CRYSTAL PROJECT
STEP-UP 2011 LESSON PLAN
WILLIAM DALY, COLLINS HILL HIGH SCHOOL
ESTIMATED DURATION: 30 MINUTE INTRO - 28 DAY EXECUTION
CLASS LEVEL: HONORS, APB, APC PHYSICS
CONTENTS

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PROBLEM

- Activation: Topics in modern physics early in physics through survey of literature
- Crystals
  - Importance to STEM disciplines and society
  - How are they grown?
  - How are they investigated?
  - What are they used for?
- Apply characteristics of science
  - Writing on topics in modern physics
  - Critical review of topics in modern physics
  - Survey of crystals and investigatory methods
ABSTRACT

- Survey of “select topics” previews:
  - Thermodynamics
  - Fields and circuits
  - Optics
  - Modern physics
- Writing simulation
  - Investigate one of 130 topics in semiconductors, crystals or equipment
  - Persuasive writing task to simulate white paper for NSF proposal
  - Calibrated Peer Review
    - Writing on modern physics topics
    - Critical review of scientific writing
ALIGNMENT WITH STANDARDS

- SCPH- E2005- 25: Analyze the properties of light and optics
- SCPH- E2005- 23: Analyze the properties of waves
- SCPH- A2006- 7: Read scientific materials to establish context for subject matter, develop vocabulary, and to be aware of current research
- SCPH- A2005- 6: Communicate scientific investigations clearly
III A 2 - Electric field and electric potential: Analyze the properties of light and optics

III B 1 - Electrostatics with conductors

III B 3 – Dielectrics

IV A 2 - Wave propagation

IV B 1 - Interference and diffraction

V A – Atomic Physics

1. Photons, the photoelectric effect Compton scattering, x-rays

2. Atomic energy levels

3. Wave-particle duality
OBJECTIVES

- Reassess classroom labs and projects
- Target lower impact classroom activities
- Identify Step-Up research experiences relevant to the classroom
- Leverage Step-Up research experiences to update low impact activities
- Create open ended exploration relating academic topics to contemporary research and engineering
Student will find relevance to topics in modern physics through survey literature on topic in materials science to related to modern physics.

Student will apply and advance persuasive writing skill on topic in modern physics.

Student will apply and advance critical peer review skills on topics in modern physics.

Student will gain exposure to at least five areas of contemporary physics research.
ASSESSMENT AND RUBRICS

- Assessment will be through online peer review tool “Calibrated Peer Review” (CPR)
  - Assessed on ability to apply rubric to sample paper
  - Assessed on persuasive writing skills
  - Assessed on critical review skills

- Rubric
  - Rubric will be built into CPR review tool (see appendix A, “Setting up CPR”)
  - Rubric will be contained in “Student Handout” See appendix B)
Students benefit from added opportunities to exercise

- Persuasive writing skills
- Critical review of scientific research from
  - The scientific community
  - Their peer group

Students benefit from seeing relevance of physics course to important topics in modern society through writing simulation

See appendix B, “Student Handout” for full background and writing prompt.
MATERIALS

- **Administrator**
  - School must have CPR administrator (see [http://cpr.molsci.ucla.edu/](http://cpr.molsci.ucla.edu/))
  - School administrator must set up teacher account, student accounts and course (see appendix B)

- **Teacher**
  - Teacher must add students to class
  - Teacher must activate assignment

- **Student internet access**
  - Galileo
  - Google Scholar
  - Text entry
  - Calibrated peer review account
PLAN:
STUDENT WRITING SIMULATION (28 DAYS)

- **Introduction – ½ class period**
  - Present example topic on Raman Spectroscopy
  - Guide students toward activation objective
  - Distribute assignment and topic list
- **Research crystal, growth method or analysis method (2 week Homework)**
- **In Calibrated Peer Review (CPR Homework)**
  - Write white paper to NSF – 1 week entry phase
  - Review 3 calibration papers – calibration phase
  - Review 3 peer papers – 1 week review phase
PLAN CNT’D:
STUDENT HANDOUT AND TOPIC LIST

- Student Handout
  - See appendix A
  - Provides background
  - Outlines writing prompt
  - Rubric

- Topic List –
  - See appendix C for suggested
  - Students are encouraged to trade topics at within 1st week of research phase.
  - Students are encouraged to find alternate topics (with instructor approval)
  - Topics must be finalized before 2nd week
SUMMARY

- **Students**
  - Explore relevance materials science to physics class
  - Persuasive writing on topic of contemporary research in physics
  - Critical review of writing
    - By the scientific community
    - By peers

- **Teachers**
  - Long term peer reviewed project
  - One time setup of CPR for additional assignments
  - Though targeted toward physics, task is cross disciplinary with chemistry and biology
Appendix A: Student Handout

The Crystal Project

A multidisciplinary writing simulation on research topics in contemporary materials science

Overview:

As a preview or reinforcement of units on Thermodynamics, Forces, Fields, Optics and Modern Physics, we will to do a writing simulation as an exploratory research project on the physics of materials and methods used to advance the effective use of technology to enhance quality of life and to solve daunting global issues.

Our modern society has grown very dependent upon understanding and engineering solid state phases of matter. Though there are exceptions, these states generally rely on the natural periodic ordering of matter. That is, these states are generally crystalline. Without such understanding and ability to manipulate these states, none of the devices that our society depends upon would be possible, such as those used in medical technology, computers, communication (smart phones, TV, eBooks, etc.) renewable energy technology, environmental science, to name just a very few. Research and development is ongoing at an ever increasing rate which requires an armada of deposition and growth techniques and analytical methods to sustain this growth. Understanding the physics behind these technologies and materials is crucial to continued advancement of our techno-centric world.

In this writing simulation you are researcher in academia or industry charged with the responsibility of acquiring grant money to support your research. The specific nature of your research is NOT the emphasis of this simulation. Rather you view either a particular crystal or analytical device as crucial to your research. Your task is to write a “white paper” to convince the National Science Foundation of the merits of the crystal that you are assigned to study or the analytical equipment that you are trying to procure.

Your white paper must be structured as follows.

I. Introduction – Briefly describe your material or equipment. You may be creative or use conventional applications that you discover in your research.

II. Historical background
   a. Give a few sentences about who discovered the material, discovered the physical process or invented the analytical technology (person or institution). Be sure to put this in historical context.
   b. Cite typical modern applications of this material or equipment.

III. Science behind the material or technology
   a. Cite at least two important characteristics of the material or equipment and how it pertains to your white. Paper possible general categories include thermal, electrical, structural, optical or magnetic properties.
   b. Looking ahead, cite two equations that are important to understanding the use of this material or equipment. Demonstrate how this applies to your white paper.

IV. Conclusion
   a. Importance of your research – you may be realistic or creative. But above all, be convincing, citing at least two specifics from your research.

V. Bibliography (APA style)
Grading guidelines:

I. Introduction – Briefly describe your material or equipment and why you are pursuing a grant. You may be creative or use conventional applications that you discover in your research.
   a. Is the description clear and sufficiently complete for the reader to know how the process or equipment works, or what the crystalline structure is and how is it made (the manmade process and/or the natural process)?
   b. Did the writer pose an argument regarding why it is important to use this equipment or process, or why it is important to pursue research on this crystal? This needs to be more than “because I need it in my research.” This needs to be a convincing argument tied to a description of the intended research.

II. Historical background
   a. Did the writer state when the process, equipment or crystal originated?
   b. Did the writer state the inventor or discoverer (person or institution)?
   c. Did the writer state the motivation of the original invention or discovery (why was the process or equipment invented or what were they trying to investigate)?
   d. Did the writer go on to cite contemporary applications of the process, equipment or crystal?
   e. Did the writer cite who uses the process, equipment or crystal (institution or type of institution)?

III. Science behind the material or technology
   a. Did the writer cite two pertinent physical characteristics of the material, equipment or crystal?
   b. Did the writer clearly relate these characteristics to their intended research?
   c. Did the writer cite two equations that are important to understanding the use of this material or equipment?
   d. Did the writer clearly state how at least one of these equations pertains to their research?

IV. Conclusion
   a. Did the writer effectively summarize the white paper in the conclusion?
   b. Was the writer convincing?

V. Bibliography and General:
   a. Did the writer cite at least two peer reviewed journals?
   b. Did the writer include at least one pertinent quote from the peer reviewed journal in the body of their text?
   c. Find a conspicuous phrase in the writer’s paper and do a web search. Did the writer plagiarize this section of their paper?
   d. Are they any spelling errors?
   e. Are there any grammar errors?
   f. Were paragraphs properly used?
   g. Were the citations APA style?

VI. Comments – Although this will not be part of the grade, lease a couple constructive comments about what you thought of the paper and possible ways to improve research and writing skills.
Appendix B – CPR Set Up

> 1200 Institutions Worldwide

- Universities
  - Georgia Tech
  - Harvard
  - Stanford
  - Hundreds internationally

- High Schools
  - Collins Hill
  - Northview
  - Hundreds more...
Setting Up the “Crystal Project”

- **Create course (done by admin) – pages 19 - 26**
  - Assumes admin account is set up for your school.
  - Assume admin has enrolled instructors
  - Is done only at the beginning of the school year
- **Upload student roster (done by admin) – pages 27 - 30**
  - Is done only once
    - Students are in system for entire HS tenure
    - Accessible across all classes and all grades.
- **Enroll students in course (done by instructor) - pages 31- 47**
  - Assumes instructor is enrolled
  - Is done once at the beginning of the year.
- **Access course to create assignment (done by instructor) or use / modify a “canned” assignment – page 48**
  - Is done once
  - May be made public
  - May be reused by other teacher and in other years
- **Access and Activate “Crystal Project” – pages 49-71**
Create course (done by admin): Log in as administrator.

http://cpr.molsci.ucla.edu/cpr/cpr/login.asp
Create course (done by admin) cnt’d:

Click **Enter as Administrator**

<table>
<thead>
<tr>
<th>Available CPR User Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Administrator</strong></td>
</tr>
<tr>
<td>- Add users</td>
</tr>
<tr>
<td>- Create courses</td>
</tr>
<tr>
<td><strong>Instructor/Designer</strong></td>
</tr>
<tr>
<td>- Author new assignments</td>
</tr>
<tr>
<td>- Administer/Edit Assignments</td>
</tr>
<tr>
<td>- View student and assignment data</td>
</tr>
</tbody>
</table>

- Enter as Administrator
- Enter as Instructor/Designer
Create course (done by admin) cnt’d: Click *your school*

Institution List

- Collins Hill High School
Create course (done by admin) cnt’d:

Click Create / Edit Course / Enter as Designer
Create course (done by admin) cnt’d: Click **Create New Course**
Create course (done by admin) cnt’d: Specify which user is having account set up (I chose method 2)

Method 2: Specify a CPR username
- Example: a01234
- Input value: 06178
Create course (done by admin) cnt’d: Enter course title and click Finish
Create course (done by admin) cnt’d: click **Close**. You are finished creating your course.

**Create New Course**  
**Step 3: Create New Course Report**


**Institution:** Collins Hill High School

**New course creation report**

A course entitled: **2011_12 AP Physics**

was successfully created.

Daly, William has been assigned as the instructor of this course.
Upload student roster (done by admin): Click Back to Admin Options to add your students to the database.
Upload student roster (done by admin) cont’d: Click Create Users from File

<table>
<thead>
<tr>
<th>Administrator Options</th>
<th>Create Single User</th>
<th>Create Users from File</th>
<th>Edit / Delete Single User</th>
<th>Edit / Delete Single User</th>
<th>Delete Users from File</th>
<th>Delete Users from File</th>
<th>Managing Course Enrollment</th>
<th>Manage Course Enrollment</th>
<th>Access as User</th>
<th>Access as User</th>
<th>Creating Courses</th>
<th>Create / Edit Courses</th>
<th>Create / Edit Course / Enter as Designer</th>
<th>Managing the Assignment Library</th>
<th>Manage Publishers</th>
<th>Delete Assignment</th>
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</table>
Upload student roster (done by admin) cnt’d: Click Browse to find your roster (you should have done this apart from CPR.)
Upload student roster (done by admin) cnt’d: Double click the .csv file containing your roster with last and first names, and student ID.

*** IMPORTANT ***
Look at your .csv file in notepad. Some versions of Excel save the .csv with quotations. These must be removed with find/replace for the upload to succeed.
Enroll students in course (done by instructor) cnt’d: Click OK and wait for the accounts to be created; the screen on the next slide should appear shortly indicating in the status column that accounts creations was successful.

---

### Create Accounts from File

**Step 2: Account Creation Preview**


**Institution:** Collins Hill High School

The following table displays any potential problems in the account creation process. CPR accounts cannot be created for any user whose account information appears in red.

- Ignore first line of file. It contains column headers (i.e., Last Name, First Name, Institution ID).

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<thead>
<tr>
<th>#</th>
<th>Last Name</th>
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**The page at http://csr.molsci.uga.edu says:**

It may take several minutes for CPR to create all of the accounts. Thank you for your patience.
• Congratulations! Administration tasks are complete;
  • Your students are in the database (for students’ entire HS tenure)
  • Your course has been set up (for the whole year, over multiple tasks)
• You may now enter as the designer,
  • Log into your account – you should see your new course.
  • You may use assignment published by others
  • Or my crystal project
  • Or create or adapt an assignment of your own
• I will log off as admin and log in as user ...
Enroll students in course (done by instructor): Login as User.

Please enter your login information

Username: 06178
Password: •••••

Login  Clear

New users: first time logging in? Users: forgot your login information?

Students: take the CPR tour!

Problems or questions? View the login Help
Enroll students in course (done by instructor) cnt’d: Click Enter as Instructor/Designer

Available CPR User Levels

<table>
<thead>
<tr>
<th>Instructor/Designer</th>
<th>Instructor/Designer</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Author new assignments</td>
<td></td>
</tr>
<tr>
<td>- Administer/Edit Assignments</td>
<td></td>
</tr>
<tr>
<td>- View student and assignment data</td>
<td></td>
</tr>
<tr>
<td>Student</td>
<td>Student</td>
</tr>
<tr>
<td>- Take assignments</td>
<td></td>
</tr>
</tbody>
</table>
Enroll students in course (done by instructor) cnt’d: Click Click Access Courses

<table>
<thead>
<tr>
<th>Instructor/Designer Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructor Options</td>
</tr>
<tr>
<td>Course Listing</td>
</tr>
<tr>
<td>Assignment Library</td>
</tr>
<tr>
<td>Designer Options</td>
</tr>
<tr>
<td>Assignment Authoring Tools</td>
</tr>
</tbody>
</table>

- Access Courses
- Access Assignment Library
- Author Assignments
Enroll students in course (done by instructor) cnt’d: Click newly added course.
Enroll students in course (done by instructor) cnt’d: Click Manage Students
Enroll students in course (done by instructor) cnt’d:
Click **Add Students from File** (must be .csv formatted with id# or username)
Enroll students in course (done by instructor) cnt’d:
I selected option 1.

Option 1: File with student IDs

<table>
<thead>
<tr>
<th>Student ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>123456789</td>
</tr>
<tr>
<td>987654321</td>
</tr>
</tbody>
</table>

Corresponding text file will appear as follows:
123456789
987654321

Download student ID example
Enroll students in course (done by instructor) cnt’d:
Click **Next** unless you wish to use option 2.

**OR**

- **Option 2: File with CPR usernames**

  Example:

<table>
<thead>
<tr>
<th>CPR username</th>
</tr>
</thead>
<tbody>
<tr>
<td>a01234</td>
</tr>
<tr>
<td>b05678</td>
</tr>
</tbody>
</table>

  Corresponding text file will appear as follows:
  123456789
  987654321

  [Download student ID example](#)
Enroll students in course (done by instructor) cnt’d:
Browse for your student ID list

Add Students from File
Step 2: Select File for Upload


Institution: Collins Hill High School
Course: 2011_12 AP Physics

**Select File with student IDs**

Select File to Upload:

NOTE: You have specified that you will be uploading a file with student IDs

1. Files must be saved in a comma separated value (CSV) format.
2. Student IDs must be unique.
3. Files must have information organized in the following manner:

**Option 1: File with student IDs**

Example:

<table>
<thead>
<tr>
<th>Student ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>123456789</td>
</tr>
<tr>
<td>987654321</td>
</tr>
</tbody>
</table>

Corresponding text file will appear as follows:

123456789
987654321

Download student ID example

Next > Cancel
Enroll students in course (done by instructor) cnt’d : Double click the .csv file containing your roster with student ID.
Enroll students in course (done by instructor) cnt’d:
Students should load with “No problems”, the click Add Students
Enroll students in course (done by instructor) cnt’d:
Click **OK** in the message box.
Enroll students in course (done by instructor) cnt’d:
Status should be “Student successfully added to course”,
then click Close.
Enroll students in course (done by instructor) cnt’d:
After closing, you will see a screen with your students, their ID#, their CPR Login (which you need to distribute to students, and their status on the pretest.)

<table>
<thead>
<tr>
<th>Name</th>
<th>Student ID</th>
<th>CPR Username</th>
<th>Email</th>
<th>Results</th>
<th>Finished Pretest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adar</td>
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<td>View</td>
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<tr>
<td>Ahla</td>
<td>1177</td>
<td>b1</td>
<td>View</td>
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<td>Ahm</td>
<td>1176</td>
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<td>View</td>
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<td>No</td>
<td></td>
</tr>
<tr>
<td>Chi</td>
<td>1166</td>
<td>m1</td>
<td>View</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Ch</td>
<td>1165</td>
<td>n1</td>
<td>View</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Cle</td>
<td>1164</td>
<td>o1</td>
<td>View</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Cro</td>
<td>1163</td>
<td>p1</td>
<td>View</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Cur</td>
<td>1162</td>
<td>q1</td>
<td>View</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>
• Congratulations! You have enrolled your students in your course. Again:
  • Your students are in the database (for students’ entire HS tenure)
  • Your course has been set up (for the whole year, over multiple tasks)
  • Your students are enrolled (for the whole year, over multiple tasks)

• You may now enter create an assignment, use assignments published by others or adapted assignments to fit your needs.

• For example, I will show you how to access and set up my “Crystal Project”
Access course to create assignment (done by instructor) or use / modify a “canned” assignment:
Click on Course Home to continue (Course Home is where you would be if you log out and log in later).
Access and Activate “Crystal Project”: Click **Enter as Instructor / Designer**

<table>
<thead>
<tr>
<th>Available CPR User Levels</th>
<th>Instructor/Designer</th>
<th>Student</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instructor/Designer</strong></td>
<td>Author new assignments</td>
<td>Administer/Edit Assignments</td>
</tr>
<tr>
<td><strong>Student</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Enter as Instructor/Designer**

**Enter as Student**
Access “Crystal Project”: Click **Access Course** (or author your own)
Access “Crystal Project”: Click your course

![Course List - Windows Internet Explorer](http://cpr.molsci.ucla.edu/cpr/cpr/designer/course_list.asp?loginID=06178)

<table>
<thead>
<tr>
<th>HOME</th>
<th>CPR Time</th>
<th>LOG OFF</th>
</tr>
</thead>
</table>

> Back to Instructor/Designer Options

**Course List**

**Collins Hill High School**

- 2009–10 AP Physics B
- 2010–11 AP Physics B
- 2011–12 AP Physics
Access “Crystal Project”: Click **Manage Assignments**
Access “Crystal Project”: Click Manage Assignments
Access “Crystal Project”: Click **Activate New Assignments**

---

**Assignment List**

- **Course Options**

**Course:** 2011_12 AP Physics

- **Not Started Yet**
  - None Available

- **In Progress**
  - None Available

- **Finished**
  - None Available

---

![Image of Assignment List](image_url)
Access “Crystal Project”: Click **Select Assignment**

Assignment Activation

Step 1: Select a Master Assignment

*1. Select Assignment* > *2. Scoring* > *3. Word Count* > *4. Grade* > *5. Timing* > *6. Participation*

**Course:** 2011_12 AP Physics

- Select a master assignment
  - Select Assignment

*No master assignment has been selected yet.*
Access “Crystal Project”: Click **Select Assignment**

**Assignment Activation**
**Step 1: Select a Master Assignment**


Course: 2011_12 AP Physics

- Select a master assignment
- Select Assignment

No master assignment has been selected yet.
Access “Crystal Project”: Expand **Server Library**
Access “Crystal Project”: Scroll down to Contributed Assignment
Access “Crystal Project”: Scroll down to Contributed Assignments “Crystal Project” (click info in case of duplicate name in the future).
Access “Crystal Project”: Select “Crystal Project” and scroll to top of screen
Access “Crystal Project”: Click Select Assignment
Access “Crystal Project”: Adapt assignment to your needs by clicking **Change Assignment**, but I will assume you will use “as is”, so click “Next”
Access “Crystal Project”: Being a literature survey assignment, I selected “Low Difficulty”, to allow students to calibrate easily.
Access “Crystal Project”: Click Next
Access “Crystal Project”: Click Next
Access “Crystal Project”: Edit maximum and minimum word count to suit your students and click Next.

Set the word count:

Directions: You must determine a minimum and maximum word count for student texts. Texts of any length can counts approximately 25% above and below the average calibration word count.

Average word count of calibrations = 813
Minimum Word Count = 1200
Maximum Word Count = 400
Access “Crystal Project”: Customize score weights if you wish, but I usually use the defaults; click Next.
Access “Crystal Project”: Enter Start Time, Text Entry End Time and Assignment End Time, then click Next
Access “Crystal Project”: Both to see how well the assignment Works, as well as to keep things honest, I usually participate; click Next.

<table>
<thead>
<tr>
<th>1. Master Assignment</th>
<th>Crystal Project</th>
<th>Preview</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Scoring Template and Word Count</td>
<td>Low Difficulty</td>
<td></td>
</tr>
<tr>
<td>3. Word Count</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Overall Grade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Timing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Instructor Participation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Master Assignment: Crystal Project
- Low Difficulty
- Minimum Word Count: 400 words
- Maximum Word Count: 1200 words
- Text Rating: 20 points
- Calibrations: 30 points
- Reviews: 30 points
- Self-Assessment: 20 points
- Assignment Start Time: 4/3/2011 at 07:10
- Assignment End Time: 4/7/2011 at 07:10
- Will the instructor participate? Yes
Access "Crystal Project": Your assignment setup is complete.
Appendix C: Suggested topic list. Students are encouraged to trade or select their own topic, subject to instructor approval within the first week of the project.

**Method list**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AES</td>
<td>auger electron spectroscopy</td>
</tr>
<tr>
<td>AFM</td>
<td>atomic force microscope</td>
</tr>
<tr>
<td>ALD</td>
<td>atomic layer deposition</td>
</tr>
<tr>
<td>ECR</td>
<td>electron cyclotron resonance</td>
</tr>
<tr>
<td>EELS</td>
<td>electron energy los spectroscopy</td>
</tr>
<tr>
<td>Electron diffraction</td>
<td></td>
</tr>
<tr>
<td>Ellipsometer</td>
<td></td>
</tr>
<tr>
<td>EMP</td>
<td>electron microprobe</td>
</tr>
<tr>
<td>EPR</td>
<td>electron paramagnetic resonance</td>
</tr>
<tr>
<td>FIB</td>
<td>focused ion beam etch</td>
</tr>
<tr>
<td>FTIR</td>
<td>Fourier transform infrared spectroscopy</td>
</tr>
<tr>
<td>IR Spectroscopy</td>
<td></td>
</tr>
<tr>
<td>ISS</td>
<td>ion scattering spectroscopy</td>
</tr>
<tr>
<td>LEED</td>
<td>low energy electron diffraction</td>
</tr>
<tr>
<td>EM</td>
<td>laser emission microprobe</td>
</tr>
<tr>
<td>MBE</td>
<td>molecular beam epitaxy</td>
</tr>
<tr>
<td>MEE</td>
<td>migration enhanced epitaxy</td>
</tr>
<tr>
<td>MME</td>
<td>metal modulated epitaxy (custom)</td>
</tr>
<tr>
<td>MOCVD</td>
<td>metalorganic vapour phase epitaxy</td>
</tr>
<tr>
<td>Neutron diffraction</td>
<td></td>
</tr>
<tr>
<td>NMR</td>
<td>nuclear magnetic resonance</td>
</tr>
<tr>
<td>PECVD</td>
<td>plasma-enhanced chemical vapor deposition</td>
</tr>
<tr>
<td>PIXE</td>
<td>Particle induce X-Ray emission</td>
</tr>
<tr>
<td>Raman Spectrometer</td>
<td></td>
</tr>
<tr>
<td>RBS</td>
<td>rutherford backscattering</td>
</tr>
<tr>
<td>RF Sputterer</td>
<td></td>
</tr>
<tr>
<td>RHEED</td>
<td>high energy electron diffraction</td>
</tr>
<tr>
<td>SEM</td>
<td>scanning electron microscope</td>
</tr>
<tr>
<td>SIMS</td>
<td>secondary ion mass spectrometry</td>
</tr>
<tr>
<td>SNMS</td>
<td>secondary Neutral Mass Spectroscopy</td>
</tr>
<tr>
<td>STEM</td>
<td>scanning transmission electron microscopy -</td>
</tr>
<tr>
<td>VSM</td>
<td>vibrating sample magnetometer</td>
</tr>
<tr>
<td>XPS</td>
<td>X-ray photoelectron spectroscopy</td>
</tr>
<tr>
<td>XRD</td>
<td>X-ray diffraction</td>
</tr>
<tr>
<td>XRF</td>
<td>x-ray fluorescence</td>
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</table>

**Crystal list**

<table>
<thead>
<tr>
<th>Crystal</th>
<th></th>
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</thead>
<tbody>
<tr>
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<tr>
<td>AgI</td>
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</tr>
<tr>
<td>Al2O3</td>
<td></td>
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<tr>
<td>AlAs</td>
<td></td>
</tr>
<tr>
<td>AlGaAs</td>
<td></td>
</tr>
<tr>
<td>AlGaN</td>
<td></td>
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<tr>
<td>AlGaP</td>
<td></td>
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<tr>
<td>AlN</td>
<td></td>
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<tr>
<td>AIN</td>
<td></td>
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<tr>
<td>AIP</td>
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</tbody>
</table>
AlSb
BaSb
BaTiO3
Bi2O3
Bi2S3
Bi2Te3
BiI3
BN
BN
BP
C
Cd3As2
CdS
CdS
CdSe
CdSe
CdTe
CdZnTe
Cu2O
Cu2S
CuCl
CuInGaSe
CuInSe2
CuO
EuS
FeO
FeS2
GaAs
GaAs
GaAsP
GaInAsSbP
GaMnAs
GaN
GaN
GaP
GaSb
GaSe
Ge
Ge
Graphite
HgCdTe
Hgl2
HgZnTe
InAs
InAsSbP
InGaAs
InGaN
InGaP
InN
InN
InP
InSb
LiCoO2
LiNbO2
LiNbO3
MoS2
NiO
PbI2
PbS
PbSe
PbTe
PtSi
Sapphire
Se
Si
SiC
SiC
SiC
SiC
SiGe
SiGe
SiO2
SnO2
SnS
SnS
SnS2
SnTe
SrTiO3
TiO2
TlBr
UO2
UO3
Zn3P2
Zn3Sb2
ZnO
ZnO
ZnS
ZnSe
ZnTe
APPENDIX D: REFERENCES

- [http://www.nanoprinttech.com/old/nanotechnology.htm](http://www.nanoprinttech.com/old/nanotechnology.htm)
- Carbon nanotube
- [http://cpr.molsci.ucla.edu/](http://cpr.molsci.ucla.edu/)
- [http://www.reciprocalnet.org/edumodules/commonmolecules/list.html](http://www.reciprocalnet.org/edumodules/commonmolecules/list.html)
- [http://www.reciprocalnet.org/edumodules/commonmolecules/list.html](http://www.reciprocalnet.org/edumodules/commonmolecules/list.html)