NANOSECOND LASER COLORATION ON STAINLESS STEEL

Materials researches driven by physical knowledges

Wei Cao, 08.06.2017
Teams & General background

Anhui Polytechnic University, China
Lab of Advanced Optical & Functional Materials
(under construction, 05.2017-04.2020)

Collaborative parts:
- Henan University of Science & Technology
- East China University of Science & Technology
- MAX IV Synchrotron Radiation Facility

We are advancing physical knowledges in materials researches, and prompt materials synthesis & functionalities.

Physics Matters!
Examples of researches

- Nanosecond laser coloration on stainless steel (case study for work explorations)
- Heat Treatment Process of Steel AISI 441 for Hydro Forming Properties
- Synchrotron radiation applications in microregional chemical determinations
- First-principles studies of alloy growth

*figure from internet*
Laser marking: Advanced painting technique

- How to color a metal?

Classic coloration: dyes, electrochemical methods

Problems: durability, pollution, costs

- In academia, fashionably, femtosecond laser marking is within hot research focus, however...

Mechanism unknown, expensive feature,

- A cheaper alternative: nanosecond laser

Can we?

Of course!
How it was done

304 steel
(18~20% Cr, 8~11% Ni, ≤ 2% Mn and ≤ 1% Si)

20 W, 1064 nm

Colors made through **nanosecond** lasers

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**From X-ray photoelectron spectroscopy to RGB values**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Cr$_2$O$_3$</th>
<th>Fe$_2$O$_3$</th>
<th>MnO</th>
<th>NiO</th>
<th>Spinel</th>
<th>Calculated</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25.36%</td>
<td>19.05%</td>
<td>4.34%</td>
<td>2.21%</td>
<td>49.04%</td>
<td>(165,110,95)</td>
<td>(123,100,75)</td>
</tr>
<tr>
<td></td>
<td>(92,121,78)</td>
<td>(130,71,57)</td>
<td>(103,112,63)</td>
<td>(183,223,164)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3.86%</td>
<td>35.31%</td>
<td>6.04%</td>
<td>7.81%</td>
<td>46.98%</td>
<td>(65,130,150)</td>
<td>(102,115,110)</td>
</tr>
<tr>
<td></td>
<td>(92,121,78)</td>
<td>(130,71,57)</td>
<td>(103,112,63)</td>
<td>(183,223,164)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4.10%</td>
<td>38.64%</td>
<td>4.02%</td>
<td>5.09%</td>
<td>48.15%</td>
<td>(111,94,87)</td>
<td>(123,91,83)</td>
</tr>
<tr>
<td></td>
<td>(92,121,78)</td>
<td>(130,71,57)</td>
<td>(103,112,63)</td>
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</tr>
</tbody>
</table>
Heat Treatment Process of Steel AISI 441 for Hydro Forming Properties

Annealing in a vacuum furnace. Tuning annealing temperature, holding time, and quenching methods

Optimal: heat treatment at 850 °C for 300 min and water quenching after treatment

Huang... Cao, submitted to Insights.
Synchrotron radiation applications in microregional chemical determinations

Figure from: http://xraysweb.lbl.gov/peem2/webpage/Project/TutorialPEEM.shtml
Researches carried out through XPEEM

a. Determination of RTFM and PL origins in Co$_x$Zn$_{1-x}$O thin films

Film amorphous

Film luminescent

WHY?

Film RTFM

But resistivity betrays
Micro-regional XAS to pick up the differences!!!
Determination chemical states of chromite from Lappland

What are these minerals?
Gravitationally selected particles

What’s the difference?

More Fe $^{2+}$ in the inclusion! Constrained the oxygen fugacity evolution of magma.

In cooperation with Oulu Mining School
First-principles studies of alloy growth

a) AuAl alloy, can be formed in any content ratio

What’s the lowest probably geometry for $\text{Au}_n\text{Al}_n$ alloy clusters? Can it grow to bulk?

![Building Block]

Crystal structure!

Theoretical stability!
MD simulation, and phonon dispersions

Zhang... Cao, Sci. Rep. 6: 19504 (2016)
Financial supports from:

OULUN YLIOPISTO

Anhui Polytechnic University

CHINA SCHOLARSHIP COUNCIL

Anhui Provincial Key Laboratory Construction Funds

Thank you for your attention!