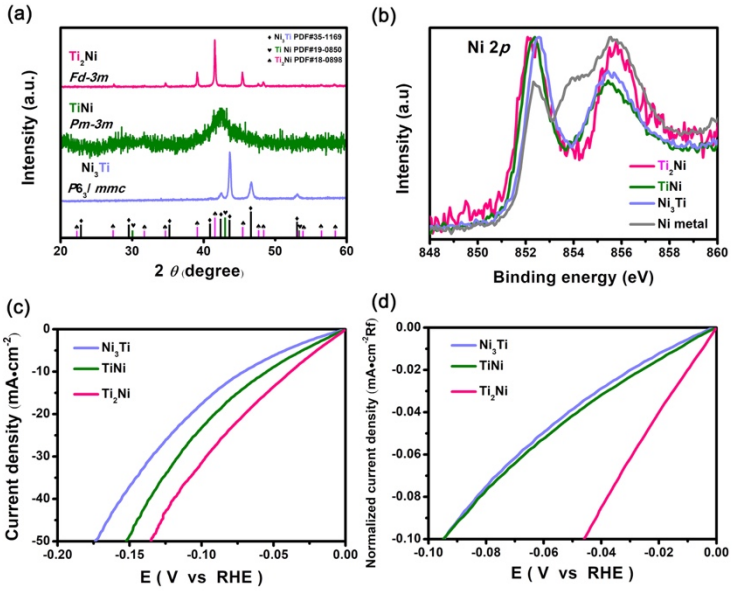

Figure S9. (a) Experimental powder X-ray diffraction (PXRD) patterns and (b) X-ray photoelectron spectrum (XPS) in the region of Ni 2*p* for Ti_2Ni, TiNi, and Ni_3Ti (c) linear sweep voltammograms (LSV) and (d) normalized LSV based on roughness factor (RF) for Ti_2Ni, TiNi, and Ni_3Ti at 1.0 M KOH (scan rate: 5 mV s^{-1}).

Table S1. Refined lattice constants of Ni_3M (*M* = Ti, Sn, Ge) series.

formula	lattice constants		averaged Ni–Ni bond distance (Å)
	a	*c*	
Ni_3Ti	5.1017(1)	8.3076(1)	2.543
Ni_3Sn	5.288(1)	4.2416(1)	2.568
Ni_3Ge	3.5781(1)	3.5781(1)	2.530

Table S2. Atomic ratio of Ni_3M (*M* = Ti, Ge and Sn).

Sample	Element	Atomic ratio (%)
Ni_3Ti	Ni	71.33
	Ti	28.67
Ni_3Ge	Ni	78.28
	Ge	21.72
Ni_3Sn	Ni	73.45
	Sn	26.55